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Transitory "green growth" without rebound effects: Fixing long-term price paths for fossil energy

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Abstract

The transformation towards a zero-carbon economy requires a comprehensive renovation of the capital stock in almost all sectors. The rebound effects of the related (transitory) "green growth" on carbon emissions can be avoided by fixing rising price paths for fossil energy so that the income effects of overall production are over-compensated by the substitution effects of rising (relative) prices of crude oil, coal, and natural gas. The (expected) profitability of investments in energy efficiency and in renewable energy would steadily and calculably rise since their profits consist primarily of the saved fossil energy costs ("opportunity profits").

Carbon tax or emission trading schemes cannot anchor the *expectation* that the *effective* emission costs will rise continuously due to the instability of fossil energy prices and CO_2 emission prices. If, e.g., fossil energy prices decline faster than a carbon tax or the emission permit price rises, then the effective emission costs decline (e.g., through falling fuel prices).

Technically, a system of effective carbon pricing could easily be implemented: The EU Council sets a path of steadily rising prices of crude oil, coal and natural gas by skimming off the difference between the EU target price and the respective world market price through a flexible quantity tax. This implicit CO_2 tax would provide planning security for "green" investments, ensure a uniform European carbon price and yield (very) huge receipts. Part of them could (co)finance "green" investments, another part could be used to strengthen the welfare state and compensate low-income groups for the energy price increase.

Keywords: Carbon taxes, emission trading, effective emission costs, long-term expectations, profitability of ecological investments.

JEL: G12, Q01, Q54

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1. Introduction

At present, the key policy challenges are preventing a climate catastrophe as well as overcoming the social and economic crisis. The first challenge calls primarily for fighting global warming as most other environmental problems are related to the latter. If a climate catastrophe is to be avoided CO2 emissions must be reduced to zero as fast as possible. Reaching this target necessitates a comprehensive renovation of the capital stock:

- Transformation of residential and commercial buildings into little power stations through the combination of better isolation, photovoltaics, heating pumps and batteries.
- Construction of a trans-European high-speed railway net as alternative to air travel.
- Expansion of local public transport, especially in large cities, as an alternative to private car transport.
- Replacing cars and trucks with combustion engines to emission-free vehicles (driven by electric power from batteries or - in the case of trucks – also from hydrogen).
- Moving in industrial production from using fossil energy to "green" hydrogen, i.e., produced by power from renewable resources.
- Massive expansion of power generation from renewable sources as well as of power grids and storing capacities to meet the massively rising electricity demand.

The realization of these investment programs will raise economic growth over the transition period of roughly 30 years. In the case of Germany, GDP would grow by roughly 3 percentage points per year higher than without such a Green Deal (as sketched in the annex).[1])

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[1]) Many studies deal with pathways towards a zero-carbon economy. See the publications of the Commission on the European Green Deal and on the intermediate target of reducing CO_2 emissions until 2030 by 55% ("Fit for 55"). *Wildauer – Leitch – Kapeller* (2020) consider a much higher volume of investments necessary to reach climate-neutrality than the European Commission. A much more optimistic scenario is sketched in *McKinsey&Company*, 2020. For a comprehensive treatment of the climate crisis in the context of environmental sustainability in general, see *European Environment Agency*, 2019. A roadmap for the global energy sector is provided by the International Energy Agency (*IEA*, 2021). For Germany, pathways towards a climate-neutral economy are investigated in *Prognos et al.* (2020A) and in *Ariadne-Report* (2021). All these studies do not quantify the impact of the different "transition investments" on economic growth and, hence, do not deal explicitly with the related rebound effects.

Such "green growth" would enable the renewal of the capital stock as the basis of a future circular economy. Once this is achieved (at least as regards energy), growth could be phased out. Over the transition period, the green growth would also mitigate the social and economic crisis through providing more jobs (particularly also "good" jobs) and more financial means for modernizing the welfare state.

But what about the rebound effects of additional growth over 30 years? This issue is particularly important as using exclusively renewable electric power necessitates, e.g., the production of at least five times more wind power stations as already exist (in the case of Germany, roughly additional 150.000 wind turbines are needed as shown in the annex). Since they consist mainly of steel and cement, their production is extremely CO_2 intensive.

This example points to the following paradox: On the way to an emission-free economy, additional CO2 emissions must be accepted, which stem from the production of those capital goods that enable an emission-free economy in the future.

Adherents of a degrowth strategy might argue that this dilemma should be solved by shrinking production and consumption in other sectors to compensate for the rebound effects of green growth. This conclusion is drawn from the empirical evidence: "Absolute decoupling" of greenhouse gas (GHG) emissions from GDP growth (i.e., declining emissions in absolute terms) have rarely been realized in the past, certainly not as large, and fast as necessary to prevent a climate catastrophe in the future (*Haberl et al.*, 2020).

In the case of CO_2 emissions, however, it is particularly problematic to extrapolate from past trends to the future for political as well as economic reasons. First, the awareness of the danger of a climate catastrophe and the willingness to fight it are much more pronounced today than in the past. Second, the prices of oil, coal and natural gas and, hence, emission costs, have fluctuated enormously in the past, and have fallen in the long term relative to the general price level. For entrepreneurs as well as for households, it has therefore been uncertain and unprofitable to invest in avoiding carbon emissions in most cases. Conversely, if everyone knew that such emissions were becoming *permanently and steadily more expensive*, then all measures to avoid them would become profitable.

In more technical terms: For any path of economic growth there exists a path of rising fossil energy prices so that the (demand raising) income effects of overall production are over-compensated by the (demand dampening) substitution effects of rising (relative) prices of fossil commodities. In this way, one can control and restrict the rebound effects of economic growth on CO_2 emissions and, hence, can reconcile economic growth with ecological targets (at least to a much larger extent than in the past). Instead of compensating for additional emissions caused by green investments through degrowth in other sectors, one could (and should) achieve a steady and permanent emission reduction through raising relative fossil energy prices.

To put it concretely: If the prices of crude oil, coal and natural gas had risen steadily faster than the general price level over recent decades, CO_2 emissions would have become progressively more expensive. This would have incentivized business and households to adjust, primarily through investments in energy efficiency and in renewable energy production. In this way, carbon emissions would have been steadily decoupled from economic growth.

The same rationale underlies the concept of carbon pricing, whether through taxes or emissions trading: Having to pay for every ton of CO_2 a certain tax or permit price should not only account for the external costs of emissions but should also provide incentives for investing in the steady reduction of carbon emissions.

However, this goal can only be achieved if the *effective* overall costs of emissions are expected to increase *steadily*. These effective costs consist of two components, the respective world market price of oil, coal and natural gas as well as the CO_2 tax or the cost of emission certificates, respectively. If people repeatedly experience that the effective emission costs decline because world market prices of fossils and/or emission prices decline, then these expectations cannot be established. In Germany, e.g., one litre diesel is taxed by 47 cents which implies a (implicit) carbon tax of 180 € per ton. Despite this high taxation, the diesel price at the filling station and, hence, the effective emission costs, declined three times by roughly 30% over the last 15 years because the crude oil price fell even more (figure 4). The effective costs of the use of oil, coal and gas in those sectors which are comprised by the EU Emission Trading System (ETS) fluctuate even more as the emission permit prices are even more unstable than fossil energy prices (figure 3).[2])

More generally speaking: In a world where (derivatives) prices of fossil commodities as well as of carbon emissions fluctuate in a sequence of "bull markets" and "bear markets" (conventional) carbon taxes as well as emission trading schemes cannot anchor the *expectation* that emitting CO2 will *steadily* become more expensive (and will never again get cheaper). Under these conditions, the future returns from investing today in the avoidance of carbon emissions remains incalculable. This uncertainty problem is massively exacerbated by the extremely long payback periods of ecological investments calling for *maximum long-term planning security*.

