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Paul J.J. Welfens

Financial Markets and Oil Prices in a Schumpeterian Context of CO2-Allowance Markets

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Paul J.J. Welfens

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EUROPÄISCHES INSTITUT FÜR INTERNATIONALE WIRTSCHAFTSBEZIEHUNGEN (EIIW)/
EUROPEAN INSTITUTE FOR INTERNATIONAL ECONOMIC RELATIONS
Bergische Universität Wuppertal, Campus Freudenberg, Rainer-Gruenter-Straße 21,
D-42119 Wuppertal, Germany
Tel.: (0)202 – 439 13 71
Fax: (0)202 – 439 13 77
E-mail: welfens@eiiw.uni-wuppertal.de
www.eiiw.eu

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Summary:

CO2 allowance pricing plays an increasingly important role in the EU, Switzerland, the US, Japan, China and other countries. One crucial question is how the CO2 allowance price and the oil price and financial markets, particularly stock markets, are linked. In the enhanced Hotelling approach developed here, the relevant links can be identified in a clear way for countries with CO2 allowance pricing and it is shown that a rise of the relative CO2 allowance price will reduce the oil price in equilibrium and could bring about a rise of stock market prices. The relative oil price is a negative function of the ratio of the real interest rate to the expected oil price inflation rate. Moreover, it is shown that the oil/gas market analysis can be linked to key aspects of the golden age debate in neoclassical growth theory and that the rate of technological progress has an ambiguous influence on the relative price of oil. Factors which reduce (raise) the relative oil price will raise (reduce) the general stock market price index, while the impact on the energy (oil & gas) sub-index in the stock market should be opposite. Policymakers should take the links between innovation and oil/gas prices and the stock markets into account where the linkages between the latter to CO2 mitigation innovation developments also have to be considered; and macroprudential supervisors certainly have to consider these dynamics. If national CO2 Emission Trading Systems are integrated internationally, there will be crucial global effects on climate neutrality, financial markets and output.

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Prof. Dr. Paul J.J. Welfens, *Jean Monnet Professor for European Economic Integration; Chair for Macroeconomics; President of the European Institute for International Economic Relations at the University of Wuppertal, (Rainer-Gruenter-Str. 21, D-42119 Wuppertal; +49 202 4391371), Alfred Grosser Professorship 2007/08, Sciences Po, Paris; Research Fellow, IZA, Bonn; Non-Resident Senior Fellow at AICGS/Johns Hopkins University, Washington DC*

Prof. Welfens has testified before the US Senate, the German Parliament, the EP, the ECB, the IMF, the UN.

welfens@eiiw.uni-wuppertal.de, www.eiiw.eu

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1. Introduction

The problem of global warming has reinforced the role of CO2 pricing in many countries (IMF, 2019). As regards CO2 Emission Trading Systems (ETS) in the world economy, the European Union (EU) has been the pioneering group of countries establishing an ETS in 2005, later followed by Switzerland, the Republic of Korea and China (from 2020 on a national scale). California is a major ETS state in the US – its coverage is 85% of CO2 emissions since 2015. Japan and Canada also have regional ETS in parts of the respective country. The EU has a coverage of 45% of CO2 emissions, namely the sectors of energy and industry; and since 2012 also intra-EU flights. A crucial question in individual countries and in the world economy concerns the links between CO2 allowance prices and financial markets, in particular stock markets as well as fossil fuel pricing. These dynamics are of key importance for both financial market stability, investment dynamics and output development.

