Physics, Welfare Optimization, Russian Gas, and Climate Change: Questions to Economics

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Physics, Welfare Optimization, Russian Gas, and Climate Change. Questions to Economics

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Most of the time only the loss of things teaches us their real value.

Arthur Schopenhauer, 1851. German original in "Aphorismen zur Lebensweisheit", Vol. 1 of "Parerga und Paralipomena".

Abstract

In modern industrial economies wealth is generated by the production factors capital, labor, and energy. The capital stock is handled by labor and activated by energy. Utilization of energy is subject to the first two laws of thermodynamics, which rule all processes of life and production. In highly industrialized countries energy's economic weight (output elasticity) is typically much larger than its share in total factor cost, whereas for labor the opposite holds. The cost-share theorem and the related equilibrium structure of neoclassical economics are contrary to that. A model calculation of output losses in German industry due to constraints on energy availability, e.g. as a consequence of the sudden stop of Russian gas imports as proposed in March 2022, shows: If one forgoes the

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cost-share theorem one obtains losses that are an order of magnitude larger than the losses that result from neoclassical equilibrium analyses based on welfare optimization without technological constraints. This, the economic consequences felt by producers and consumers by the actual lack of Russian gas in Western Europe, and the need to reduce fossil energy combustion to mitigate climate change, raise a number of questions to economics.

Keywords: economic growth, energy, entropy, output elasticities, constraints, cost-share theorem, Russian gas, climate change

JEL-Codes: A12, E23, O47, Q43

1 Introduction

On April 4, 2022, *The Los Angeles Times* published the article "Germany gets fresh criticism over its purchase of Russian natural gas" [1]. It reported reactions to the March 2022 policy report outlet *EconPol* "What if? The economic effects for Germany of a stop of energy imports from Russia" by Bachmann et al. [2]. These prestigious scholars had estimated that the losses in German gross domestic product (GDP) due to an immediate embargo on Russian gas imports, because of the aggression against Ukraine since February 24, 2022, would be between 0.2 percent of GDP for the most complex model calculations and up to 2.2 percent for simplified models. These estimates stirred up quite some fuss in the media – and professional critique [3], [4] as well.

We have looked into the mathematical foundation of the study [2], which uses standard neoclassical mathematics. We worry about this math, and economic advice based on it, for two reasons: 1) Conventional neoclassical equilibrium theory disregards the two most powerful laws of nature. These are the first and the second law of thermodynamics. In condensed formulation they say: Nothing happens in the world without energy conversion and entropy production. Entropy production destroys *exergy*, the valuable part of energy.

It is associated with the emissions of heat and particles, which cause environmental problems. 2) The neoclassical cost-share theorem, according to which the economic weight of a production factor is equal to its share in total factor cost, is invalid at the prices of energy and labor we have known so far: In its derivation via the optimization of profit or time-integrated utility the technological constraints that result from energy's economic role of activating the capital stock are not taken into account. If one does observe them in optimization, one finds that the duality of factor quantities and factor (market) prices, so convenient in the neoclassical theory of production and growth, actually does not exist [5, 6, 7].

In the following we estimate economic losses due to a reduction of energy use, for whatever reason, be it due to climate policies or a lack of Russian gas as a consequence of the war in the Ukraine, by avoiding the cost-share theorem.

Rather, we use economic weights (output elasticities) of energy and labor, that are for energy much larger and for labor much smaller than these factors' shares in total factor cost. They result from production functions that are computed econometrically and well reproduce economic growth in Germany and elsewhere since 1960, thereby mostly resolving the Solow Residual of neoclassical growth theory. The (time-averaged) output elasticities obtained from them are for energy about 0.44 (and for labor about 0.19) in Germany's total economy (GTE) [8, 10], see also [6, 7], whereas the cost share of energy, and thus energy's economic weight in the simplified models of Bachmann et al., is a meager 0.04. Finally, we point out questions raised by the still blurred view on the production factor energy and its crucial role in future economic evolution.

