The "Baqaee-Farhi approach" and a Russian gas embargo

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Abstract

In a controversial policy paper, Bachmann et al. (2022) argued back in March 2022 that the economic effects for Germany of a complete immediate stop of energy imports from Russia would be small, between 0.5% and 3% of GDP. Baqaee et al. (2022) even presented 0.3% GDP loss in the case of an embargo as the headline number in a follow-up report for the French Council of Economic Analysis (CAE). This note argues that these estimates are both problematic from a scientific point of view, and also strongly biased towards finding small effects of a gas embargo: this is true of the (so-called) "Baqaee-Farhi approach" arriving at 0.2-0.3% of GDP, the "production function approach" arriving at 1.5% to 2.3% of GDP, as well as the "sufficient statistics approach" (also based on Baqaee-Farhi) arriving at 1% of GDP. This note argues that Olaf Scholz was correct in saying that the mathematical models which were used "don't really work" here, and tries to explain why. In any case, these models do not permit such categorical statements.

Keywords: Energy, sanctions, economic models.

JEL codes : D2, E1, Q4.

Introduction

A few weeks after the invasion of Ukraine by Russia on 24 February 2022, Bachmann et al. (2022) argued in a controversial policy paper that the economic impact on Germany of a complete *immediate* stop (in March 2022) of energy imports from Russia (including natural gas) would be small, **between 0.5% and 3% of GDP**. A few weeks later, Baqaee et al. (2022) even presented a **0.3% GDP loss** for Germany as the headline number in a follow-up report for the French Council of Economic Analysis (CAE). They also estimated the losses for other European economies, including France and the EU, totalling these at around 0.2%-0.3% of income per year for Europe as a whole. This work by internationally renowned economists has been very influential, both in academia and in the public debate. It was strongly endorsed and promoted by leading authorities in the profession, including Nobel Laureates such as Paul Krugman or Esther Duflo, and on 1 May, a majority of a panel of European macroeconomists declared themselves convinced.

This policy paper by academic economists was, however, at odds with the assessment of German officials. On 27 March 2022, on Germany's most important political talk show (Anne Will's Show), Chancellor Olaf Scholz sharply criticized economists: "But they get it wrong! And it's honestly irresponsible to play around with some mathematical models that then don't really work." This comment caused a backlash: for many economists, especially those working outside of Germany, Olaf Scholz had left the camp of reason and science. On the German government's side, many of the country's economists and policy experts, including at the German Council of Economic Experts, were also much more critical and cautious, and thought that an immediate embargo could have more dire consequences (GCEE, 2022).

[1] To Emmanuel Farhi, who was my mentor and pushed me to stay in academia and try to "convince the profession", even though I had strong doubts about "mainstream macro". I thank the seminar participants at the German Council of Economic Experts (GCEE) workshop, the University of Geneva Political Economy Seminar (UNIGE), as well as Bruno Amable, David Cayla, Cédric Durand, Simon Grothe, Monika Schnitzer and Achim Truger, for their valuable feedback, and José M. Labeaga for sharing his data. I also thank David Baqaee for conversations about this particular piece of work, even though (as often in our many years at UCLA!) we did not agree in the end. A first version of this paper was presented at the German Council of Economic Experts on 25 April 2022.

This article discusses the approach in Bachmann et al. (2022) and Baqaee et al. (2022). It argues that these papers are very problematic from a methodological point of view and strongly biased towards finding small effects of a natural gas embargo. Overall, this article argues that Olaf Scholz was correct in saying that the mathematical models which were used "don't really work" here and do not permit such categorical statements. Section 1 discusses the simplest "production function approach". This is a natural starting point, since this approach is used in the Bachmann et al. (2022) paper to compute worst-case scenarios, and the concept of an elasticity of substitution is central to the whole discussion. Section 2 then discusses the more sophisticated "Baqaee-Farhi approach" that arrives at the figure of 0.2-0.3% of GDP, the main bottom line of their follow-up paper. Section 3 discusses the "sufficient statistics approach", and finally section 4 provides more general remarks prompted by this study and concludes.

1 The macroeconomic production function approach

1.1 Computing the % change in GDP

Bachmann et al. (2022) use a simple production function approach for the main bottom line in their paper, which allows them to argue that the economic losses would be 1.6% or 2.3% of GDP at the maximum. The production function approach assumes that GDP (Y) is a function of Energy (E) and Non-Energy (NE) with a constant elasticity of substitution σ and a share of energy α, implying the following formula for GDP:

$$Y(\sigma, \alpha, \mathrm{E}, \mathrm{NE}) = \left(\alpha^{\frac{1}{\sigma}}\mathrm{E}^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}}\mathrm{NE}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}.$$

Set the elasticity $\sigma = 0.04$, the share of energy to $\alpha = 0.04$, so $(E_0, NE_0) = (0.04, 0.96)$ before the shock and $(E_1, NE_1) = (0.04 * 0.9, 0.96)$ after the 10% drop in energy supply. (In this calculation, the supply of other non-energy factors NE is assumed to be fixed.) The percentage change in GDP is:

$$\frac{\Delta Y}{Y} = \frac{Y_1}{Y_0} - 1 = \frac{Y(\sigma, \alpha, E_1, NE_1)}{Y(\sigma, \alpha, E_0, NE_0)} - 1 = \frac{Y(0.04, 0.04, 0.04 * 0.9, 0.96)}{Y(0.04, 0.04, 0.04, 0.96)} - 1 \approx -1.6\%.$$

Alternatively, the authors assume that GDP is a function of Gas (G) and Non-Gas (NG), with a constant elasticity of substitution σ and a share of gas α:

$$Y(\sigma, \alpha, \mathrm{G}, \mathrm{NG}) = \left(\alpha^{\frac{1}{\sigma}}\mathrm{G}^{\frac{\sigma-1}{\sigma}} + (1-\alpha)^{\frac{1}{\sigma}}\mathrm{NG}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$$

Set the elasticity $\sigma = 0.1$, a share of natural gas to $\alpha = 0.01$, so $(G_0, NG_0) = (0.01, 0.99)$ before the shock and $(G_1, NG_1) = (0.01 * 0.7, 0.99)$ after the 30% drop in natural gas. The percentage change in GDP is:

