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The economic power of energy and the need to integrate it with energy policy

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HIGHLIGHTS

- The article indicates the importance of thermodynamics for economics.
- Due to technological constraints output elasticities deviate from factor cost shares.
- We point out energy policy implications from the high output elasticities of energy.

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ABSTRACT

Drastic oil price changes, the associated economic perturbations, the coupling of energy conversion to entropy production in the form of emissions, and the problems of climate change call for a reappraisal of energy in economic theory. We review econometric growth analyses that do *not* weigh the production factors capital, labor, and energy by their cost shares. Their reproduction of economic growth in Germany, Japan, and the USA during the second half of 20th century is good. According to these analyses, energy's output elasticity, which measures its economic power, is much larger than energy's share in total factor cost, while for labor's output elasticity and cost share the opposite is true. This is consistent with profit and welfare optimization, if hitherto ignored technological constraints are taken into account. Computing the motion of the German industrial sector in its cost mountain, employing empirical data on factor quantities and prices, supports these results. The pivotal role of energy in economic growth provides leverage to energy policies that care about social well being and climate stability.

1. Introduction

The first global economic recession of the 21st century resulted from the financial crisis that was triggered by the bursting of the US housing bubble in 2007. Fig. 1 shows that crude oil prices had steeply risen in the years before, reached nearly 100 US $\$_{2011}$ in 2008, plummet to roughly 65 US $\$_{2011}$ in 2009, and shot up again to about 110 US $\$_{2011}$ in 2011, thus exceeding the maximum of the 1973–1981 oil-price explosions. In 2013 the oil price was somewhat less than 110 $.[1] Recently, between July 2014 and January 2015, the oil price had dropped to less than 50 dollars per barrel as a consequence of the exploration of non-conventional oil wells, unconstrained oil recovery from conventional oil fields, and political crises that have damped global economic growth and energy demand.

The real growth rate of global GDP, which was 5.2% in 2007, dropped to 3.1% in 2008 and to −0.7% in 2009; then it recovered to 4.9% in 2010.[2] The annual global carbon dioxide (CO_2) emissions from fossil fuel combustion, which had permanently risen since 1990, reached a maximum of 29.5 billion tons in 2008, dropped to 29 billion tons in 2009, and then rose again, to 31 billion tons in 2010, see Fig. 2. World primary energy consumption varied roughly parallel to the global GDP growth rates, and to the variations of CO_2 emissions as well, following their downturn and upswing between 2008 and 2010.[3]

Are there any causal relations between these observations? The financial crisis resulted from special behavior of influential actors on financial markets, e.g. irresponsible lending, plain fraud, and

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[1] Source: BP Statistical Review of World Energy 2014, p. 15.

[2] Source: The CIA World Factbook as quoted by http://www.indexmundi.com/g/g.aspx?c=xx&v=66.

[3] Source: International Energy Statistics, Energy information Administration, as quoted by http://en.wikipedia.org/wiki/World_energy_consumption.

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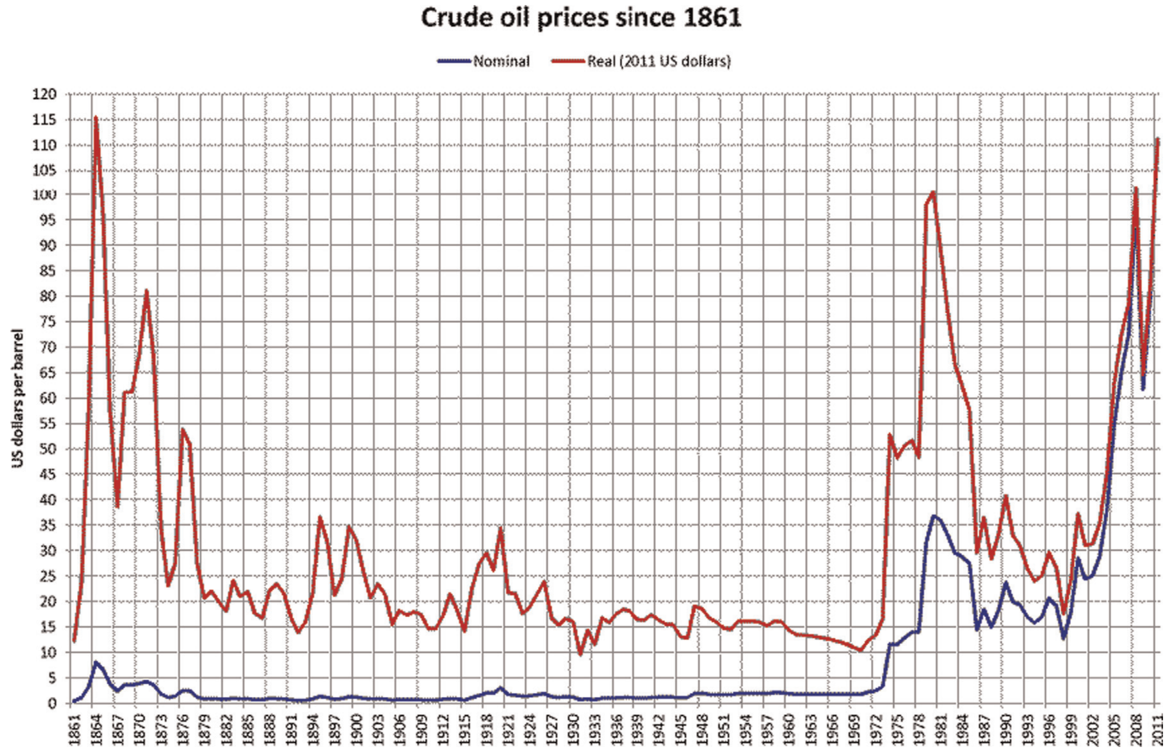