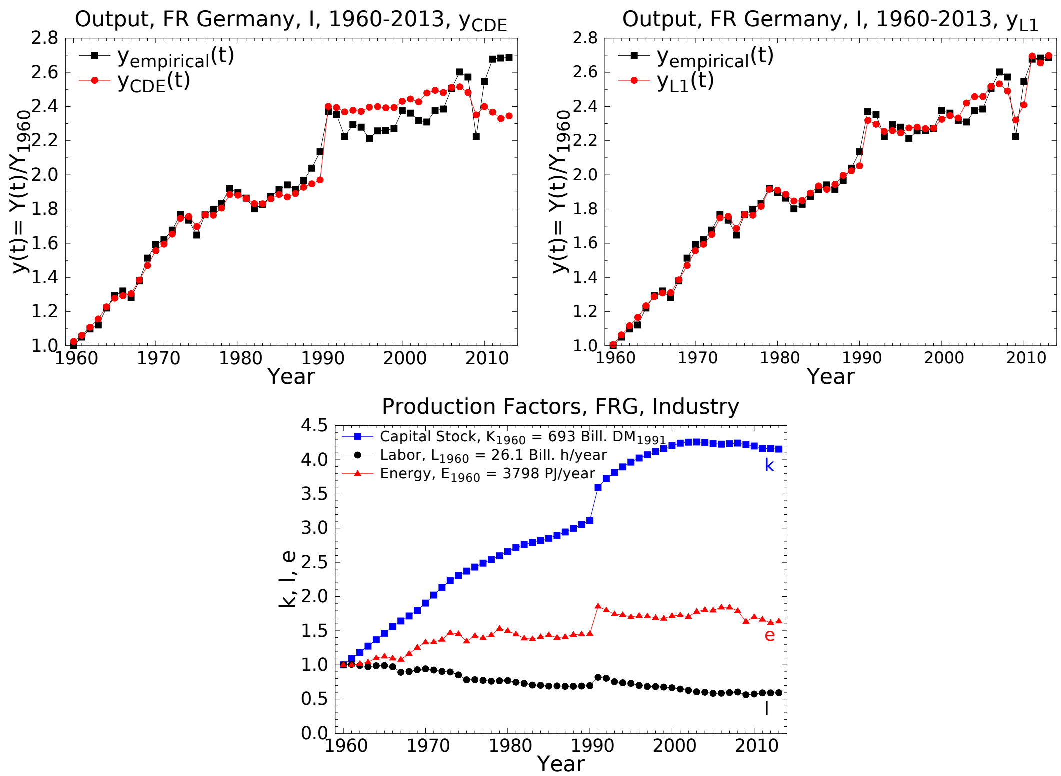

Figure 1: Growth from 1960 to 2013 of the empirical (inflation-corrected) output $y = Y/Y_{1960}$ in the industrial sector of the Federal Republic of Germany (FRG I), black squares, and theoretical growth computed with the energy-dependent Cobb-Douglas function, red circles (top, left), and the LinEx function, red circles (top, right). Empirical growth of (inflation-corrected) capital $k = K/K_{1960}$, labor $l = L/L_{1960}$, and energy $e = E/E_{1960}$ (bottom). 1960 is the base year to which output and inputs are normalized. $Y_{1960} = 453.5 \cdot 10^9 \mathrm{DM}_{1991}$. [8, 10]

2 Capital, labor, and energy in Germany's industrial growth

Germany's economic performance depends heavily on its industry. Therefore we look into the impact of gas-supply shortages on the output of value added in the German industrial sector "Produzierendes Gewerbe" (defined in the German national accounts by the classification system WZ 2008). This sector, FRG I, is the pillar of German economy. If it crumbles, the other sectors will follow.