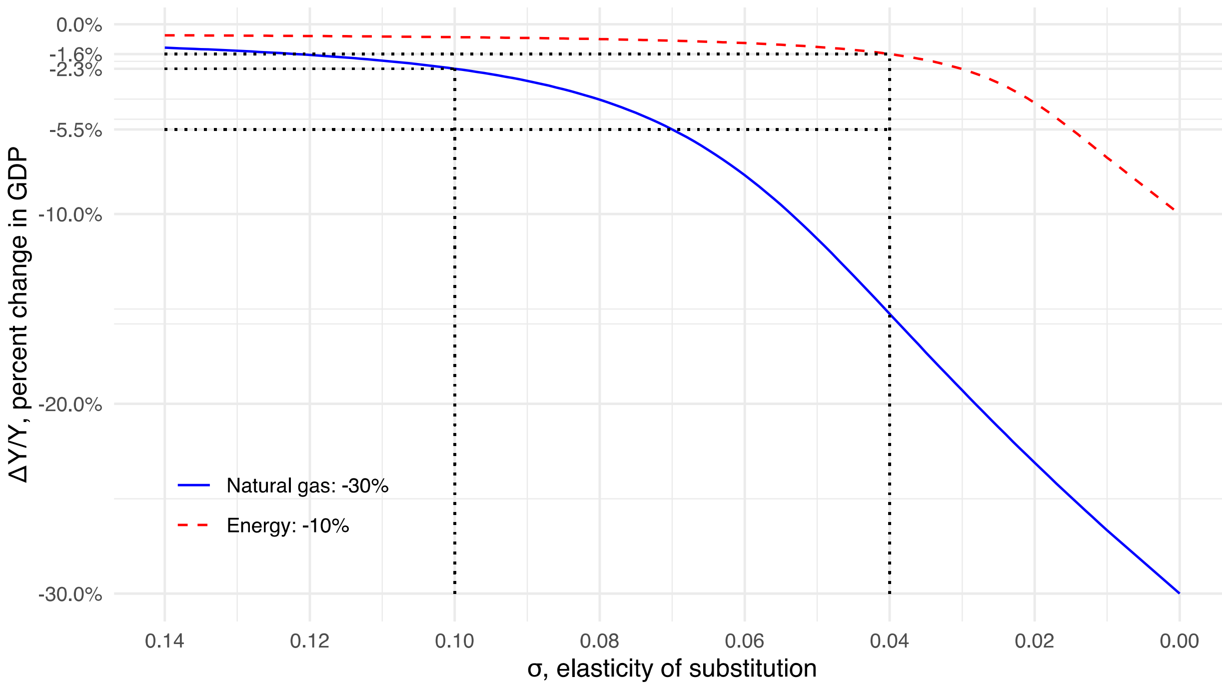
$$\frac{\Delta Y}{Y} = \frac{Y(0.1, 0.01, 0.01 * 0.7, 0.99)}{Y(0.1, 0.01, 0.01, 0.99)} - 1 \approx -2.3\%.$$

This -2.3% number is rounded up to -3% to give the paper's upper bound for the reduction in GDP. More generally, the GDP decline as a function of the aggregate elasticity of substitution σ is shown on **Figure *1***: past a certain threshold, the change in GDP depends a lot on the elasticity. This figure shows that the claim by Baqaee et al. (2022) - that "a world where substitution is impossible, and a world where even a small amount of substitution is possible, behave drastically different at the macro level" - is mathematically incorrect. For example, with $\sigma = 0.04$ for natural gas as for energy, there is a 15.3% drop in GDP:

$$\frac{\Delta Y}{Y} = \frac{Y(0.04, 0.01, 0.01 * 0.7, 0.99)}{Y(0.04, 0.01, 0.01, 0.99)} - 1 \approx -15.3\%.$$

This calculation shows that, contrary to the authors' claim, a world where a small amount of substitution is possible (small σ) can behave very much like a world where substitution is impossible ($\sigma = 0$). There is no discontinuity at a zero elasticity of substitution: according to this model, everything depends on this elasticity. Unfortunately, as shown in section 1.4, there is huge uncertainty as to what the elasticity of substitution actually is. An even more problematic issue is that there is no reason to believe that the elasticity of substitution really is constant. But before discussing GDP losses further, let us first talk about prices.

Figure 1: Percent change in GDP $\Delta Y/Y$ as a function of the aggregate elasticity of substitution σ



1.2 Implied change in prices before and after the embargo

The definition of the elasticity of substitution σ, assuming that Non-Energy NE is constant, and $\mathrm{p}^{\mathrm{NE}} = 1$ (p^{E} is the relative price of energy) gives us the change in (relative) energy prices $\Delta \log(\mathrm{p}^{\mathrm{E}})$ needed to achieve a given change in energy demand $\Delta \log(\mathrm{E})$:

$$\sigma = -\frac{\Delta \log(\mathrm{E}/\mathrm{NE})}{\Delta \log(\mathrm{p}^{\mathrm{E}}/\mathrm{p}^{\mathrm{NE}})} \quad \Rightarrow \quad \Delta \log(\mathrm{p}^{\mathrm{E}}) = -\frac{\Delta \log(\mathrm{E})}{\sigma}.$$

If the energy supply before the embargo is E_0 and after the embargo is E_1 and the price of energy is $\mathrm{p}_0^{\mathrm{E}}$ before the embargo and $\mathrm{p}_1^{\mathrm{E}}$ after the embargo, then:

$$\frac{\mathrm{p}_1^{\mathrm{E}}}{\mathrm{p}_0^{\mathrm{E}}} = \left(\frac{E_1}{E_0}\right)^{-1/\sigma}$$

With $\sigma = 0.04$ and $E_1/E_0 = 0.9$ as above, the price faced by energy users to achieve a reduction in energy use equal to 10% needs to increase by around 1300%, since:

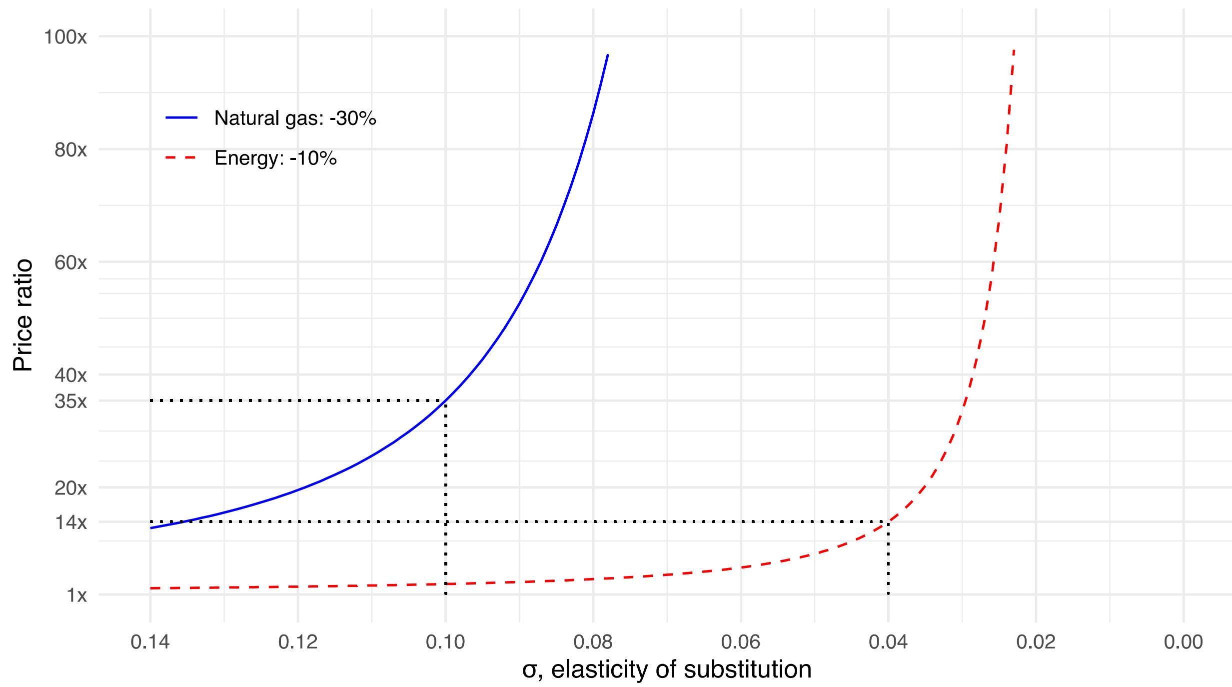
$$0.9^{-1/0.04} \approx 14.$$

This is bigger than what Bachmann et al. (2022) report in their appendix, where they claim that "the marginal product of energy and hence its price rises by a factor of almost 10". The *relative* price change, which is what matters for substitution, is in fact greater than the absolute price change, so the price rises by

a factor of almost 14. (Their model predicts deflation for the price of non-energy goods.) For this reason, they consider the 1.6% of GDP estimate in case of an embargo to be "borderline reasonable". As explained in section 1.3, it is the joint prediction on energy price changes and GDP drop which actually is unreasonable. Therefore, this statement is confusing an assumption with a conclusion.
With $\sigma = 0.1$ and $E_1/E_0 = 0.7$, prices faced by natural gas users would need to increase by around 3400% to achieve a reduction in natural gas use of 30%:

$$0.7^{-1/0.1} \approx 35.$$

Figure 2: Price ratio p_1^E/p_0^E as a function of the aggregate elasticity of substitution σ



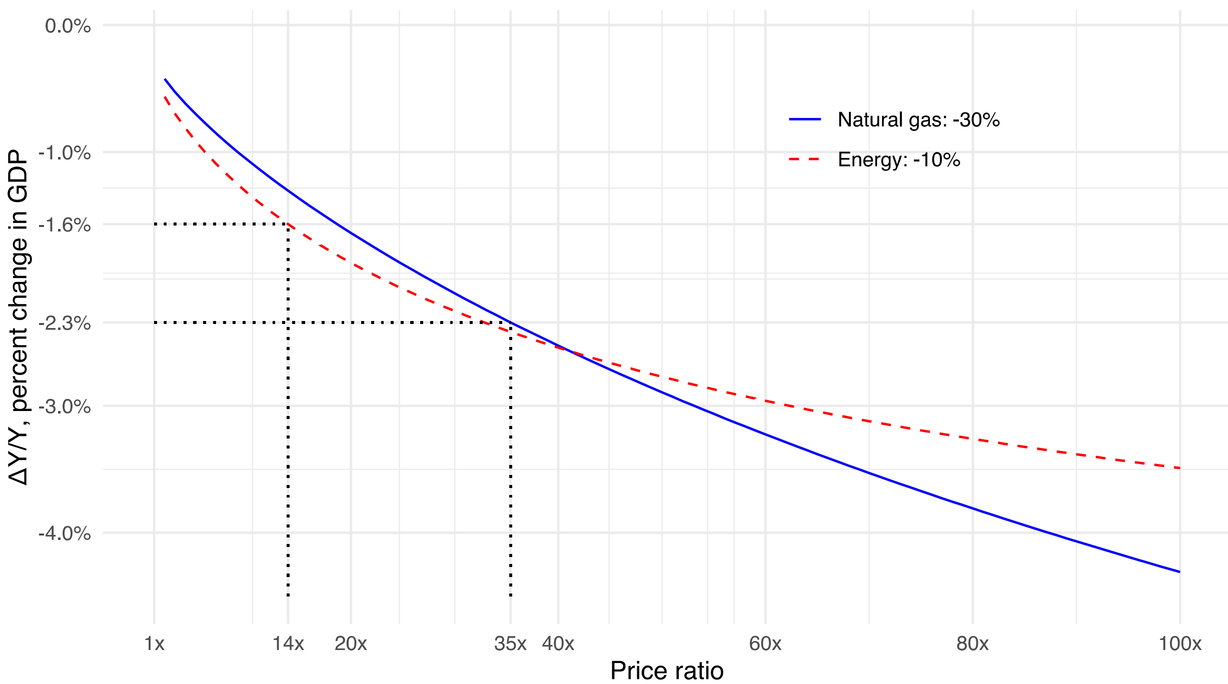
Bachmann et al. (2022) do not report that the price of natural gas needs to rise by a factor of almost 35 in the case where the model predicts GDP losses equal to 2.3% of GDP. These gigantic price changes shown on **Figure *2*** need to be taken seriously, as Bachmann et al. (2022) forcefully advocate letting the price mechanism work in order to incentivize substitution away from natural gas.

1.3 Joint predictions on change in energy prices and % change in GDP

What seems problematic in these two cases is not just the gigantic price rise that these calculations imply, it is that the *joint prediction* on GDP drops and price changes seems unreasonable. How could GDP fall by only 2.3% when natural gas prices are multiplied (permanently) by a factor of 35? More generally, **Figure *3*** shows the link between price ratios and GDP losses implied by the production function approach: even with a price of energy or natural gas multiplied by 80, GDP losses would remain lower than 4%. This suggests that there is something wrong with the production function approach, regardless of the elasticity of substitution.