As neither (rising) carbon taxes nor emission trading schemes can sufficiently incentivize the necessary investments in a permanent reduction of carbon emissions, this paper presents an alternative approach taking the EU and its European Green Deal as example: The EU sets a path of steadily rising prices (e.g., by 5% per year) of crude oil, coal and natural gas by skimming off the difference between the EU target price and the respective world market price through a monthly adjusted quantity tax (the flexible tax would compensate for the fluctuations of fossil energy prices). In this way, the uncertainty about future emission costs would be eliminated. Firms and households could calculate the profitability of investments in avoiding

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[2]) This is in no way to suggest that the current forms of CO2 pricing do not have a dampening effect on emissions. That this is indeed the case is shown by developments in countries such as Great Britain, Sweden, Denmark, or Germany, where absolute decoupling has succeeded to a noticeable extent (for the effects of CO2 pricing to date, see *Andersson*, 2019, *Best et al*., 2020, *World Bank Group*, 2020). However, much greater efforts are needed to achieve a climate-neutral economy by 2050.

them. Such a tax would ensure a uniform European carbon price in all sectors, provided the initial level of the price paths of crude oil, coal and natural gas account for the different CO_2 intensities of these types of fossil energy.

The paper is structured as follows: The next section deals with the contradiction between the particularly long time horizons of "green investments" and the instability of those prices which determine to a large extent the profitability of these investments, i.e., the prices of fossil energy as well as of carbon emission permits. Then, I discuss the reasons why the conventional ways of CO_2 pricing through trading schemes or carbon taxes cannot incentivize a sustained reduction of carbon emissions. The next section explains the alternative approach of fixing long-term price paths for crude oil, coal and natural gas. The paper concludes with some considerations on the climate crisis as a challenge to organize a "collective action" at the global level as well as on a transitory "green growth" as compatible with the normative fundament of the degrowth literature.

2. Planning horizon and planning (in)security of "green investments", oil price instability and global warming

Investments in energy efficiency and/or in renewable energy only pay for themselves after many years (energetic refurbishment of buildings, diffusion of electric cars including supply networks, etc.) or even decades (hydrogen technology in industry, a trans-European net of high-speed trains, renewable energy additionally needed in a zero-carbon economy, etc.). The socio-ecological transition therefore requires *maximum long-term planning security*.

At the same time, market prices of the main carbon emitters, i.e., fossil commodities, do not include the "external costs" caused by their use, i.e., the costs of the climate crisis. A second market failure has deepened the crisis, which is typical for asset prices in general, and, hence, also for the prices of crude oil or of CO_2 permits: They fluctuate in a sequence of bull and bear markets. Between 1973 and 1982, e.g., the crude oil prices increased tenfold, mainly due to the two "oil price shocks" in 1973 and 1979, respectively (figure 1). In both cases, OPEC took advantage of political turbulences in the Middle East to "retaliate" for the preceding dollar depreciations 1971/73 and 1976/79, respectively (*Schulmeister*, 2000).

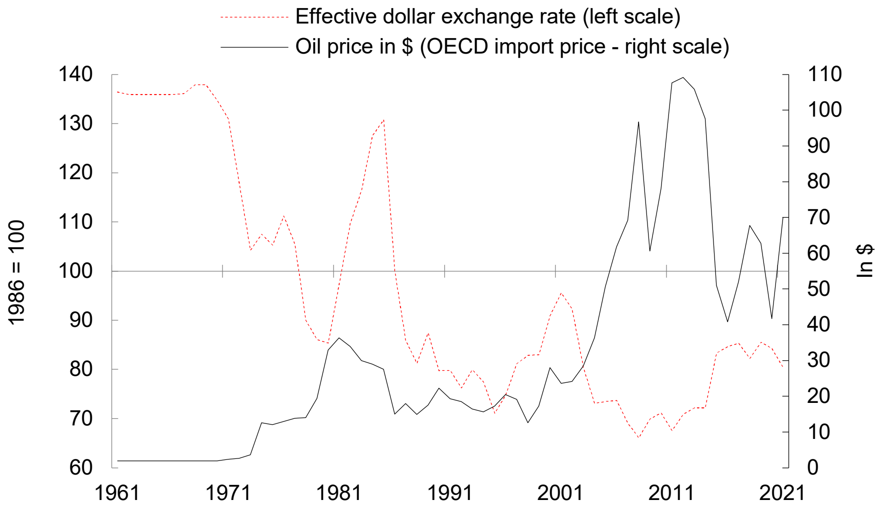
Triggered by the global recession 1980/82, oil prices fell by more than 50% between 1980 and 1985. However, oil producers were compensated by the rising value of the dollar. When the dollar started to fall again, Saudi-Arabia flooded the oil market with additional supply to restore production discipline within the OPEC cartel. This strategy failed and oil prices stagnated at a low level for roughly 15 years (figure 1).

After the recession of 2001, oil prices started to boom again, interrupted by a sharp fall during the Great Recession. Between 2011 and 2016, oil prices declined by roughly 70%, mainly caused by the emergence of additional supply stemming from fracking technologies. Prices recovered between 2016 and 2018 but then fell again and almost collapsed in early 2020 when Saudi-Arabia returned to her strategy of 1986, i.e., flooding the market with additional oil supply

- this time to "punish" Russia for not reducing oil supply in a coordinated manner. At the same time also stock prices collapsed (diffusion of Covid19 in Western countries).

The unprecedented intervention by central banks in March 2020 "aborted" the bear markets and fostered a "bullish" sentiment in all asset markets (stocks, bonds, commodities, crypto currencies). The increase of crude oil prices (from $15 to $75 – figure 2) but also the quadrupling of EU emission prices (figure 3) was embedded in this "bullish regime".

Figure 1: Dollar exchange rate and oil price fluctuations



Source: OECD, IMF

As sketched above, important turning points in oil price trends are triggered by economic and political events ("fundamentals"). But why do the subsequent upward or downward trends last so long? Such an "overshooting" of asset prices can be explained as follows.

Speculative prices like those of stocks, foreign exchange, oil futures or CO_2 emission permits fluctuate almost always around "underlying" trends (figures 2 and 3).[3]) The phenomenon of "trending" repeats itself across different time scales ("self-similarity"). E.g., there occur trends based on tick or minute data as well as trends based on daily data.

"Technical" or "algo(rithmic)" trading aims at exploiting the trending of asset prices. In the case of *trend-following* moving average models, a trader would open a long position (buy) when the current price crosses the MA (moving average) line from below and sells when the opposite occurs (figures 2 and 3). By contrast, *contrarian* models try to profit from trend reversals and, hence, change open positions when a trend "loses momentum".

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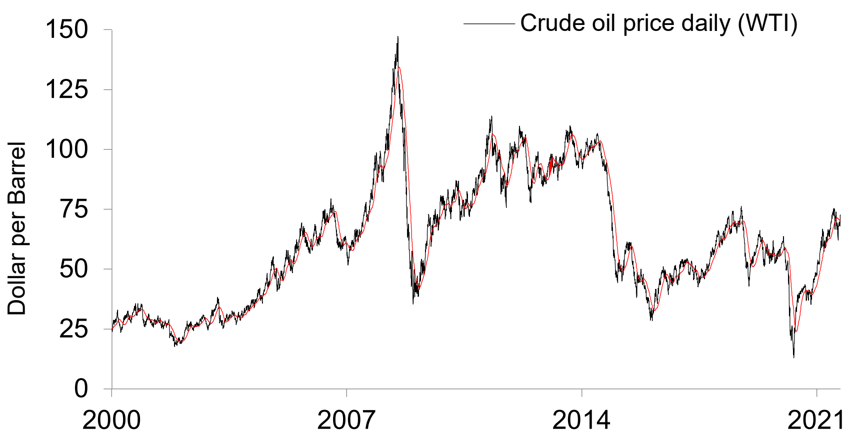
[3]) Empirical research on the role of technical trading in asset price dynamics in general is documented in *Schulmeister*, 2009, as regards commodities prices, in particular oil prices, in *Schulmeister*, 2012.