Fig. 1 shows the empirical evolution of output and of the production factors capital, labor, and energy in FRG I from 1960 to 2013, and the theoretical reproductions of output by the energy-dependent Cobb-Douglas production function, with its constant output elasticities, and the (first) LinEx production function as well [8, 10]. The output elasticities of capital, α, labor, β, and energy, γ, turn out to be $\alpha = 0.41$, $\beta = 0.06$, $\gamma = 0.53$ for the Cobb-Douglas function. In the LinEx function, on the other hand, the factor-dependent α, β, and γ contain two time-dependent technology parameters which reflect the impact of human ideas, inventions, and value decisions, in short "creativity" (or "disembodied technical progress") [7]; at a given time t the contribution of creativity to the growth of output is denoted by δ. Consequently, in the LinEx function the output elasticities of capital, labor, and energy are complemented by that of creativity; their time-averages result to be $\bar{\alpha} = 0.28$, $\bar{\beta} = 0.08$, $\bar{\gamma} = 0.64$, and $\bar{\delta} = 0.13$.

The output elasticities were computed by SSE minimization subject to the constraints of non-negativity, using the Levenberg-Marquardt algorithm [8, 9]. The sudden system enlargement at German reunification in 1990 caused structural breaks in the economy of the political entity "Federal Republic of Germany" (FRG), which the Cobb-Douglas function with its constant output elasticities is less able to take into account than the LinEx function with its factor-dependent output elasticities.

The contribution of FRG I to the GDP of the FRG was 51.7% in the year 1970, 39.6% in 1992, and 27.1% in 2009 [6, p. 193]. (The corresponding contributions of the service sector were 44.9%, 59.2%, 72.0%.) After 1990 the capital stock has increased less and less, because of the outsourcing of more and more "simple" energy-intensive industries such as textiles, basic pharmaceuticals, iron and stone. What is left for "Made in Germany" are novel chemical products and medical instruments, special, high-quality metals, sophisticated machine tools, design and installation of complex industrial plants, transportation systems for people and cargo, etc. The successful export of these energy-intensive products in the course of increasing globilization provided the basis for the expanding German service sector and the associated jobs; an econometric analysis of this sector is in [14]. If the industrial basis breaks down because of a sudden lack of indispensable energy, the service sector will follow.

The fundamental importance of the production factor energy is due to its economic role of activating the capital stock. This implies bidirectional causality between energy conversion and value generation and manifests itself for Germany in the four economic recessions and recoveries and the simultaneous downs and ups of the energy input shown in Fig. 1: Demand for goods and services was damped in the FRG by political uncertainties between 1965-1967 and by the global financial crisis 2007-2009, which led to the 2008 Lehman-Brothers bankruptcy; the first and the second oil-price shocks and the ensuing recessions 1973-1975 and 1979-1981 were caused by the Yom-Kippur war and the Iraq-Iran war. And in times of reduced energy input into the capital stock, demand for capital-handling labor also weakens.

The strong coupling between energy conversion and economic growth has also been observed in other major industrial countries since 1970 [6] -[12].

Actually, Germany, as many other countries, faces a triple challenge: by the Covid 19 pandemic, the war in Ukraine, and the threats from climate change. Political leaders and the population wonder whether to invest the scarce resources of the country in reducing social disparity, strenghthening the military forces, or environmental protection.

The lower income classes suffer significantly from price hikes of food and fuel, induced by Covid 19 lockdowns in the world and the war in Ukraine; the parliament struggles for appropriate state support. Environmental activists fervently oppose the substitution of coal for natural gas, the building of terminals for LNG tankers in environmentally sensitive regions of the German North Sea Coast, and plans not to shut down for good the last three German nuclear power plants by December 31, 2022, as originally prescribed by the German nuclear-exit law. Actually, this shut-down is scheduled for April 2023.

In this third, and probably most severe energy crisis of highly industrialized democracies since World War II we concentrate on industry to exemplify our worry that the cost-share theorem may mislead political advice given by economists who believe in the small economic weight of energy.