The reason for this counterintuitive and surprising result is that the production function approach emphasizes a specific economic force – substitution across inputs – which implies that there is a weak relationship between energy or natural gas price increases and GDP losses. Unfortunately, this would probably not have been the main force driving the link between natural gas prices and GDP in practice, if an immediate embargo had taken place in March 2022. Indeed, a key short-run margin of adjustment in practice is not substitution across inputs but rather demand destruction: as energy prices increase, the most energy-intensive companies shut down, which reduces the consumption of natural gas and leads to a reduction in GDP. In this example, a firm does not choose simply to use less natural gas but the same amounts of the other inputs. Instead, it reduces its use of *all* inputs, which leads to a reduction in production. This phenomenon is not captured by an aggregate production function that emphasizes substitution across inputs.

Figure 3: Percent change in GDP $\Delta Y/Y$ as a function of the price ratio p_1^E/p_0^E

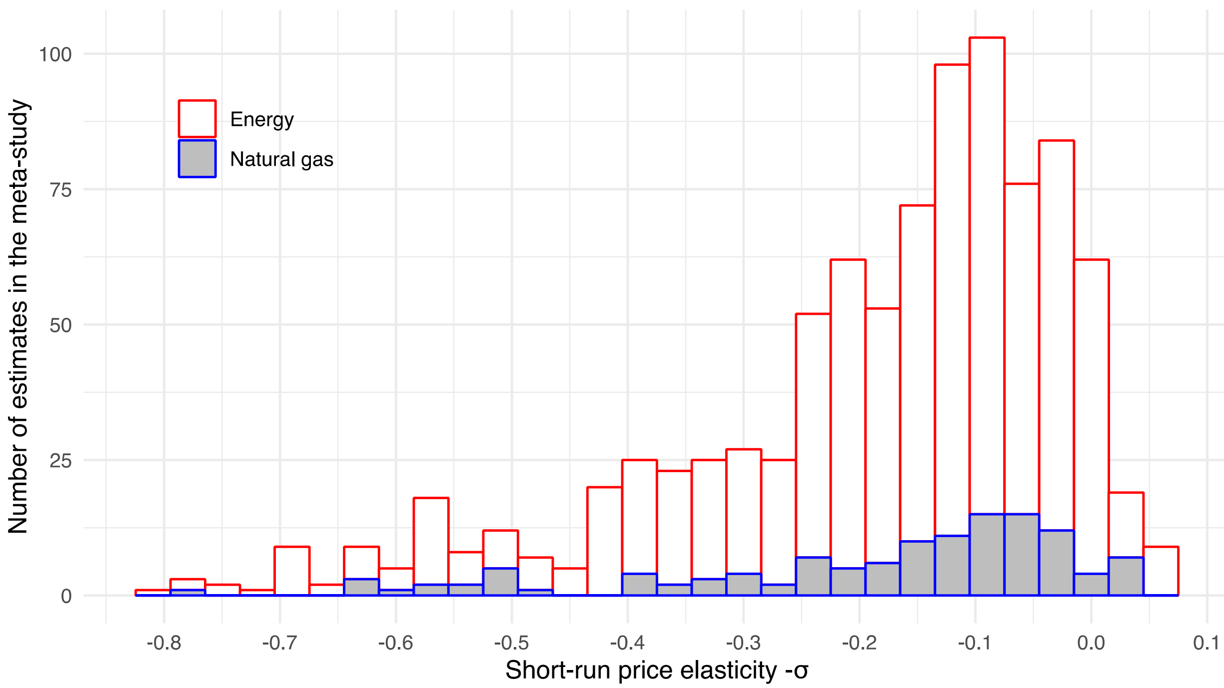


Moreover, as has been noted before, these gigantic price effects certainly have big consequences for aggregate demand that are not captured in the production function approach: there would be a large transfer of wealth towards energy producing countries, and households' purses would be severely hit which would reduce spending on other goods. Lump-sum transfers targeted to low-income households would not be enough to avoid these consequences, as some households might have particularly large budget shares on energy because they live in rural areas and don't have access to other heating technologies: with lump-sum transfers, everyone would by definition receive the same transfers, regardless of their consumption of energy. Not to mention the social and political consequences of such large increases in prices, which explain why some economists have instead advocated price caps on energy: see Dullien & Weber (2022).

1.4 What is "the" elasticity?

Assuming away these problems, everything depends on "the" elasticity of substitution as shown on **Figure *1*.** This elasticity of substitution cannot be estimated directly, but assuming that substitution across inputs really is the only underlying mechanism and that the aggregate production function approach applies, the elasticity of substitution σ is also the opposite of the elasticity of demand for energy (or natural gas). Bachmann et al. (2022) report that the mean short-run elasticity is -0.186 for energy and -0.18 for natural gas in a meta-study by Labandeira et al. (2017). The data underlying this meta-study, provided by José M. Labeaga, reveals that the estimates underlying these means are very heterogeneous, as shown on **Figure *4***.

Figure 4: Distribution of short-run price elasticities in the meta-study by Labandeira et al. (2017)



The median is already much closer to 0 than the average estimate, and the distribution has a lot of negative skewness, which is probably due to publication bias, as the sign of the elasticity is known so that many studies with positive price elasticities are not published: the median is -0.14 for energy, and -0.12 for natural gas. The 75th percentile is -0.07 for energy and -0.05 for natural gas. As shown in **Table *1***, the percentage change in GDP if the elasticity is 0.05 is equal to:

$$\frac{\Delta Y}{Y} = \frac{Y(0.05, 0.01, 0.01 * 0.7, 0.99)}{Y(0.05, 0.01, 0.01, 0.99)} - 1 \approx -11.3\%.$$

Table 1 : Distribution of GDP drops according to Labandeira et al. (2017)

Quantile	**Mean**	**Median (P50)**	**P75**	**P90**
$\boldsymbol{\sigma}$	0.18	0.12	0.05	0.02
$\boldsymbol{\Delta Y / Y}$	-0.8%	-1.6%	-11.3%	-23.1%

If one takes this approach seriously, this would mean that there is a 25% chance that GDP losses could be larger than 11.3%. The 90th percentile estimate being -0.02 for natural gas, there is a 10% chance that GDP losses would be larger than 23.1%. Moreover, taking the GDP losses corresponding to the mean estimate has a downward bias, because the function mapping elasticities to GDP losses is nonlinear: for example, the GDP losses corresponding to $\sigma = 0.07$ are equal to 5.5%, which is lower than the average of GDP losses obtained for $\sigma = 0.04$ (15.3%) and $\sigma = 0.1$ (2.3%), equal to 8.8%. Taking the average of σ before plugging in the production function is therefore a mistake if there is a distribution of estimates for σ.