BUSHNELL/CHONG/MANSUR (2013) argue on the basis of a theoretical and empirical analysis that the rise of CO2 allowance prices in the EU could be expected to lead to a higher percentage increase in terms of the final goods product price than an increase in terms of cost so that a rise of CO2 allowance prices would go along with higher stock market prices – empirical evidence presented by the authors is based on the EuroStoxx Index which is similar to the US S&P 500 index. This view, however, is quite misleading as the event-methodology used did not take into account the role of the allocation of free emission certificates in the first two trading periods of the EU ETS. If firms get free CO2 certificates – in an environment with positive allowance prices – there will be windfall profits derived from the balance sheet and hence stock market prices should increase; and a combination of a government's allocation of free allowances in a period of rising CO2 prices can easily be misinterpreted if there is no controlling in the regression for free CO2 certificates. Indeed, it is quite implausible that higher CO2 prices lead directly to higher profits and hence higher stock market indices. Subsequently, a different and more consistent theoretical approach is used for analyzing the interplay of higher CO2 prices (which raise the production costs of firms) and lower oil & gas prices – due to higher CO2 prices; these two price developments could jointly bring about a net improvement in the cost situation of many firms in industry and thus a higher stock market price index; it is, however, not excluded that induced product innovations also play a positive role here.

As regards the link between CO2 allowance prices and stock market prices one should consider two possible links:

- A stock market price rally raises management's willingness to pay for machinery and equipment as well as for complementary energy resources and the associated CO2 allowances in countries with ETS.
- A rise of the relative CO2 allowance price will affect fossil fuel prices and this in turn will affect the stock market price index (and also the exchange rate).

As regards the analytical perspective, the subsequent approach takes a closer look at the second point and the approach developed clearly shows that CO2 price increases will put downward pressure on fossil fuel equilibrium prices and thus have an indirect effect on stock market price indices. Since a downward energy price impulse, parallel to the CO2 allowance price increase, is – as shown subsequently – a positive impulse for stock markets, from the combined effects of higher CO2 allowance prices and lower fossil fuel energy prices, could emerge.

Key aspects of CO2 allowance markets are that a CO2 ETS amounts to an efficient reduction of CO2 emissions: Government can reduce the cap in the ETS – the maximum admissible emission volume in a given year – in a consistent way in order to achieve a certain reduction percentage by a certain target date. It is not excluded, however, that volatility in financial markets will affect CO2 allowance markets – and in principle CO2 market pricing dynamics could affect financial market dynamics. There is a particular link between CO2 pricing and the demand for oil and gas, on the one hand, and the relative oil price in market equilibrium on the other. These links so far have not been investigated much in the literature, although the rising climate change policy activities in OECD and G20 countries – actually the UN countries after the UN Paris Climate Convention of 2015 – make such analysis quite important for both investors and policymakers. Moreover, the enhanced green innovation dynamics in the context of climate policy should be taken into account as well as a more general increase of government promotion of research and development in the world economy. Subsequently, the analysis begins with a new look at theoretical aspects of the equilibrium price in the oil and gas market, followed by conclusions for policymakers.

2. Oil Markets, CO2 Allowance Markets and Financial Markets in an Enhanced Hotelling Rule

The traditional Hotelling rule looks at the intertemporal optimization problem of a resource site owner who has to decide, in a marginal perspective, whether the last unit of resource for extraction (e.g. oil) should be taken out in the current period, where market price is P” and unit extraction costs is H - so that the cash flow P”-H can be invested in financial markets with a nominal yield of i; or whether to leave that last unit in the ground to be extracted in the future in which case the expected profit is given by the increase in the expected oil price $dP"^E/dt$ (t is the time index). Hence the optimization condition yields:

$$(1) \qquad i\left(P" - H\right) = \left(dP"^{E} / dt\right)\left(1+Z'\right)$$

An extended version of the Hotelling Rule has been considered in WELFENS (2008) where the new focus included anticipated technological progress (Z”) in the exploration of oil. Moreover, the nominal interest rate (i; real interest is denoted by r) was considered carefully since $i= r + \pi^E$ (whereby π^E is the expected inflation rate where the relevant price index consists of oil/energy as well as non-oil goods). The expected inflation rate π (we drop the superscript E) can in turn be written as $\pi = V\pi' + (1-V)\pi''$ where V is the weight for non-oil goods, π' is the non-oil goods inflation rate and π'' the oil price inflation rate.

Subsequently we will additionally consider that real unit production costs H’ is proportionate to oil production Q, so that there are rising marginal costs (H’=v’Q; positive cost parameter is v’). Moreover, the availability of renewable energy – quantity is denoted as R - will be considered in the demand equation in the oil market and R is considered to be a positive function of the relative allowance price p':=P'/P where P' is the price of CO2 allowances and P the general price level. Thus we can determine the market-clearing price of oil (or other natural resources).