We think that an application of "What if?" to the German industrial sector may best facilitate orientation. We turn back to the not so distant, but more peaceful years 2008-2009, when the financial crisis hit hardest. In sort of a *Gedankenexperiment* we ask: What would have happened to the output of FRG I between the years 2008 and 2009, if, for whatever reason, the primary energy input in the German economy had been reduced from 2008 to 2009 by the same percentage as Bachmann et al. assume for the year 2022, namely 8%? We ask and answer this question for the sole purpose of demonstrating the dramatic difference made by *non* use and use of the cost-share theorem.

Table 1 of [2] shows the total amount of German primary energy usage in 2021 to be 3387 TWh (= 12.193 PJ). Gas contributes 905 TWh to this amount, and about 55% of this gas, i.e. 498 TWh, is of Russian origin. Bachmann et al. assume that substituting coal and liquid natural gas (LNG) for part of the 905 TWh of gas could reduce the energy loss by a total embargo of Russian gas to $30\% \times 905$ TWh =271 TWh. This is 8% of the 3387 TWh primary energy used in Germany in 2021.

In 2008 the primary energy input in Germany was 14.380 PJ [13]. Reducing it by 8% yields a loss of primary *energy* input of 1150 PJ. For the sake of simplicity we assume that this loss would essentially occur in industry.

The empirical primary energy input in FRG I was 6797 PJ in 2008 [9, p.83]. Division of the (hypothetical) loss by this quantity yields 1150/6797 = 17%. Multiplying this percentage with the LinEx energy output elasticity $\bar{\gamma}$= 64% results in a hypothetical loss of industrial *output* Y of **11%**.

Actually, the loss of industrial output in 2009 during the financial crisis was **13%** [9, p.83].

Thus, the result of our *Gedankenexperiment* is: If one weights energy not by its cost share but by output elasticities determined econometrically, the computation of the hypothetical output loss of German industry due to an energy loss of 1150 PJ yields a loss that is of the order of magnitude of the empirical loss in 2009, the year of the deepest depression of the financial crisis.

Had we weighted energy by its neoclassical **cost share** of about 4%, we would have obtained an output loss of only **0.7%**.

3 Questions

By October 2022, the flow of Russian gas to Germany has stopped. This is the situation that – earlier – Germans should have induced themselves, as demanded especially by those who quoted the results of [2]. In the new reality, however, Germans worried: How do we get through the winter? Luckily, the 2022/23 winter turned out to be extraordinarily mild, considerably less gas was needed for heating, and severe economic repercussions of reduced gas availability did not occur. But, is the issue really resolved?

Finally, with a delay of more than half a year after the outbreak of the war in Ukraine, the paramount importance of energy for German industry and the general welfare has been realized by the population. After trade sanctions against Russia and an energy price cap had been introduced by the EU, the German *Angst* was and still is that exporters of oil and gas don't accept the cap and sell their stuff to Non-EU customers. Economically somewhat weaker EU members fear that German egoism, as they say, would break up the union of European democracies when it is needed most in the face of a ruthless aggressor. How can solidarity and cooperation within the European Union be preserved, if there are sharp differences in energy policy and still insufficient clarity about the fact that capital is dead without the energy that activates it?

A question to the European Central Bank (ECB) suggests itself in the face of the accelerating inflation. Since 2014 oil and gas had been cheap. On April 20, 2020, for the first time in history, oil was even sold at *negative* prices on the world market, because the Corona epidemic had curbed demand, and there was a lack of storage facilities. Since oil and gas are considered as commodities in the basket of goods and services, whose prices determine the rate of inflation calculated by the ECB, one had obtained inflation rates below the 2% level, considered by central bankers as the necessary minimum; at less inflation they fear deflation and recession. Thus, the monetary policy of the ECB before 2021 had been to drive the Euro-area-rate of inflation up to the 2% level. There was too much drive: Inflation has grown up to 9.9 % in February 2023 with respect to Feb. 2022 [15]. How would have been the policy of the ECB with respect to energy-price levels, if it had taken into account the *dual* utility of energy consumed by humans since taming of the fire: as a commodity, like other natural resources, *and* as a factor of production?