Technical models are applied to price data of almost any frequency. Due to the increasing use of intraday data, algo trading has become the most important driver of the rising "speed" of trading and the related boom in the volume of financial transactions.

Long-term price trends result from the following process. "mini-trends" (e.g., based on minute data) add up to one trend based on 10-minute data. Several of these trends accumulate to one trend based on hourly data, and so on. Over a longer period, upwards (downward) trends last longer than counter-movements (mainly due to a "bullish" or "bearish" sentiment), causing the price to rise (fall) in a stepwise process. Figure 2 shows how oil price trends based on daily data accumulate to bull markets and bear markets.

Figure 2: Trending and speculation in the crude oil futures market



Source: NYMEX

The concurrence of both types of market failure in the dynamics of fossil energy prices, i.e., disregarding environmental costs and "overshooting", has contributed to global warming reaching a life-threatening dimension. This is so because the low level of fossil energy prices caused an excessive use of crude oil, coal and natural gas, exhausting a great deal of the global carbon budget. In addition, the instability of these prices rendered the returns of investments in avoiding carbon emissions incalculable. As consequence, a consensus has (slowly) emerged since the 1990s that CO_2 emissions should be priced, either through emission trading schemes or carbon taxes.[4]) Unfortunately, neither instrument can ensure that the effective emission costs will steadily and permanently rise so that companies and households can rely on the profitability of their investments in avoiding emissions.

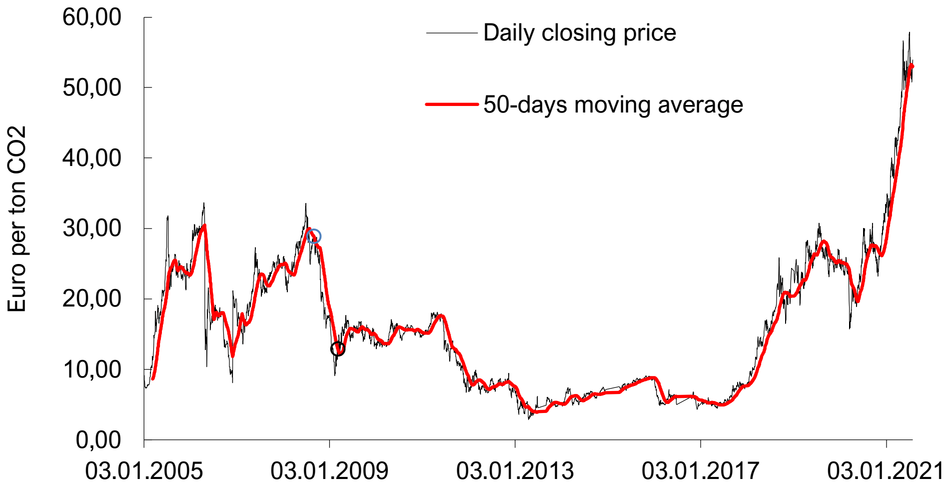
[4]) The general issue of carbon pricing is analysed in *Edenhofer et al* (2019), *Guttman* (2018), *Köppl – Schleicher – Schratzenstaller*, 2019, *OECD* (2018), *Sachverständigenrat* (2019) and in the report of the *Stiglitz-Stern-Commission* (2017).

3. Carbon pricing through emission trading systems

The EU Emission Trading System (ETS) was introduced in 2005 and covers the main CO_2 emitters from industry such as steel, paper, chemical or cement producers as well as power generators which together account for about 45% of all CO_2 emissions in the EU.[5])

In theory, emission trading is an optimal control instrument: CO_2 emissions are limited by the volume of permits and this cap is gradually reduced. A uniform price is formed on the permit exchanges, which ensures that the emissions take place where their benefit is greatest: A company that needs additional certificates buys them via the exchange from another company that has a surplus. These transactions constitute *compliance transactions*.

Figure 3: Fluctuations of the futures price of EU CO_2 emission allowances



Source: Intercontinental Exchange (ICE)

For emissions trading to create incentives to invest in the CO_2 reduction, permit prices would have to rise steadily, at least they should not widely fluctuate. But this is precisely the case: Since the introduction of the ETS, the price for the emission of one ton of CO_2 has been fluctuating between (roughly) €3 and €30. Only during the recent bullish period did the price increase to almost €60 (figure 3). However, it will fall again when market sentiment tilts into bearishness. Between 2009 and 2018, i.e., most of the time, the price was at such a low level that it did not create an incentive to invest in reducing emissions.

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[5]) For an overview of the EU Emissions Trading System see *Schleicher et. al.*, 2015, *Marcu et al.*, 2020, *European Environment Agency*, 2020, and *Ellerman et al.*, 2016. A summary of emissions trading worldwide is *ICAP*, 2018. The microstructure of carbon emission markets is discussed in *Kachi – Frerk*, 2013, and *Mizrach – Otsubo*, 2014. The importance of (destabilizing) speculation in the spot and derivatives markets of EU emission allowances is examined by *Berta et. al.*, 2017. *Schultze* (2021) provides anecdotical evidence about the rising importance of hedge funds and other financial speculators in EU emissions trading.

This failure has two main causes. First, the amount of certificates must be fixed in advance for a longer period. This organisational necessity leads to misallocations and thus "wrong" CO_2 prices due to the fundamental uncertainty about the medium-term economic development. E.g., the financial crisis was - of course - not foreseen, resulting in an oversupply of emission permits so that their price fell to below €10 in 2009 and further to below €5 by 2013 (figure 3). [6])

Second, financial actors on the CO_2 permit exchanges "interpose" themselves between companies with a surplus or deficit of permits and use permit futures as vehicles for speculation. Thus, since 2010, 99% of all permit transactions have been carried out in derivatives and only 1% in genuine certificates. Already in 2012, the total CO_2 transactions volume (including derivatives) of all actors was more than 33 times higher than the companies' "compliance needs" (*Berta et al*., 2017) Moreover, the CO_2 price dynamics shows the pattern typical for speculative prices in general: Short-term trends, which are exploited by algorithmic trading, accumulate into longer-term bull or bear markets (figures 2 and 3).

A comparison of the dynamics of crude oil prices and emission permit prices provides indirect evidence of the importance of speculation unrelated to market fundamentals. Both prices should move inversely over the medium run as falling oil prices should generate the expectation of rising oil demand and thus should cause CO2 prices to increase, and vice versa. However, such an inverse development is not empirically ascertainable (figures 2 and 3). In particular, the simultaneous and pronounced rise in both prices since the spring of 2021, which began at approximately the same time as the boom in stock prices, points to the influence of speculative factors embedded in a "bullish sentiment" on almost all asset markets. At the same time, professional traders like hedge funds massively increased their engagement in EU carbon (derivatives) markets (*Schultze*, 2021).

4. Carbon pricing through emission taxes

In all EU countries there has long been a tax on fuels. It is equivalent to a tax on CO_2 emissions caused by fuel consumption since there prevails a fixed relationship between the quantity of fuel consumed and the related CO_2 emissions. [7])

In Germany, e.g., the tax on diesel is 47 cents per litre. Since the burning of one litre diesel produces 2.65 kg CO_2, the diesel tax burdens the emission of one ton of CO_2 by roughly 180 €

[6]) The problem of uncertainty about the effective carbon emission costs is even bigger in the case of emission trading schemes as compared to carbon taxes as actors can know the carbon tax rate but not the future emission permit prices (*Aldy – Armitage*, 2020). *Bayer – Aklin* (2020) argue that even if carbon prices are low, an emission trading system can reduce emissions if it is a credible institution which is believed to become a more stringent in the future. They show that the EU ETS saved 3.8% of overall emissions relative to a world without carbon markets. The extent of this reduction is, however, much too low compared to what is required.

[7]) An overview of carbon taxes on CO_2 emissions from energy use in 42 countries can be found in *OECD* (2018). *Kirchner et al.* (2018) analyse the macroeconomic and distributional effects of CO_2 taxes for Austria.