This heterogeneity is also worrying, because it could be explained by the fact that "the" elasticity is most likely not constant: it could drop as natural gas arrives in shorter supply, so that the estimates closer to zero would be closer to the elasticity corresponding to a large shock. There are in fact reasons to believe that elasticities of substitution start declining as the quantity of an input such as natural gas goes to 0, as in Geerolf (2019), where "super-elliptic" production functions are proposed as an alternative to constant elasticity of substitution (CES) production functions that have this property. In the chemical industry, for example, natural gas used for heating purposes can be replaced, but natural gas used as a material input in production cannot (Krebs (2022)). Thus, examples of *some* substitution (such as substitution of gas for heating) at some point are not a proof that perfect complementarity is nonsensical later (once you start wanting to replace natural gas as material). Proofs of some substitution at the microeconomic level do not tell us much about how easy natural gas is to substitute when quantities fall in large amounts.

In any case, one should probably not take these calculations too seriously, as subsuming the process of replacing natural gas through a single parameter in an aggregate production function seems like a hopeless endeavour. There is probably not such a thing as "the" elasticity, even regardless of the magnitude of the shock. "The" elasticity of substitution seems a very crude and limited way of trying to capture what would happen if the price of natural gas were to increase substantially, or if natural gas were rationed through some other (non-price) mechanism. Finding new technologies that economize more on gas requires time, but also resources and some R&D by engineers: there is no reason to think that these costs would be captured in a reduced form elasticity of substitution, especially since these costs would probably depend on other factors such as the overall availability of such skills.

Moreover, comparing the formula where GDP depends on Gas and Non-Gas and the formula where GDP depends on Energy and Non-Energy should lead us to ask the following question: which formula should we favour, and if we believe that breaking energy up into natural gas and other types of energy is necessary because they are imperfect substitutes, then why stop here? For example, considering natural gas as a whole, why not assume that there is imperfect substitution between gas available in one location in Germany and gas available in other locations, and the rest of the economy? Indeed, natural gas cannot be easily transported through Germany and usually is transported through existing pipelines, which take a lot of time and resources to build. Therefore, it matters a lot where the natural gas actually comes from and goes to. To quote Olaf Scholz in his interview on the Anne Will talk show, in the case of natural gas, location is of crucial importance because it's important to know "where is the gas actually supposed to run through, where are the pipelines, what is the regasification capacity, where are the terminals". One could for instance imagine that there would be a complete shortage (drop of -100%) in one particular location, which according to the production function approach would then lead to a -100% drop in GDP as well.… The point is not to take any of this seriously, but rather that it is very hard to determine this with any precision: the GDP numbers one gets from the production function approach seem largely arbitrary, depending on the level of sectoral and geographical decomposition.

One paradox is that Baqaee-Farhi's research agenda with input-output networks was precisely to move away from these extremely stylized production functions. Baqaee and Farhi (2019b) argued against exactly such an approach, especially for quantitative analysis: "As micro data becomes more plentiful, parsimonious reduced-form aggregate production functions look more antiquated." Even intuitively, it's a priori very hard to see how such a crude approach could allow us to compute the effects of something as complex and multifaceted as an embargo… This brings us to the "Baqaee-Farhi approach", which allows to circumvent some of these limitations.

2 The so-called[2] Baqaee-Farhi approach

The "Baqaee-Farhi approach" is another approach used in Bachmann et al. (2022) to calculate the impact of a Russian gas embargo. According to this approach, the effects of an embargo would be 0.2% of GDP when the baseline parameters in Baqaee-Farhi (2021) are used, and around 0.3% of GDP using the most

[2] "So-called" as, for reasons put forward later, I am not sure it's really true to Emmanuel Farhi's and David Baqaee's earlier work.

conservative estimates. This estimate from the Baqaee-Farhi approach (0.3% of GDP) is also used as the central estimate for the follow-up paper by Baqaee et al. (2022), published by the French Council of Economic Analysis, advising the French Prime Minister. This number is then rounded up to yield the lower bound for the bottom line of Bachmann et al. (2022), i.e. the effects of an embargo would be between 0.5% and 3% of GDP. This number was also put forward in the German public debate by Nobel Laureate Esther Duflo when endorsing the paper on 15 April 2022, in an interview with *Bild*: "Germany is fortunate to have many very competent economists, and they have rightly made their voices heard.… Their standard model says that the negative impact of an embargo will be 0.3% of GDP, and they consider worst-case scenarios that come to 3%." The Baqaee-Farhi approach is no doubt the most sophisticated methodology applied to this subject, and it is also the basis for the sufficient statistics approach, which will be discussed in the next part. But unfortunately, it is problematic for many reasons. I list some of these below.

2.1 A long-run model: Permanent embargo, few factors

The macroeconomic model used in Bachmann et al. (2022) is actually based on a specific version of the "Baqaee-Farhi approach", i.e. the paper by Baqaee and Farhi (2021), which is a long-run model that was designed to investigate trade questions, such as what happens when a country opens up to trade, or when its trade barriers are suddenly and *permanently* lifted. One implication is that in Bachmann et al. (2022) the embargo will be put in place *permanently*, and the question is how much lower GDP will be in the new *steady-state equilibrium*. The model is doing "comparative statics", that is, comparing different economies at steady-state: one with natural gas from Russia and the other without, assuming Germany needs to forever run without such gas.

This approach poses a problem, because it amounts to answering a very different question: what would happen if Germany had to cope with a permanent -30% reduction in gas *supply*, in which case it would be clear that, for example, labour would need to be reallocated away from the natural gas-intensive sectors. Some of what makes the current situation very different to that situation is that part of the reduction in gas supply will be transitory, so that the German authorities would have to deal with a temporary situation. We do not in fact know how long the situation would exactly last, which does not help: it could last for one or more winters. People would have to be put onto temporary unemployment schemes, but the model assumes no such thing: in the model, a reallocation of labour is immediate and permanent. Overall, it's not even clear whether a permanent drop would be harder or easier to deal with, but it doesn't matter so long as we can agree that it would in any case be very different. Moreover, by construction a comparative statics exercise does not allow to compute "adjustment costs". These are probably substantial on both the labour and capital markets, when one wants to move to an economy that consumes 30% less gas overall.

The other issue is that, because it's a trade paper, designed to deal with the long run, the Baqaee and Farhi (2021) model assumes only four factors of production for the whole economy, with only three factors for labour (low-, medium-, high-skilled) and one for capital: the assumption is that high-skilled workers are supposed to be able to reallocate across sectors (and locations) costlessly, which is perhaps a reasonable assumption for the long run, but definitely not for the short/medium run.[3] Indeed, this is way too strong an assumption for the short or even medium run: there are reasons to believe that an engineer in the chemical industry cannot work from one day to the next as a banker, and then go back to their old job when the embargo is lifted. This is another very important reason why this study tends to overestimate the possibilities of substitution.