Fig. 1. Development of the price of one barrel of crude oil since 1861 in 2011 US dollars, upper curve, and in dollars of the day, lower curve [source: http://en.wikipedia.org/wiki/Price_of_petroleum; data from "BP workbook of historical data": 1861–1944 WTI, 1945–1983 Arabian Light, and 1984–2011 Brent (yearly average)].

gambling with financial products hardly anybody understood. At hindsight, it is not surprising that it resulted in problems of the real economy, given the history of bubbles. (Another thing is that, apparently, people do not learn from history.) Furthermore, economic growth had suffered in the past during the first and the second oil-price shocks between 1973 and 1981, and the oil price increases since 2005 may have contributed to the financial and economic crises since 2007 (Murray and King, 2012). But are the economic downturns and upswings, on the one hand, and the simultaneous variations in energy consumption and CO_2 emissions, on the other hand, accidental,[4] just as the number of babies in Sweden decreased with the number of storks, or are there physical interdependencies at work, in conjunction with market mechanisms?

Edenhofer et al. (2010), in a report prepared for the NGO "Misereor" and the "Munich Re Foundation",[5] emphasize the urgent need to fight climate change in the interest of both the developing and the industrialized countries. Relating that to energy policy, they reason that, historically seen, growing wealth has been intimately connected to the combustion of fossil fuels and the resulting emissions of carbon dioxide. This conclusion from the observed simultaneously rising time-series of fossil fuel consumption and GDP can (and should) be made even more stringent by basing it on the fact that energy is a powerful factor of production. It is the purpose of this review to recall the arguments for accepting this still heterodox economic position. If it were considered in the computation of the economic losses due to climate change, pioneered by Stern (2008), the expected losses may turn out to be even more dramatic than the ones computed so far in climate-change scenarios. In these scenarios, the discount rate that is applied to future damages plays an important role and has stimulated heated discussions.[6] Nevertheless, there is no doubt that greenhouse-gas emissions must be reduced drastically, by up to 80% until the year 2050, if the increase of the surface temperature of the earth should not exceed 2 °C. This is consensus among practically all nations, by now. However, an agreement on internationally binding emission limits is difficult to reach, because important actors like the USA, China, and India fear that emission reductions will restrict energy utilization – which causes about 65% of greenhouse-gas emissions (Stern, 2008) – and thus threaten economic growth.

Despite the crucial role of energy in industrial production and climate economics, most mainstream economists still disregard energy as a factor of production. In their view, only capital and labor matter for the generation of goods and services, which make up the output of an economy. Technological progress – the "Holy Grail of Economics", or "Mannah from Heaven"– takes care of the rest. However, this rest, the notorious "Solow residual", exceeds 50% of gross domestic product (GDP) in many highly industrialized economies. This "has lead to a criticism of the neoclassical model: it is a theory of growth that leaves the main factor in economic growth unexplained", as stated by the founder of neoclassical growth theory Solow (1994) himself.

If, occasionally, established economists like Nordhaus (2008) do take energy into account as a factor of production, energy's economic weight, which is called *output elasticity*, is set equal to its share in total factor cost. (The mathematical reason for doing that will be criticized in Section 2.) Since in industrialized countries this share has been much smaller than the shares of capital and

[4] Econometricians like Denison (1979) argue that the recession 1973–1975 and the simultaneous oil-price hike could not have been related, because "Energy gets (only) about 5 percent of the total input weight in the business sector…".

[5] The proper business of Misereor is development assistance; its financial basis are donations from German Catholics. Munich Re is the largest reinsurance company of the world.

[6] A review of the Stern report, and the controversies it has raised among economists, is given in *Ökonomische Bewertung der Klimawandel-Folgen* in: "Weltklima und zukünftige Energieversorgung" (M. Keilhacker Hrsg.), Deutsche Physikalische Gesellschaft, Bad Honnef, 2007, pp. 73–89; the review is also on http://www.physik.uni-wuerzburg.de/~kuemmel/English/indexE.html, Section "Teaching".