(= 0.47/2.65 per kg). This is much more than in most planned or – like in Sweden or Switzerland – already implemented (general) carbon taxes (see *Kettner – Kletzan-Slamanig*, 2017).[8])

Due to the extent of fluctuations in the world market price of crude oil, phases of marked price reductions for petrol, diesel and heating oil are inevitable despite a CO_2 tax (even as high as 180 € per ton). This also applies if the CO_2 tax would be raised gradually, given the extent of the instability of fossil energy prices.

A concrete example illustrates the issue: Between 2004 and 2008 and between 2009 and 2012, the price of crude oil rose dramatically and with it the price of fuels, heating oil and natural gas. In Germany, e.g., the diesel price rose to € 1.50 (figures 2 and 4). However, the oil bull market was followed by a bear market, and the diesel price fell again to only about € 1 in 2009 as well as in 2016. Consequently, the demand for (diesel-consuming) SUVs picked up again and investments in CO_2 reductions, which were profitable at an oil price of € 70 (and more), turned into "sunk investments". In early 2020, oil and diesel prices fell once again strongly, followed by a reverse movement afterwards.

The combination of small price elasticities of both, demand and supply in oil markets, with frequent demand and supply shocks cause sharp oil price changes which are then reinforced by technical speculation. Under these conditions even rising carbon tax rates cannot anchor the *expectation* of steadily rising paths of the price of CO_2 emissions.

Rather the opposite: the more the EU (and other countries) succeed in reducing the consumption of fossil energy, the more likely it is that world oil prices will fall over the long run, which in turn will counteract the increase in the price of fossil energy through CO_2 taxes.

Regardless of this "rebound effect", new drops in oil prices are likely also in the future because even small increases in global supply (e. g. stemming from "undisciplined" OPEC countries or other oil producers) and/or a weakening of demand (e.g., due to a recession or a financial crisis) trigger significant price declines. Thus, the short-term volatility of fossil energy prices dampens the willingness to invest in CO_2 saving technologies.

These investments are further disincentivized by the long-term outlook: Due to the diminished OPEC market power, the tensions between OPEC and other oil producing countries, the emergence of new suppliers and the rise in supply from the US once the oil price exceeds the threshold for fracking to be profitable (roughly $ 50 per barrel), oil prices will probably remain lower than over the past 15 years.

As regards climate change, the basic structural problem is as follows: The global reserves of fossil energy are much larger than the global "CO_2 budget" - if a climate catastrophe is to be avoided, the reserves must not be exhausted.[9])

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[8]) In fact, fuel taxes compensate also for other externalities like air pollution and noise as well as for the wear and tear of infrastructure. However, in this paper I focus on the effective costs of CO_2 emissions for households and enterprises.

[9]) Proven oil, coal and natural gas reserves amount to roughly 47, 133 and 52 times global annual demand – (https://www.worldometers.info). For a documentation of the discrepancy between countries' planned fossil fuel production and global production levels consistent with limiting warming to 1.5°C or 2°C see http://productiongap.org.

5. Fixing long-term rising paths of fossil energy prices

If neither emission trading schemes nor carbon taxes can *ensure* that emitting CO_2 becomes *permanently* more expensive, and if anchoring such an expectation is a precondition for steadily raising the (expected) profitability of ecologically necessary investments, how then could a rising path of fossil energy prices be achieved?

The EU should set a path with steadily rising prices for these energy sources (initially for about 30 years) and skim off the difference between the EU target price and the respective world market price by means of a monthly adjusted quantity tax - instead of the final prices of fossil raw materials (including taxes and/or emission permit costs), the quantity tax should fluctuate. Hence, this tax can be conceived as a (implicit) carbon tax just constructed differently.

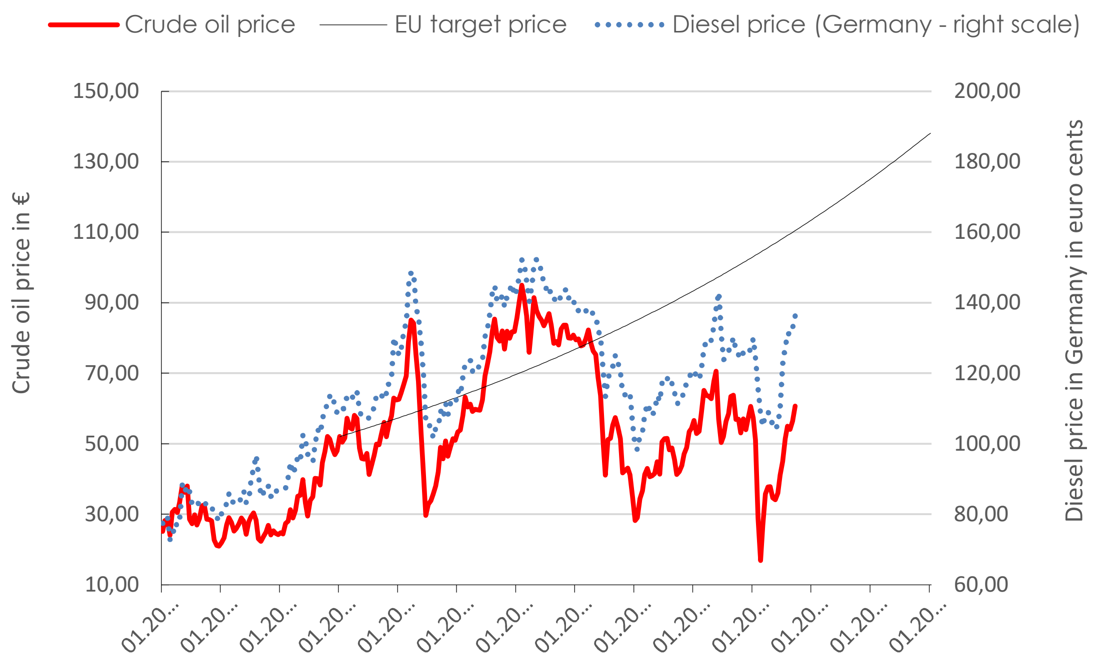
Here is a thought experiment using the example of crude oil to illustrate the working of such a price and tax regime. On January 1, 2006, the following regulation came into force in the EU: Starting from the (then) current oil price (Brent) of 52.0 €, the price valid within the EU would rise along a predetermined path by 5% per year (just 3 percentage points higher than target inflation). This rate of change would be much smaller than the fluctuations realised since then, but it is *always positive* – and everybody knows it in advance.

As a result of a second bear market, the oil price fell from €95.0 to €28.3 between March 2012 and January 2016, while the diesel price in Germany fell from €1.52 to €0.99 (figure 4). However, the EU guideline price for oil would be € 84.8 in January 2016. For February 2016, (the EU oil tax would thus amount to 56.5 € - 84.8 minus 28.3 - per barrel, about twice the oil bill (the figures are for illustrative purposes only; if an EU price path had been introduced, the world market price would have been dampened further). The (final) diesel price in Germany would have risen continuously (as figure 4 shows, both prices – expressed in the same currency – move very much in tandem). In any case, the final oil price would have risen faster and more steadily than the general price level.

If one considers that the EU had to pay a total of € 414.5 billion in 2016 for energy imports - almost exclusively fossil - it becomes clear: Such a fossil energy tax could yield more than € 500 billion in the medium and long run (depending on the "start price") and its returns would increase at an above-average rate. On the one hand, the EU target price is rising, while on the other hand the EU's climate policy is curbing its energy imports and thus world market prices. Under these conditions, the price spread would rise over the long run and so would also tax receipts, dampening the rents of the owners of the fossil energy reservoirs. Whenever oil prices, e.g., rose in the past, producing countries as well as oil companies, made extra profits. By constantly increasing the price *itself*, the EU is dampening world market prices. As result, part of the "fossil energy rents" would be diverted to the EU and, hence, into the budgets of the Member States (tax receipts could be distributed according to the national CO_2 emissions, provided they are – mainly – used for investments in the reduction of CO_2 emissions, another part of tax receipts could go to the EU budget as "own resources").