The importance of the number of factors one assumes was illustrated in the previous paper by Baqaee and Farhi (2019a), where they showed how crucial the number of factors was for the conclusions one draws:

[3] In fact, even for the long run, recent empirical research in trade such as Autor et al. (2013) casts doubt on this assumption: two decades after China's entry into the WTO, the labour market effects of import competition are still apparent.

the more factors, the less substitutability at the aggregate level, which is intuitive. Again, the timing is absolutely essential. David Baqaee and Emmanuel Farhi, in their 2019 paper, indeed write: “We view the no-reallocation case as more realistic for modelling the short-run impact of shocks, and the full-reallocation case as better suited to study the medium to long-run impact shocks.” In the case of natural gas, one could even argue that one does not need to assume just a few factors for each sector (say, engineers and technicians in the chemical industry) but also that one needs to assume that factors are located in a particular region and cannot easily move from one month to the next.

2.2 Many sectors but only one for energy (which includes water)

The model is also ill-suited to the question at hand when it comes to modelling the energy sector, which is nonetheless crucial here. Water supply is mixed with electricity and gas in the “Electricity, Gas and Water Supply” sector – one should remember that within one sector and one country, goods are assumed to be perfect substitutes: as a consequence, here by assumption, when there is less gas, one can replace it with water. The model has 30 sectors, but only one of them actually corresponds to energy (the World Input Output Table they use has 35 sectors originally, but they wanted to get rid of zeros, which cannot be dealt with in trade models), and, therefore, only as many goods. The manufacturing sector, which is a very important sector for this particular question, is also not detailed enough: for example, the chemical industry is mixed with rubber and plastics (sectors 9 and 10 in Table 5 from Baqaee and Farhi (2021)), and it is assumed that in Germany this whole aggregate produces only one product. Because of the importance of the chemical industry for the issue of computing the consequences of a natural gas embargo, one would have perhaps liked to zoom a bit more onto this particular industry rather than assume that this whole sector simply produces one commodity (“plastics”). Tom Krebs (2022) noted very early on that the treatment of the chemical industry was essential. Again, we could contrast this to Baqaee and Farhi (2019a), which had 88 sectors. One could also have thought to use the 2016 vintage of WIOD instead, which has more sectors even though it has much less detail on factors (but in any case, it’s probably better to assume that factors are industry-specific).

There are plenty of other questionable assumptions in the model. There are in general very few parameters compared to large-scale quantitative models, as the model here is more medium-scale, in that it abstracts from complexities, which allows to understand comparative statics. For example, only one elasticity of substitution governs the substitution between all consumption goods entering symmetrically. This is a very debatable assumption in the context of a natural gas embargo, as heating for example, may be less substitutable with other consumption – which implies that the consumer surplus is large for heating, so that the utility losses are much larger than the monetary losses: 100€ per year in heating expenses is worth much more than 100€ per year in restaurants, when one is already freezing because of a natural gas embargo. Moreover, there is only one good in each sector and each country, and goods from the same sector and different countries are also assumed to be imperfect substitutes. The elasticities of substitution are taken from the median estimates of a paper using elasticities in the US in 1993 before NAFTA, and it extrapolates “other manufacturing industries” to services. All of this shows that, despite all its complexities, the model still is quite stylized and simplified, and the quantitative estimation is probably no more than a first pass.

2.3 Are the implied price changes as big as in the production function approach?

As I showed in the case of the production function approach in section 1.3, the price of natural gas needs to increase by +1300% to +3400% for GDP to drop by only 1.6% or 2.3%. One would really like to know what the *implied price changes* of natural gas are in the Baqaee and Farhi (2021) model that are needed to achieve a large reduction in natural gas consumption. I posed this question when David Baqaee and Ben Moll presented their paper at the “Markus’ academy” on 7 April 2022 (hosted by Professor Markus Brunnermeier), but at that time at least, the authors had not looked at what prices would lead to such a drop in natural gas consumption in their model. This really looks like a first-order issue, also from a policy perspective, just because too large price changes might be intolerable, both for the industry and households.

Related to the price issue, Bachmann et al. (2022) implicitly assumes that energy reductions would be broken down "efficiently" between the industrial and household sectors, because in the model, the price mechanism allocates energy reductions efficiently (the price of energy is the same for households and for businesses). This implies that if households can substitute more, then they will bear more of the adjustment. Among households, poorer households would be forced to turn down heating, because they cannot afford the extra cost. If the price increases are indeed 13-fold, or even 34-fold, this would clearly be politically infeasible. And in fact, in Germany, in the case of an energy crisis that triggered an emergency programme, gas rationing would occur primarily in industry and businesses, with private households and hospitals being protected. This of course violates the notion that the constraint would be broken down between households and businesses according to the price mechanism. In such a situation, the GDP decline would clearly be much greater, because industry would have to bear more of the adjustment, while it also has a lower elasticity of substitution. It would be interesting to know how this affects the results.

Finally, in reality neither households nor industry tend to pay the spot price of natural gas. There are long-term contracts, which likely renew every few years for households and the industry, and there are hedging possibilities for industry. Primarily, what will determine who will need to reduce consumption is much more a matter of when these contracts renew (and that depends also on luck!) and how much hedging firms were able to buy, rather than who needs natural gas the most. This is another reason why the losses will be much greater than what is implied in Bachmann et al. (2022): the price mechanism will apply only to a subset of households and firms. Again, these are first-order issues that determine in the end how a reduction in natural gas can reasonably be achieved.

3 The so-called sufficient statistics approach (also based on Baqaee-Farhi)

As one can see, neither the so-called Baqaee-Farhi approach (section 2), nor the production function approach (section 1), can reassure us that the impact of an immediate embargo of natural gas in March 2022 would likely be around 0.3% of GDP, and in any case not larger than 3% of GDP. What about the so-called sufficient statistics approach? This approach, also based on work by Baqaee-Farhi, holds that for a large class of models, regardless of the structure of the production system, a second-order approximation of the effect of losing natural gas depends only on the initial share of natural gas $\mathrm{s^E}$, and the change in that share $\Delta \mathrm{s^E}$ should the embargo takes place. According to the authors, applying this sufficient statistics approach to the problem at hand guarantees that the economic losses from an embargo would remain "small"[4], and it allows to get at a point estimate of 1% of Gross National Expenditure (GNE). But unfortunately, this approach is not really operative here either, for many reasons, and in any case it does not at all guarantee that the losses from an embargo would be "small".