In the case of a setting with technological progress in the oil exploration (natural resource exploration) we have instead of (1) the new equation (1'). Hence we have the following equations:

(1') $$i\left(P'' - H\right) = \left(dP''^{E}/dt\right)\left(1+Z''\right)$$

The oil price can be assumed to be denoted in $ and hence H is also expressed in $. The relevant nominal interest rate is that of the US if one assumes that both OPEC oil producers and US oil producers will invest in US financial markets. We have, after dividing by P":

(2) $$i\left(1-H''\right) = \pi''\left(1+Z''\right)$$

Let us define H":= H/P"; H"= (H/P)(P/P")= H'(P/P"); p':= P/P"; p":= P"/P. Assuming rising marginal costs, one can state equation 3:

(3) $$H' = v'Q$$

(4) $$i\left(1-v'p'Q\right) = \pi''\left(1+Z''\right)$$

Assuming that the expected oil inflation is different from zero one can write:

(5) $$\frac{\left(r+V\pi'+(1-V)\pi''\right)}{\pi''} = \frac{\left(1+Z''\right)}{1-v'p'Q}$$

Given that by assumption and for the sake of simplicity v'p''Q is close to zero (say, because v' is very small), we get:

(6) $$\frac{\left(r+V\pi'+(1-V)\pi''\right)}{\pi''} = (1+Z'')(1+v'p'Q)$$

(7) $$\frac{r}{\pi''}+\frac{V\pi'}{\pi''}+1-V-1-Z'' = (1+Z'')v'p'Q$$

(8) $$Q^{s} = \frac{\left(\frac{r}{\pi''}+\frac{V\pi'}{\pi''}-V-Z''\right)p''}{v'(1+Z'')}$$

The supply of oil (and gas) depends on various influences:

- Output is a positive function of the ratio r/π", the relative ratio of the real interest rate to the oil inflation rate and the current relative price of oil (it is noteworthy that the real interest rate has shown a long run decline in the US and other OECD countries since the mid-1980s – the main reason for this seems to be the absolute decline of the ICT capital goods price combined with the rising share of ICT capital goods in total capital formation where the rising share is a positive function of the declining relative price of ICT capital goods; the observed rise of nominal ICT capital goods in the total nominal capital stock implies that the substitution eleasticity of ICT capital goods exceeds unity. Profit maximization requires that the marginal product of capital has to be equal to $(i - (\pi^{K}_{t+1} - \pi) + \delta)P^{K}/P$ where P^{K} is the price of the capital stock, t the time index and δ the capital depreciation rate. The fall of P^K/P raises the optimal capital intensity and thus is expansionary and this includes the steady state per capita consumption and hence the consumption of energy – assuming that households consume both goods and energy, e.g. for light, heating.The relevant impact of the decline of the ICT Investment goods price is an OECD-wide and China-wide decline of the real demand for loans in the business sector).

- Output is a negative function of the cost parameter v' and the technological progress rate in the oil sector.

It will be assumed that the demand for oil is a positive function of Y (V' is a positive parameter) and a negative function of p" (h" is a positive parameter) as well as a negative function of renewable energy volume R where R' is a positive parameter (indicating the degree of substitution between fossil fuels and renewable energy); and R is assumed to be a positive function R(P'/P) of the relative allowance price P'/P. Subsidies – in real terms - for fossil fuels (here, oil) are denoted by S' and s" is a positive parameter. The global subsidization of fossil fuels was already identified as a major problem at the 2009 Pittsburgh G20 summit; in 2018 the subsidies worldwide still stood at about 6% of world GDP (COADY ET AL., 2019). As regards the influence of the relative CO2 allowance price on R, namely R(P'/P), a linear function R(P'/P)= R"P'/P – with R" denoting a positive parameter – will be used where aggregate oil demand is dampened by R'R. The demand function for oil therefore is given by:

(9)
$$Q^D = V'Y - h''\frac{P''}{P} - R'R(\frac{P'}{P}) + s''S'$$

(10)
$$Q^D = V'Y - h''p'' - R'R''\frac{P'}{P} + s''S'$$

In a pragmatic way one should interpret Y as world output. Thus the equilibrium price ratio can be determined from the equilibrium condition in the oil market:

(11)
$$\frac{\left(\frac{r}{\pi''} + \frac{V\pi'}{\pi''} - V - Z''\right)p''}{v'(1+Z'')} = V'Y - h''p'' - R'R''\frac{P'}{P} + s''S'$$

(12)
$$\left[\frac{r}{\pi''} + \frac{V\pi'}{\pi''} - V - Z'' + v'(1+Z'')h''\right]p'' = (1+Z'')\left[v'V'Y - v'R'R''\frac{P'}{P} + v's''S'\right]$$

One should note that equilibrium requires π'=π" and hence the equilibrium relative oil price is given by:

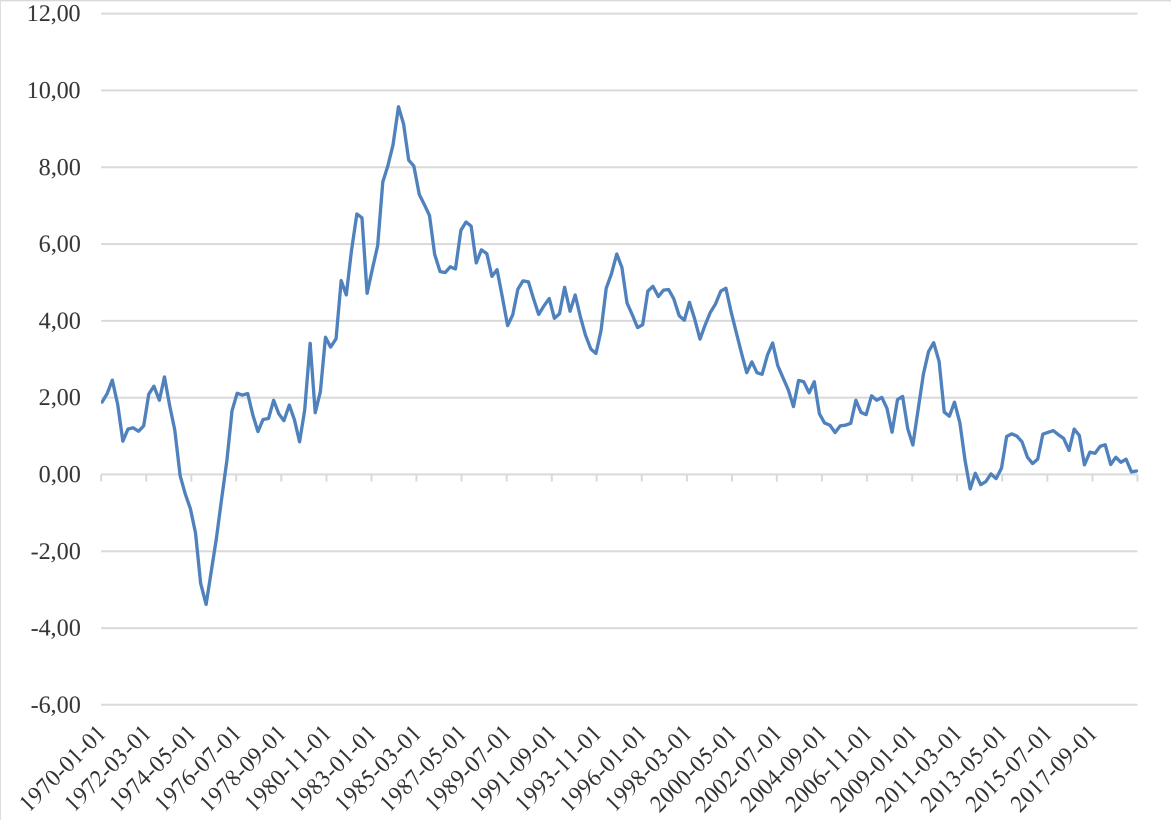
(13)
$$p'' = \frac{(1+Z'')\left[v'V'Y - v'R'R''\frac{P'}{P} + v's''S'\right]}{\left[\frac{r}{\pi''} - Z'' + v'(1+Z'')h''\right]}$$