Technically, the implementation of such a flexible quantity tax would be simple in the "digital age": Based on the difference between the EU target price and the world market price, the tax per unit of quantity of oil, coal, and natural gas valid in the following month is determined at the end of each month by the EU Commission and paid in the Member States by producers and importers of fossil energy in the EU.

Figure 4: Price incentives for CO_2-reduction – market prices versus target prices



Target price path: Crude oil prices in the EU rise by 3 percentage points faster than target inflation, i.e., by 5% per year (fictitiously from January 1, 2006).

The levels from which the crude oil, coal and natural gas price paths start as well as their annual growth rate are to be determined in a political process (which will certainly be complicated as discussed later): The higher is the priority given to incentivizing investments and consumption behaviour consistent with limiting climate change, the higher should be the initial price levels as well as their growth rate.

Since reliable expectations about the future profitability of ecological investments are the most important determinant of sustained willingness to invest, a comparatively small but permanent relative increase in the price of fossil energy could be sufficient to generate a sufficiently large volume of investment. If this turns out to be insufficient, price paths can be adjusted upward. Since a reduction in the price of fossil energy is ruled out, the following holds: the earlier an investment is made, the greater is its profit. Such a system of pricing fossil energy would therefore initiate a long-lasting investment boom in avoiding CO_2 emissions.

Goods imported into the EU would be subject to an analogous energy tax (border carbon adjustment tax – see *Krenek – Sommer – Schratzenstaller*, 2019). Since EU price paths "internalise" the environmental costs of fossil fuel consumption and apply also to domestic supply, such a levy would not contradict the rules of the World Trade Organisation (WTO). As long as no comparable CO_2 taxes exist in the EU's trading partners, EU exports would have to be relieved from the EU fossil energy tax paid (analogous to VAT).

As the proposed concept just replaces an explicit and fixed carbon tax with an implicit and flexible tax, competition would remain in force in all markets - the extent to which producers or importers of fossil energy pass on the tax to their customers is up to them.[10]) Even the national fuel taxes could remain in place, at least over a transition period until the fossil energy price path model would replace the national fuel taxes.

Technically, it would be far easier to implement just three flexible quantity taxes on oil, coal and natural gas than managing the complex and bureaucratic EU emissions trading scheme (not to speak about extending it to transport and housing).

What would be the most important price and investment effects of EU target prices for fossil energies? All goods and services would become more expensive within the EU to the extent that fossil energy is used in their production - from fuels including kerosene to plastic products. Products produced with renewable energy or less energy would become relatively cheaper.

The predetermined rise of the prices of oil, coal, and natural gas, will be processed in an almost Hayekian manner on the various submarkets, i.e., completely decentralized. This will eliminate the need for much regulation. If coal becomes steadily and predictably more expensive, then coal-fired power plants will be closed for cost reasons. Conversely, the increasing profitability of energy production from renewable sources will make the current system of surcharges on electricity consumers and their diversion to producers obsolete.

The main impact of rising fossil energy price paths on CO2 emissions will not be direct, but rather indirect via the thereby induced investments. For any given capital equipment, the reaction of demand to rising prices is rather low, i.e., its short-term price elasticity. In the case of fuels, e.g., even the wide price fluctuations by 30 percentage points and more (figure 4) had very little impact on driving behaviour and, hence, on fuel demand. By contrast, if people *know for sure* that the price of fuels will steadily rise, then a growing number will choose an electric vehicle when replacing their old car. The same reasoning holds for the investments of industry, electricity producers or the energetic refurbishment of buildings.

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[10]) A recent study for the German Council of Economic Experts ("Sachverständigenrat") recommends the introduction of a German carbon tax or of a "National Emissions Trading System for Transport and Heating". However, in either system policy interventions are necessary: "A carbon tax needs to be assessed and adjusted frequently in order to achieve the targets of the EU emissions sharing decision. A German emissions trading scheme requires a price collar to facilitate investments and to prevent extreme price fluctuations." (*Edenhofer et al.*, 2019, p. 15). The "Sachverständigenrat" endorsed this procedure (*Sachverständigenrat*, 2019, chapter 4). If policy must intervene anyway, why not do so in such a way as to ensure a reliable price path of fossil energy and, hence, of CO_2 emissions?

The investment effects of setting fossil energy price paths would therefore be most significant: Since owners of single-family homes, housing cooperatives etc. *know* how much heating costs they could save by making buildings more energy-efficient, they would expand their investments accordingly (however, in case of privately owned residential buildings one would need additional rules to overcome the "owner-tenant-dilemma"). The same logic holds true for the still more complex transition from fossil to "green" energy in industrial production.

In any case, even though steadily rising fossil energy prices are not a sufficient condition for successful fighting global warming, they are a necessary condition for incentivizing all projects which will enable the transition towards a new energy system as part of a circular economy.[11]) Using part of the (enormous) returns from the fossil energy tax for long-term infrastructure projects would foster the ecological transformation (another part of tax revenues should offset the burden of energy price increases on low-income groups).[12]) These projects include the creation of a trans-European network for high-speed trains, investments in power grids as well as in hydrogen pipeline networks and in local public transportation systems.

Finally, a Green Deal based on an effective carbon pricing system, would stabilize economic growth in the EU. By reducing unemployment and atypical employment, and with it the (fear of) poverty, the transition towards a circular economy would strengthen the European Social Model and, hence, the integrative forces within the EU.

6. Some complementary considerations

The implementation of the price path model for a uniform and effective CO_2 pricing in the EU appears - at least at present - utopian for several reasons. First, national interests diverge particularly strongly on the issue of combating global warming. Second, the EU has no competence to legislate on tax issues (both reasons have favoured emissions trading over carbon taxes). Third, the proposal to deprive "the market" of its core function, namely price discovery, is totally at odds with the economic paradigm of recent decades.

However, if during the 2020s the effects of global warming in the form of serious catastrophes of various kinds become increasingly depressing and if at the same time it becomes obvious that the climate targets set for 2030 cannot be achieved with the current policy, then the pressure will increase to find a simple and flexibly applicable instrument for CO_2 pricing. The price path model meets these requirements also because it represents a uniform method, but its concrete application can be differentiated according to countries and economic areas

[11]) *Köppl – Schleicher* (2018) demonstrate that any sustainable strategy of fighting climate change calls for an approach "that covers the full energy value chain from the required functionalities for mechanical, thermal and specific electric energy services via application and transformation technologies up to primary energy." A path of rising fossil energy prices as proposed in this paper can be considered as basic price incentive for "integrating all components of a newly structured energy system" (quotes from the Abstract of *Köppl – Schleicher,* 2018). *Schleicher – Steininger* (2018) concretize the main components of an efficient carbon management.

[12]) To mitigate the fluctuations of tax earnings and to account for negative tax payments (in the – improbable - case fossil energy prices exceed the respective EU target prices) tax authorities could and should establish a buffer fund.

(developing countries, e.g., could introduce a fossil energy price path with a lower level and/or smaller rate of growth of target prices as compared to industrial countries).

These features of the price path model are so important for the fight against global warming because all important countries and regions must pull together. Never in human history has the problem of “collective action” arisen with such force at the level of the entire planet.

In his seminal work "The Logic of Collective Action: Public Goods and the Theory of Groups", Mancur Olson examined already in 1965, the essential problems that arise when a group wants to maintain and preserve a common good, i.e., a good from whose consumption no one can be excluded (*Olson*, 1965). His thoughts can be applied to the way the "world group" deals with its most important common good, the natural environment.

The focus is on the conflicts between individual and collective rationality. Thus, the larger the group and therefore the smaller the consequences of his selfish behaviour and the less conspicuous it is, the more likely an individual will not contribute anything to the preservation of the common good, i.e., act as a "free rider". In a small group, such as a farming community, "free riding" can therefore be contained in terms of a common at the local level (*Ostrom*, 1990), but not in terms of preserving biodiversity at a region level or the climate at the global level (hence, the climate crisis can be conceived as a “tragedy of the commons” on a planetary scale). Therefore, incentives are needed to encourage individuals to engage in such behaviour that preserves the commons.