3.1 The sufficient statistics approach is not operative: The "energy share of natural gas" conditional on an embargo is unknown

In order to apply the sufficient statistics approach, one needs to know how much the share of energy imports would rise conditional on an embargo $\Delta \mathrm{s^E}$, since the size of the shock to GNE is equal to the shock to the natural gas supply multiplied by $\mathrm{s^E} + 1/2 * \Delta \mathrm{s^E}$. Unfortunately, there is no way to know what that number would be, since it depends on what would occur, should an embargo take place. In other words, the

[4] The full quote is: "The model simulations in the next section imply that, while this share rises considerably, it does not rise by an unreasonably large amount. This will imply that the GNE losses of an embargo on Russian energy are *small*."

"sufficient statistic" here is not readily observable and, in any case, cannot be identified through exogenous microeconomic variation, which is acknowledged very transparently in Baqaee and Farhi (2019a).[5]

One approach to measure this would be to refer to a historical precedent. But here too, the problem is the same: neither Germany, nor for that matter any other country, has ever had to cope with a natural gas embargo of that magnitude. In particular, the two oil shocks in the 1970s are not a good point of comparison. There is no reason to think that a Russian gas embargo would lead to a change in the energy share similar to what the world has experienced during the two oil shocks in the 1970s, where the energy share tripled, and yet this is what the authors assume. This past situation is not even remotely comparable: oil is very different from natural gas in terms of its use; the way the economy works in 2022 is very different from the way the economy was working in 1973-1979; the shock was then at the world level, while this time it would be at the level of Germany, or at the level of Europe; and so on. In such a situation, there is no reason to think that the energy share, or the natural gas share would only triple.

Moreover, the adjustment would need to take place through rationing and not just through the price mechanism, even though the authors forcefully argue against it from a policy perspective. This is simply because markets would shut down given the large price changes which are needed, so that the energy share of natural gas could rise by less through these non-price mechanisms, and the formula would not apply anymore. In the 1970s, many countries were similarly resorting to non-price rationing mechanisms in order to reduce their energy bills. Without this, the share of energy imports in GDP would probably have increased by even more.

3.2 Hulten's theorem: A faulty logic

Even if this sufficient statistics approach were applicable, the second-order approximation (sufficient statistics approach) is only an improvement on a first-order approximation (Hulten's theorem), which is very problematic. According to that first-order approximation, the impact of an embargo on natural gas would be given by the share of natural gas in output. Since the share of natural gas in output is rather small, say equal to $s^E = 1.2\%$, then to the first-order a cut of 30% in gas supply would then lead to a reduction of only $0.3 * s^E = 0.3 * 1.2\% = 0.36\%$ of GNE, which is very close to what comes out of Baqaee-Farhi (2021). Underlying this theorem there is a hypothesis of production efficiency.

The problem is that in the case of energy, "Hulten's theorem" really isn't a good starting point. Larry Summers at the 2013 IMF Annual Research Conference likened the financial crisis in 2007-09 to a power failure. He mocked a naïve vision some neoclassical economists could have (mentioning "people in Minnesota and Chicago") who would then use "Hulten's theorem" in order to calculate the effects of such a power failure, as everyone could see that if there weren't much electricity there would not be much economy.[6] Arguably, this is not what Bachmann et al. (2022) have done, but improving on such a faulty logic unfortunately does not always lead to something good. Baqaee and Farhi (2019a) warned us: "In (these) limiting cases, the first-order approximation is completely uninformative, even for arbitrarily small

[5] As such, it is not as useful and powerful as the "sufficient statistics" approach in public finance, where it allows to avoid fully specifying a structural model and to estimate sufficient statistics through quasi-experimental evidence. It just says that the initial energy share s^E and the change Δs^E is all that matters, and that two models will have the same predictions (at the 2nd order) if both figures are the same. For more on the sufficient statistics approach in public finances, see Chetty, R. (2009). "Sufficient Statistics for Welfare Analysis: A Bridge Between Structural and Reduced-Form Methods". *Annual Review of Economics*, *1*(1), 451-488.

[6] The speech is available here: "There'd be a set of economists who would sit around explaining that electricity was only 4% of the economy and so if you lost 80% of electricity you couldn't possibly have lost more than 3% of the economy. And there would be, you know, there'd be people in Minnesota and Chicago and stuff would be writing that paper... but it would be stupid! It would be stupid! And we'd understand that, somehow, even if we didn't exactly understand in the model, that when there wasn't any electricity there wasn't really going to be much economy."

shocks." In 2007, many economists were also arguing that subprime losses were tiny as a percentage of GDP, so could not lead to a major crisis.

Intuitively, we can see that Hulten's theorem isn't a good starting point also because the share of energy in GDP varies a lot over time, mostly with the price of oil (since, again, substitution is limited). Thus, depending on when Hulten's theorem might be applied to a forecast, the forecaster might conclude that the effects of an embargo will be high when energy prices are high, and low when energy prices are low.…

3.3 "Second-order" effects should not be first-order

Unfortunately, the second-order effects calculated through the so-called sufficient statistics approach are first-order according to the authors' own calculations, which contradicts the hypothesis that would justify this calculation. For example, assuming that the share of natural gas is initially 1.2% and triples in the event of an embargo (again, there is a question of whether this is a reasonable assumption, see section 3.1), so rises by $\Delta s^E = 2.4\%$, the first-order effect is equal to the second-order effect, equal to -0.36% of GDP (see numbered equation (8) page 13 of the appendix):

$$\Delta \log W \approx (s^E + 1/2 * \Delta s^E) \times -30\% = (1.2\% + 1/2 * 2.4\%) \times -30\% = -0.36\% - 0.36\% = -0.72\%$$

This invalidates the first-order approximation. It implies that the second-order approximation is really not enough, and that third-order or fourth-order terms, etc., would lead to much larger estimates.

3.4 Some other problems

The sufficient statistics approach has other problems. First, the whole sufficient statistics approach relies on a local approximation, and therefore relies on the assumption that the shocks considered are rather small, which is clearly not the case with an embargo and a 30% reduction in natural gas supply. There is a similar problem when one log linearizes a macroeconomic model, which is then used to study large shocks, such as the Great Depression. Even for small shocks, the sufficient statistics approach relies on non-Leontief production functions, even in the limit. In such a case, Hulten's theorem does not even provide a good first-order approximation, even for small shocks (Baqaee and Farhi (2019a)). Finally, another assumption which needs to be valid for the sufficient statistics approach to be practicable is that there is what economists call "efficiency", which is far from certain. This is especially true where much of this is taking place, in the manufacturing sector, which is characterized by increasing returns to scale and thus by scope for inefficiency in the neoclassical sense.