In August 2022 the authors of [2] published a new study [16]. They confirm that the economic losses because of a stop of Russian gas imports should be of the same order of magnitude as published previously, without giving any specific numbers, though. Rather, they call upon a number of examples from industrial practice, which show how Russian gas can be substituted by imports of *energy* and *energy-intensive* intermediate goods. Why did they not continue the theoretical research presented in [2], just replacing its *two-factor* constant-elasticity-of-substitution (CES) function of energy and another input named X by the precisely defined CES production function of capital, labor, and energy [17], and look into the substitutability of energy by the two other production factors *without* using the cost-share theorem? (How one might proceed in detail is indicated in https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4127764.) This would have been consistent with their prior mathematical reasoning – although, of course, inconsistent with neoclassical equilibrium economics and its belief that energy's economic weight is given by its small cost share.[1]

The marginal importance assigned to energy and the laws of physics by standard

[1] For a more detailed reply to [16], see [18], where we also present the basic engineering and economic facts for energy being an important factor of production and for the neoclassical cost-share theorem's role in misleading policies.

economic theory also showed strikingly during an international conference on natural resources. There, the (then young) economist Wolfgang Ströbele pointed out that because of the second law of thermodynamics capital cannot completely substitute for energy [19]. At that, a world-famous mathematical economist rose and shouted with reddening face: "You must never say that! There is always a way for substitution."

Climate change became an issue in the 1990s. W. Beckerman, W. Nordhaus, and T. Schelling estimated that climate change would only cause small losses of welfare, because climate change would only affect agriculture, which contributes just 3 percent to the GDP of the USA. Aptly, Herman Daly [20] commented on that.

And the gap between the natural sciences and the teaching of modern economists has been deplored by Wassily Leontief, Nobel laureate in economics, when he asked : "How long will researchers in adjoining fields ... abstain from expressing serious concern about the splendid isolation in which academic economics now finds itself?" [21, p.104], [22].

In his book "A Question Balance. Weighting the Options on Global Warming Policies" [23] the 2018 Nobel laureate in Economics W. Nordhaus employs cost-share weighting of production factors. On Slide 4 of his Nobel Lecture "Climate Change: The Ultimate Challenge for Economics", he shows "The mathematics of the DICE model" [24]. This math is based on the abovementioned neoclassical foundation of the cost-share theorem, i.e. the maximization of welfare, given by the time-integrated utility $U[c(t)]$. Nordhaus' maximization is only subject to a constraint on consumption $c(t)$. The *technological* constraints [6, p.189f, p.243ff, p.248ff], [7, p.9f], that invalidate the cost-share theorem, are ignored.

Furthermore, in the DICE model, and other estimates of economic losses because of global warming, the rate ρ, at which future welfare and its losses are discounted, is important – and highly controversial [25, 26]; N. Stern favors low discount rates. Economists such as Ramsey [27] and Arrow [28] question time preferences and discounting of the future for ethical reasons. The welfare optimization subject to *technological* constraints in [5]-[7] follows Samuelson and Solow's procedure on discounting: "…society maximizes the (undiscounted) integral of all future utilities of consumption subject to the fact that the sum of current consumption and of current capital formation is limited by what the current capital stock can produce" [29]; as in [30] optimization of time-integrated utility is done within finite time horizons. But despite the crucial and controversial role of the discount rate ρ in the DICE model our *main* problem with this model is its use of the cost-share theorem and the associated massive underestimation of the economic importance of the production factor energy.

A critical assessment of Nordhaus' DICE model has recently been published by Hänsel et al. [31]. They suggest updates that include changes like "more accurate calibration of the carbon cycle and energy balance model." This leads to our last question: What results would be obtained from integrated assessment models like DICE, if in the production functions, which enter the consumption function $c(t)$, the output elasticities of capital, labor, and energy were determined econometrically and *not* by the cost-share theorem?

Declaration

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