Such incentives are usually provided by the state, for example through taxes or subsidies, however, there is no "world state" that could protect the climate. Hence, at the global level the greatest progress has been made only in diagnosing the problem, e.g., by the International Panel on Climate Change (IPCC). Policy has yet only set targets without binding and verifiable agreements on how these targets will be achieved (as in the Paris Agreement of 2015).[13])

This problem is deepened by the fact that the conflict between individual and collective rationality also arises at the international level in the form of national self-interest on the one hand and the global commons on the other hand: If there are no common rules on the method of combating CO_2 emissions, each country's own way will also serve its national interests. The idea that nation states compete against each other on a global level like companies rather than cooperating with each other as partners, reinforces this danger.

Felbermayr (2021) gives a realistic example. If one country (e.g., the EU) increases the price of fossil energy compared to renewable energy through taxes and another country (e.g., the USA) increases it to the same extent by subsidizing renewable energy, this has very different consequences for the economies of the two countries, both in terms of their international competitiveness as well as the internal distribution of income.

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[13]) Even considering the efforts to fight global warming, OPEC expects in its forecast (released in September 2021) that global oil demand and production will rise by 19,4% between 2020 and 2045 - a catastrophic development for the climate (see https://www.opec.org/opec_web/en/press_room/6619.htm). However, if the problem of a global collective action is not successfully tackled, this forecast is plausible.

It would therefore be ideal if, as a first (major) step towards harmonizing methods to combat CO_2 emissions, the three largest emitters, China, the USA, and the EU, were to agree on common price paths for oil, coal, and natural gas, and on corresponding "carbon border adjustment taxes" to prevent "carbon leakage" to countries with no or low CO_2 taxation (the idea of "climate clubs" stems from William Nordhaus and has been adapted to fit the WTO rules; see *Tagliapietra and Wolff*, 2021; *Felbermayr*, 2021).[14]) Exports of non-member countries to the "club" would be burdened by a border adjustment tax.

The efforts of these countries to reduce carbon emissions would be much more strengthened if they could be convinced to also introduce price paths for fossil energy (this should not be too difficult, given the enormous importance of the USA, the EU and China as export markets of less developed countries). The starting level and the rate of increase of the price paths could be adjusted to the different level of economic development of countries. In contrast to other policy measures, fossil energy price paths can easily be introduced, adjusted (if necessary) and controlled. In a stepwise manner, the great majority of countries could join the "climate club".

Under this condition, global demand for fossil energy could be steadily dampened and, hence, also carbon emissions. But what about supply? Wouldn't the oil and gas producing countries react to the price path model because it drives a wedge between steadily rising fossil energy prices for consumers/users (to dampen demand) and low prices for producers (to dampen supply)? Oil and gas producing countries could try to annul the rationality of the price path model in two ways.

First, they could intensify their cooperation to form - at least temporarily – a global quasi-cartel to drive prices up, thereby shifting part of the tax revenues of price path countries back into their own pockets. In face of the extent of the proven (excess) reserves of fossil energy and the different interest of the producing countries (beside high prices), such a strategy can hardly succeed over the medium and long run. To prevent oil or gas price "shocks" from happening over the short run (as at present), large inventories buffer stocks should be built up.[15])

Second, producer countries of fossil energy, could increase their production of crude oil and natural gas, and use part of it themselves and export the rest to "free rider countries" (non-members of the "climate club"). It is also for the reason of this "green paradox" (*Sinn*, 2012) that maximizing the number of member countries would be indispensable for steadily reducing global carbon emissions. In addition, one could offer fossil energy producing countries some compensation for not extracting these commodities (their willingness to accept such a deal

[14]) Harmonizing the effective carbon prices between the member countries would provide a level playing field also within the club. This would not be the case if, e.g., China burdens CO_2 to a lesser extent than the EU. In this case, China would enjoy a comparative price advantage (only imports from non-members would be treated equally).

[15]) Also, in this case there prevails a conflict between individual and collective rationality. In the face of uncertainty over future price movements, entrepreneurs will not invest in oil, gas, or coal inventories. Fossil energy consuming economies would, however, profit from being more independent from short-term fluctuations of supply. E.g., had industrial countries built up oil and gas inventories equal to – at least – their consumption of one year, the present price boom would not have taken place (which was and still much more expensive than keeping higher inventories).

would depend on a low fossil energy price level which in turn depends on the extent of the decline of the respective demand of the "climate club").

Achieving a circular economy necessitates not only a permanent reduction of burning crude oil, coal, and natural gas but also a steadily rising share of recycling of raw materials of all kinds. This is the more important as the "material consumption" in the EU amounted to 13,4 tons per person in 2020.[16]) Only 30% of the waste left at the end of the production process is recycled ("output recycling rate") or 10% of the overall material consumption ("input recycling rate").

Even though the most important instruments for raising the recycling rates consist of regulations with respect to the product design (durability, reusability, reparability), economic incentives also play a role, in particular the development of the prices of raw materials as production input. If, e.g., plastics producers *know* that crude oil prices will permanently rise faster than the general price level, then investing in more recycling capacity becomes reliably profitable. This argument holds for recycling in general as the profits of the respective investments consist primarily of the saved raw material costs. As in the case of fossil energy, setting rising price paths of (recyclable) raw materials would anchor the respective expectations.[17])

Finally, a remark to those who are convinced that degrowth is "the" necessary (though not sufficient) condition for a transition towards a circular economy. For me, economic growth is by no means an intrinsic value. Economic activities should aim at providing the basis for a good life of the greatest possible number of people at present and in the future. At present, the biggest challenge is organizing a collective action at the global level to fight the climate crisis. The necessary renovation of the capital stock as one fundament of a future circular economy implies huge investment programs which would contribute to economic growth and cause additional carbon emissions. This effect could be (over)compensated by steadily rising prices of fossil energy. This combination of a *transitory* "green growth" and rising fossil energy price paths seems to me much more in line with the goal of providing the basis for a good life of the many than shrinking economic activities in other sectors of the economy. Such a degrowth strategy would call for a radical change of the economic system as regards the distribution of working time, income, wealth, and political power (if a deepening of the social crisis is to be avoided).[18] Given the extremely unequal distribution of economic and political power at present, striving for a radical change of both, the ecological as well as the social-economic system, seems to me a mission impossible. Hence, at present one should focus all political energies on fighting global warming through the combination of "green growth" and rising price paths of fossil energy. The related decline in unemployment and a possible strengthening of the welfare state might then – gradually – also mitigate the social crisis.

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[16]) See https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20210713-2.

[17]) A plan for the transition towards a circular economy in the EU (though without considering the role of raw material prices) is sketched in *European Commission* (2020).

[18]) For a primer in degrowth economics see *Kallis et al.* (2018).

7. Concluding remarks

The paper proposes a new approach to pricing CO_2 emissions: Setting a path of steadily rising prices of crude oil, coal, and natural gas by skimming off the difference between the EU target price and the respective world market price through a monthly adjusted quantity tax. In this way, the uncertainty about future price developments of crude oil, coal, and natural gas and, hence, of the effective emission costs would be eliminated. Firms and households could calculate the profitability of investments in avoiding carbon emissions. By contrast, neither carbon taxes nor emission trading schemes can provide such a planning security, indispensable for successfully combatting global warming. The price path model of efficient carbon pricing could also serve as a common basis for "climate clubs", initially comprising the greatest carbon emitters, i.e., China, the USA, and the EU.

At first glance, fixing a path of steadily rising fossil energy prices by means of economic policy might appear as falling back to a "centrally planned economy". However, if one takes into consideration the causes of global warming, the specific conditions in (derivatives) markets for fossil energy and CO_2 emission permits as well as the theory of externalities and public goods, then the proposal should appear worth being discussed. The global natural environment is the most valuable common good of mankind. Confronted with the threat of its destruction, the courage to escape from conventional modes of thinking should not be lacking.