The equilibrium price p" is positive – hence the numerator is assumed to be positive - thus is:

- a positive function of the cost parameter v' as well as GDP and the real subsidies (S') for fossil fuel demand; the expected technological progress parameter Z" has an ambiguous impact on the equilibrium oil price;
- a negative function of the relative CO_2 allowance price P'/P and the ratio of the real interest rate r to the expected oil price inflation rate.

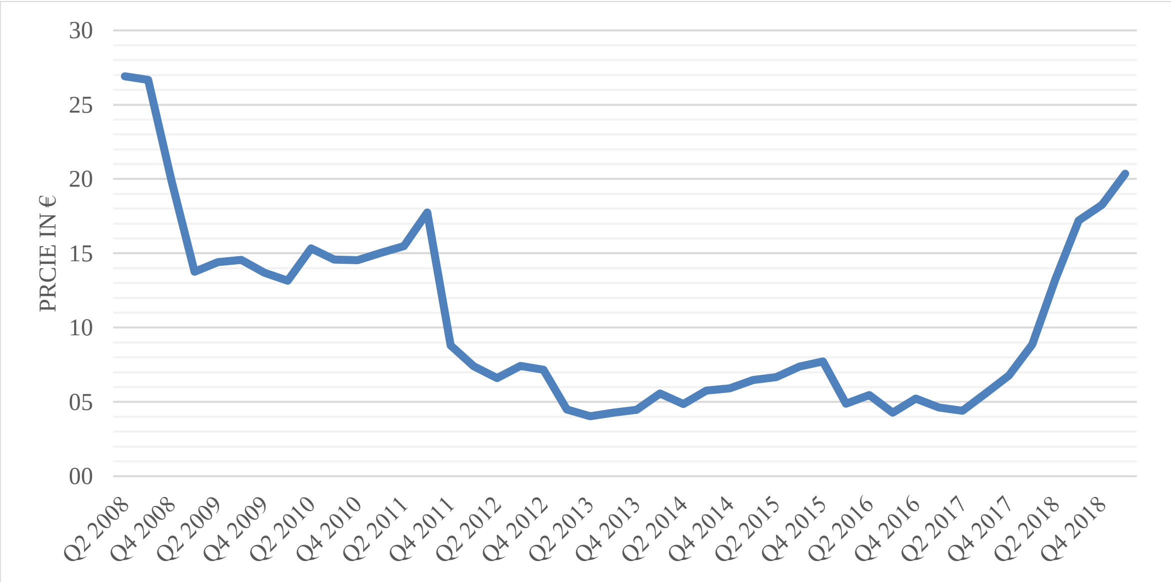
In the following graph the long run decline of the US real interest rate in the period 2012-2019 implies an upward shift of the supply curve in the world economy. At the same time, one should not overlook the impact of the rise in the global CO_2 allowance price which has stimulated the use of renewable energy which, in turn, has reduce the demand for oil (and gas) so that a leftward shift of the demand curve has occurred in 2012-2019. The overall impact could be a lowering of the relative oil price, but a rise also cannot be excluded, namely if the upward shift of the supply curve is relatively strong. As regards the ratio of the oil price to the US GDP price deflator, it is obvious that the relative oil price has reduced between 2012 and 2019 (and between 1918 and 2019). The relative CO_2 allowance price in EU has reduced after 2008 over many years, it has strongly increased in the period 2017/2018. It is noteworthy that in the first two EU CO_2 allowance trading periods governments in EU member countries had allocated high shares of free CO_2 certificates which, of course, has brought about a fall of the relative CO_2 allowance price. The Great Recession 2008-2010 also has dampened the relative allowance price over several years in the EU. To the extent that the Great Recession is the result of insufficient financial market regulation in the US and the EU one may argue that the CO_2 allowance market of the EU has faced major political shocks over time. Another shock is looming in Germany where the government's climate policy package aims to phase out in a bureaucratic approach coal mining and coal-fired power stations by 2038 which amounts to phasing out almost 1/3 of Germany's emissions. One cannot rule out that the CO_2 emissions from coal-fired power stations could be re-allocated to other countries in the EU so that phasing out coal in Germany would not translate into lower CO_2 emissions of the EU. In 2022 Germany is phasing out all nuclear power plants so that expansion of renewable energy will be crucial.