4 Concluding remarks

In my mind, this policy paper is indeed revealing about many economists' perception of engineers, but also about the shortcomings of the neoclassical school's approach towards energy, and the manufacturing sector more generally.

4.1 Engineers vs. economists

In the paper and in the public debate, Bachmann et al. (2022) tend to have very little regard for the "engineering view", which is the view that substitution of natural gas is really very hard, if not sometimes infeasible. They contrast it with what they call the "economic view", which to them is more general, because it for example takes into account substitution through imports but also creative destruction. But the fact that these key inputs will be sourced through trade rather than internally isn't an adjustment mechanism that only increases substitution, it's also a force which might hurt Germany in the long run, just as would creative destruction: imports will strengthen German manufacturing firms' competitors, and creative destruction implies that German industry will indeed be hurt. In my view, engineers might be right after all when they are more pessimistic and do not see this process as a true adjustment mechanism.

Moreover, only engineers can tell us how easy substitution on that scale would be, given that this has never been done before in history. In the context of substituting Russian natural gas, only engineers can help us find technologies that economize more on energy: for neoclassical economists, there is somewhat of a contradiction in assuming that everything will be fine because engineers will always find a way, while at the same time they tend to look down upon engineers.[7]

4.2 Energy is special, and manufacturing is special as well

One thing which engineers know well, perhaps better than economists, is that energy is really special for the workings of the economy, especially in the manufacturing sector. In particular, energy is much more important for the macroeconomy than its share in GDP would suggest, which again explains why Hulten's theorem is such a failure.[8]

Manufacturing is also key to economic prosperity, again much more than its share in GDP would seem to suggest – again a failure of Hulten's theorem and growth accounting. In the economics literature, this phenomenon - the fact that productivity gains in the manufacturing sector are much higher than in the service sector on average - is often referred to as Baumol's disease. This is actually another one of Baqaee and Farhi (2019a)'s examples in their *Econometrica* paper, which presents the limit of Hulten's theorem: the first application of this paper is energy, and the second is on Baumol's disease…. As a consequence, the comparisons in terms of GDP losses between Covid-19 and what would happen should Russian gas be cut are not valid, nor does the number of employees working in both sectors represent the relative economic importance of manufacturing versus restaurants for an economy like Germany's.

Manufacturing is also special in many other significant ways that the authors do not take into account. Perhaps most importantly, there are strong hysteresis effects in manufacturing, which matters a lot in this case. Indeed, many industries (e.g. German glass manufacturing companies) fear that if they have to shut down for a year were Russian gas to be shut off, the industries would not come back. Many of high value-added industries are indeed "winner-takes-all" industries, because of increasing returns, learning by doing, and the dynamic effects would need to be seriously taken into account. In that respect the "economic view" takes into account channels of substitution (imports, creative destruction) that engineers would tend to see more as threats.

The policy report by Bachmann et al. (2022) is also revealing in that neoclassical economists are often sceptical, even critical towards the industrial sector. They complain about industrial policy, about "manufacturing fetishism", and that the industry too often has the ear of governments. Why that is the case

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[7] Abhijit Banerjee and Esther Duflo have a more modest view of the role of economists in *Good Economics for Hard Times*. To them, economists are "several rungs below engineers": "Anyone who has watched the comic TV series *The Big Bang Theory* knows that physicists look down on engineers. Physicists think deep thoughts, while engineers muck around with materials and try to give shape to those thoughts; or at least that's how the series presents it. If there were ever a TV series that made fun of economists, we suspect we would be several rungs below engineers, or at least the kind of engineers who build rockets. Unlike engineers (or at least those on *The Big Bang Theory*), we cannot rely on some physicist to tell us exactly what it would take for a rocket to escape the earth's gravitational pull. Economists are more like plumbers; we solve problems with a combination of intuition grounded in science, some guesswork aided by experience, and a bunch of pure trial and error."

[8] This problem is very pervasive in the neoclassical school. I think it also explains why neoclassical models of trade tend to understate so much the "gains from trade" (not more than a few percentage points of GDP): energy, which many advanced economies are net importers of, is much more useful than in models with CES production functions, and also much more useful than its price suggests. As stated before, the share of energy imports anyways fluctuates a lot over time with its price, for reasons that have nothing to do with how useful energy is for the importing country.

would deserve some independent analysis: perhaps because increasing returns open the scope for government intervention (industrial policy, strategic trade policy[9], etc.), make the assumptions of "welfare theorems" invalid and tend to lead to "anything goes" results? Or perhaps for sociological reasons: economists do not have as much expertise on this sector as engineers (vs., for example, the financial sector)?

4.3 "Whereof one cannot speak, thereof one must be silent?"[10]

I do not wish to argue that I (or the authors) could have done much better, if getting a quantitative estimate through a macroeconomic general equilibrium model were the name of the game: in fact, the speed at which the authors carried out this analysis is impressive, especially given the time limit (a few weeks) and that they had no other choice than to use existing models. But to me, the costs of an immediate embargo were nearly incalculable in March 2022, and I think it would have been best for economists to admit that "economic science" was unable to provide us with a reliable quantitative estimate. A quantitative analysis should have taken into account "where is the gas actually supposed to run through, where are the pipelines, what is the regasification capacity, where are the terminals", as Olaf Scholz then said, because these were first-order issues.

The point that I wished to illustrate in this note is that economists should have been way more prudent in communicating their results, and the large uncertainty / limitations should have been conveyed to decision makers rather than pretend that economists have great models to answer these issues. Since then, the baseline or adverse scenarios in the case of a cut-off of natural gas by major German institutes (such as the Joint Economic Forecast), the Bundesbank, or the IMF have also been much higher (see, for example, Table 1 of Lan et al. (2022); see also a more recent evaluation by Tom Krebs (2022)). In Germany, the policy question was whether the effect of an immediate Russian gas embargo in March 2022 would be major or not. As this note has hopefully helped show, economic reasoning and evidence more generally were unfortunately guaranteeing no such thing.

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[9] This is a long-standing issue. See, for example, the debates in *Foreign Affairs* in 1994 with Paul Krugman, Lester Thurow, etc. Thurow, L. C. (1994). Microchips, Not Potato Chips. *Foreign Affairs*, *73*(4), 189-192. Prestowitz, C. V. (1994). Playing to Win. *Foreign Affairs*, *73*(4), 186-189. Krugman, P. (1994). Competitiveness: A Dangerous Obsession. *Foreign Affairs, 73*(2), 28-44.
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