To put it in the words of Albert Einstein: "You can never solve a problem on the level on which it was created."

Annex: A back-of-the-envelope estimation of the growth effects of a decarbonisation of the German economy

The purpose of this exercise is to gauge in an extremely rough manner how the investments necessary to achieve a carbon-free economy might impact upon growth and the related rebound effects on carbon emissions. The more the ecological renovation of the capital stock would induce a significant "green growth", the more important an effective carbon pricing becomes.

As a first step, I take estimates of the additional electricity production needed for a decarbonization of the German economy in general and its industry in particular. I estimate the number of additional wind turbines which could produce the required power as well as the costs of their installation (as regards the rated power, effective electricity production, and investment costs, I use data for the already existing wind power stations in Germany). As power production costs (per KWh) are roughly the same for wind, solar and biogas installations (*Fraunhofer*, 2018), this assumption simplifies the estimation of overall power plant investment costs (of course, future decarbonization will also rely on solar and biological resources). Based on the results of another study, I present estimates of renewable power demand and investment costs of a decarbonization of German industry.

As second step, I estimate the volume of investments needed to replace combustion engine cars and trucks with electric vehicles, to energetically refurbish residential buildings, and to contribute to the enlargement of the European high-speed railways net.

Power production and installation costs of wind turbines in Germany

Power production:

(https://www.wind-energie.de/themen/zahlen-und-fakten/ - retrieved September 25, 2021 – numbers are rounded)

Number: 31.100

Total rating power: 63 GW

Total production: 132 TWh

Ø Rating power: 2,03 MW (=63.000/31.000) = 2.026 KW

Ø Production: 4,24 GWh (=132.000/31.100)

Investment costs:

(*Fraunhofer ISI*, 2018)

Costs per KW rating power: 2.030 € (weighted average of the average costs of onshore and offshore turbines)

Ø Costs per installation: 4,112 Mill. € (= 2.030 € * 2.026 KW)

Renewable power and investments needed for a climate-neutral German economy

In a brand-new and extremely comprehensive study, a consort of many research institutions investigates decarbonization pathways of the German economy which might lead to climate neutrality by 2045 (*Ariadne-Studie*, 2021). As regards the power production necessary to achieve this target, different models arrive at estimates between 639 and 1.480 TWh (*Ariadne-Studie*, 2021, p. 19). Taking the mean value of 1.055 TWh and subtracting the actual production volume in 2020 of 251 TWh, I arrive at an estimate of roughly 800 TWh as additionally needed renewable power. The estimate of the less differentiated Prognos study of 632 TWh is smaller but not completely at odds with the Ariadne study (*Prognos et al.*, 2020B, fig. 8).

Additional power from renewable resources: 800 TWh

Number of additional wind turbines: 188.679 (= 800.000 GWh/4,24 GWh)

Investment costs: 774 bn. € (= 188.679* 4,1 Mill. €) = **22,1% des BIP** (2021: 3.500 Mrd. €)

Investments needed for carbon-free buildings

Single-family homes (40% of population)

Number: 16 Mill.

Estimated average costs of a complete energetic renovation, i.e., combining better isolation, photovoltaics, heat pumps and batteries: 60.000 €

Total investment costs: 960 bn. € (= 60.000 * 16.000.000)

Apartment buildings (including houses with only few flats - 60% of population)

Here, I operate with an extremely rough estimate since apartment buildings differ very much from one another as regards size, quality of isolation, heating system, etc. Considering that a complete energetic refurbishment of apartment buildings is more expensive as compared to single-family homes (per m^2 living space) and that roughly 60% of the population live in apartment houses, I use as estimate of overall investment cost 1.500 bn. €

Investment cost of renovating all residential buildings: ~2.460 bn. €

Commercial buildings

As the floor space of commercial buildings in Germany amounts to 10% of the overall floor space of residential buildings, I take 10% of the renovation costs of residential buildings as estimate for commercial buildings, i.e., 246 bn. €

Estimate of renovation costs of all buildings: 2.706 bn. € or **77,3% of GDP**

Investments needed for carbon-free road transport

If one assumes that an electric car costs on average 20.000 € more than a combustion engine car and that the stock of passenger cars falls from 48 mill. to 25 mill. between 2020 and 2050, then additional investment costs can be estimated at 500 bn. € or **14,3% of GDP**.

For electric and hydrogen trucks, additional costs can be estimated at 50.000 € per truck. If the number of trucks declines until 2050 from 3.5 mill. to 2 mill. due to shifting goods transport to railways, then overall additional investment costs can be estimated at 100 bn. € or **2,9% of GDP**.

[The additional production of power for electric cars and trucks is already included in the above estimate of power production in a climate-neutral Germany and is therefore not estimated separately].

Investments needed for the enlargement of a trans-European high speed railways network

As part of the construction of a European Green Deal the high-speed railways network should be accelerated. If additional 30.000 km would be constructed (at present: 10.000 km), then investment costs would amount to 600 bn. € in the EU or 4,3% of GDP of the EU (according to the International Union of Railways, construction cost per km vary in Europe between 12 and 30 mill. €; assuming 20 mill. €, one arrives at overall cost of 30.000 * 20 = 600 bn. €).

If Germany contributes an equivalent share to the European railways network, then the respective investments would amount to **4,3% of its GDP**.

Overall costs of investments in the transition towards a climate-neutral economy in Germany

The above back-of-the-envelope estimates sum up to **120,9%** of German present GDP (2021). If all these investments were continuously carried out until 2050, they would "ceteris paribus" raise economic growth by 2,7 percentage points per year. The actual growth effect of a complete decarbonization of the German economy would be higher since the above estimation exercise did not account for investments in energy storage (beyond batteries in buildings), in energy distribution through additional power grids and hydrogen pipelines, in the production of biofuels, in particular for aircrafts (and the related retrofits), in improvement of local public transportation (in particular in metropolitan areas), in reducing emissions in agriculture (biogas plants) and in carbon capture and storage. My personal guess is that a complete decarbonization of the German economy would raise economic growth over roughly three decades by 3,0 to 3,5 percentage points per year.

There are two reasons why I tried estimate the potential growth effects of a transition towards a climate-neutral economy. First, studies which sketch or even elaborate in detail the respective pathways assume a certain GDP growth over the transition period without analyzing the feed-back of the emission reducing investments on overall growth. *Prognos et al*. (2020), e.g., assume a growth rate of 1,3% per year until 2050 which seems inconsistent with the size of the necessary investment programs as elaborated in their study.

Second, the results of the estimation of the growth effects of decarbonizing the economy suggest that the income effects on additional carbon emissions would be massive. Hence, emissions can only be steadily reduced through a simultaneous substitution effect of permanently and sufficiently rising prices of crude oil, coal, and natural gas (overcompensating the income effects).

References

Aldy, Joseph E., Armitage, Sarah, "The Cost-Effectiveness Implications of Carbon Price Certainty", AEA Papers and Proceedings, American Economic Review, May 2020, 113-118.

Ariadne Report, Deutschland auf dem Weg zur Klimaneutralität 2045 - Szenarien und Pfade im Modellvergleich, Oktober 2021.

Andersson, Julius J., "Carbon Taxes and CO_2 Emissions: Sweden as a Case Study", American Economic Journal: Economic Policy, 11(4), 2019

Bayer, Patrick, Aklin, Michaël, "The European Union Emissions Trading System reduced CO2 emissions despite low prices", Proceedings of the National Academy of Sciences of the United States (PNAS), 117 (16), April 2020, 8804-8812

Berta, Nathalie, Gautherat, Emmanuelle, Gun, Ozgur, „Transactions in the European carbon market: a bubble of compliance in a whirlpool of speculation", Cambridge Journal of Economics, 41, 2017, 575-593.

Best, Rohan, Burke, Paul J., Jotzo, Frank, "Carbon Pricing Efficacy: Cross-Country Evidence", Environmental and Resource Economics, 2020, 77, 69–94.

Edenhofer, Ottmar, Flachsland, Christian, Kalkuhl, Matthias, Knopf, Brigitte, Pahle, Michael, Optionen für eine CO_2-Preisreform, MCC-PIK-Expertise für den Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung, Mercator Research Institute on Global Commons and Climate Change (MCC), Potsdam-Institut für Klimaforschung (PIK), Berlin, Juli 2019.

Ellermann, A. Denny, Marcantonini, Claudio, Zaklan, Aleksander, „The European Union Emissions Trading System: Ten Years and Counting", Review of Environmental Economics and Policy, vol. 10 (1), Winter 2016, 89-107.

European Environment Agency (EEA), The European environment – state and outlook 2020, Copenhagen, 2019.

European Commission (EC), Circular economy action plan, Brussels, 2020.

European Environment Agency (EEA), The EU Emissions Trading System in 2019: trends and projections, Copenhagen, 2020.

Felbermayr, Gabriel, „Steuerliche Aspekte der Klimapolitik", Wirtschaftsdienst 2021, Heft 6, 428-431.

Frankel, Jeffrey, "The Best Tool to Fight Climate Change", Project Syndicate, January 20, 2020, https://www.project-syndicate.org/commentary/higher-carbon-price-best-tool-to-fight-climate-change-by-jeffrey-frankel-2020-01

Fraunhofer ISE, Stromgestehungskosten erneuerbare Energien, März 2018.

Fraunhofer ISI, "Kapitel 4 Industriewende". ARIADNE-Bericht: Deutschland auf dem Weg zur Klimaneutralität 2045 - Szenarien und Pfade im umfassenden Modellvergleich (forthcoming).

Guttmann, Robert, Eco-Capitalism – Carbon Money, Climate Finance and Sustainable Development, Palgrave Macmillan, 2018.

Haberl, Helmut, Wiedenhofer, Dominik, Virag, Doris, Kalt, Gerald, Plank, Barbara, Brockway, Paul, Fishman, Tomer, Hausknost, Daniel, Krausmann, Fridolin, Leon-Gruchalski, Bartholomaus, Mayer, Andreas, Pichler, Melanie, Schaffartzik, Anke, Sousa, Tania, Streeck, Jan, Creutzig, Felix, "A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: synthesizing the insights", Environmental Research Letters, 15 065003, 2020.

ICAP (International Carbon Action Partnership), Emissions Trading Worldwide: Status Report 2018. Berlin 2018.

International Energy Agenc (IEA), Net Zero by 2050, Paris, May 2021.

IPCC (Intergovernmental Panel on Climate Change), Special Report: Global Warming of 1.5°C, October 2018 (https://www.ipcc.ch/sr15).

Climate Change 2014 - Synthesis Report. Cambridge, UK: Cambridge University Press, 2014.

Kachi, Aki, Frerk, Michel, Carbon Market Oversight Primer, International Carbon Action Partnership (ICAP), Berlin 2013.

Kallis, Giorgos, Kostakis, Vasilis, Lange, Steffen, Muraca, Barbara, Paulson, Susan, Schmelzer ,Matthias, "Research on Degrowth", Annual Review of Environment and Resources, 2018, 291-316.

Kettner, Claudia, Kletzan-Slamanig, Daniela, "Carbon taxation in EU Member States: evidence from the transport sector," in: Weishaar, Stefan E., Kreiser, Larry, Milne, Janet E., Ashiabor, Hope, Mehling, Michael (eds.), The Green Market Transition, chapter 2, 17-29, Edward Elgar Publishing, 2018.

Kirchner, Mathias, Sommer, Mark, Kettner-Marx, Claudia, Kletzan-Slamanig, Daniela, Köberl, Katharina, Kratena, Kurt CO_2 Tax Scenarios for Austria - Impacts on Household Income Groups, CO_2 Emissions, and the Economy, WIFO Working Paper 558, February 2018

Köppl, Angela, Schleicher, Stefan, What Will Make Energy Systems Sustainable? WIFO Working Paper No. 566, June 2018.

Köppl, Angela, Schleicher, Stefan, Schratzenstaller, Margit, Policy Brief: Fragen und Fakten zur Bepreisung von Treibhausgasemissionen, WIFO, November 2019.

Krenek, Alexander, Sommer, Mark, Schratzenstaller, Margit, Sustainability-oriented Future EU Funding A European Border Carbon Adjustment, WIFO Working Paper 587, 2019.

Marcu, Andrei, Vangenechten, Domien, Alberola, Olsen, Jahn, Emilie, Caneill, Jean-Yves, Schleicher, Stefan, de Rafael, Roman, 2020 State of the EU ETS Report, ERCTS, Wegener Center, ICIS, I4CE, ecoact (eds.), 2009.

McKinsey&Company, Net-Zero Europe, December 2020.

Mizrach, Bruce, Otsubo, Yoichi, The market microstructure of the European Climate exchange, Journal of Banking & Finance, Vol. 39, February 2014, 107-116.

OECD, Effective Carbon Rates 2018 - Pricing Carbon Emissions Through Taxes and Emissions Trading, Paris, September 2018

Olson, Mancur, The logic of collective action: public goods and the theory of groups. Cambridge, Mass., Harvard University Press, 1965.

Ostrom, Elinor, Governing the commons: the evolution of institutions for collective action, Cambridge University Press, 1990.

Prognos, Öko-Institut, Wuppertal-Institut, Klimaneutrales Deutschland (2020A), Studie im Auftrag von Agora Energiewende, Agora Verkehrswende und Stiftung Klimaneutralität, 2020.

Prognos, Öko-Institut, Wuppertal-Institut (2020B), Towards a Climate-Neutral Germany. Executive Summary conducted for Agora Energiewende, Agora Verkehrswende and Stiftung Klimaneutralität, 2020.

Schleicher, Stefan, Marcu Andrei, Köppl, Angela, Schneider, Jürgen, Elkerbout, Milan, Türk, Andreas, Zeitlberger, Alexander, Scanning the Options for a Structural Reform of the EU Emissions Trading System, CEPS Special Report, No. 107, May 2015

Schleicher, Stefan, Steininger Karl, Dekarbonisierung und Carbon Management für Österreich, Wegener Center für Klima und Globalen Wandel, Karl-Franzens-Universität Graz, November 2018.

Schulmeister, Stephan, „Globalization without global money: the double role of the dollar as national currency and as world currency", Journal of Post Keynesian Economics, 2000, 22(3), 365-395.

Schulmeister, Stephan, "Profitability of technical stock trading: Has it moved from daily to intraday data?", Review of Financial Economics, 2009, vol. 18, issue 4, 190-201.

Schulmeister, Stephan, Technical Trading and Commodity Price Fluctuations, WIFO Study, 2012.

Schultz, Stefan, Wie Hedgefonds den Kohleausstieg befeuern, DER SPIEGEL, 29. März 2021 (https://www.spiegel.de/wirtschaft/service/emissionshandel-wie-hedgefonds-den-kohleausstieg-beschleunigen-a-44bf3116-4557-4f05-b1c3-f7a4944f7be3)

Sinn, Hans-Werner, The Green Paradox. A Supply-Side Approach to Global Warming. The MIT Press, 2012.

Stiglitz-Stern-Commission, Report of the High-Level Commission on Carbon Prices, International Bank for Reconstruction and Development and International Development Association/The World Bank, May 29, 2017.

Tagliapietra, Simone, Wolff, Guntram B., "Form a climate club: United States, European Union and China", Nature, vol. 59, (1), March 2021, 526-528.

Wildauer, Rafael, Leitch, Stuart, Kapeller, Jakob, How to boost the European Green Deal's scale and ambition, Foundation for European progressive studies, Arbeiterkammer, Renner-Institut (eds.), 2020.

World Bank Group, State and Trends of Carbon Pricing 2020, Washington DC, May 2020.