Figure 1: Real Interest Rate in the US, 1970-2019 (quarterly values: nominal interest minus growth rate of the GDP deflator)



Source: FRED, Federal Reserve Bank of St. Louis; own calculations

Figure 2: Relative CO2 Allowance Price in the EU, Q2 2008 – Q4 2018



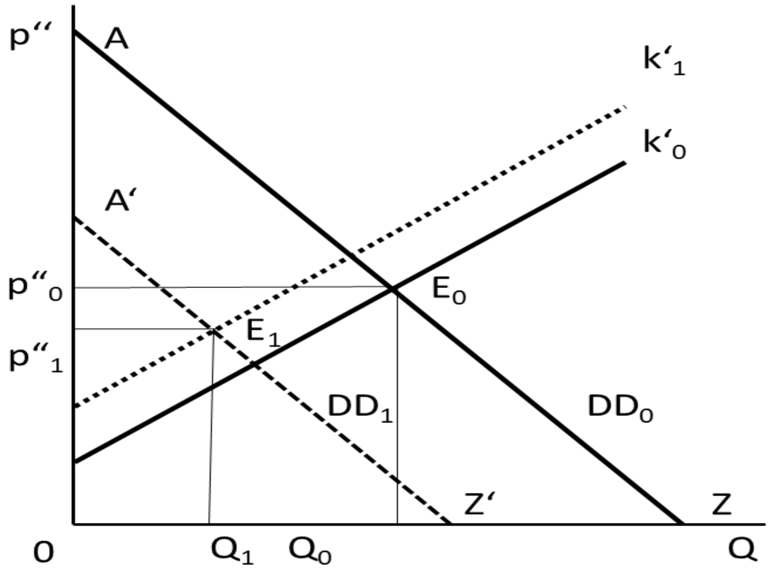
Source: Sandbag.org.uk, Eurostat; own calculations

Figure 3: Relative Price of Oil, 1970-2019 (US Oil Price Divided by US GDP Deflator, monthly values)

Source: FRED, Federal Reserve Bank of St. Louis; own calculations

The interaction of a fall of real interest rates in the decade after 2008, on one hand, and a rise of the relative allowance price in the EU after 2017, on the other, should contribute to a dampening of the relative oil price (see Figure 4), while the joint impact of the allowance price increase and the rise of the relative price of oil (and gas) could lead to a rise of the real aggregate stock market; the combined effects of higher allowance prices and lower fossil fuel prices could bring about a net cost reduction in certain sectors, particularly in sectors which use fossil fuels intensively (e.g. Chemicals).

Figure 4: Relative Equlibrium Price in the Oil Market (decline of real interest rate and rise of relative CO2 allowance price)



Source: Own representation

Clearly, EU and Eurozone stock market dynamics should normally also reflect US stock market price dynamics. This is mainly a theoretical contribution and not an empirical paper, but the complementary analysis of WELFENS/CELEBI (2020) sheds new light on the link between CO2 prices and stock market index developments in the EU.

Link to the Golden Rule in Growth Analysis

It can be shown that the oil market analysis can be linked to key aspects of the golden age debate in modern growth theory (WELFENS, 2011). The golden age requires that the real interest rate is equal to the output growth rate where one can indeed argue that outside of a situation with the realization of the golden rule, capital intensity is non-optimal in a serious way:

- If the real interest rate is equal – in a setting with a given population L – to the general progress rate (a), there is a maximization of per capita consumption. This indeed is also necessary for climate neutrality: a capital intensity below the golden age capital intensity means that maximum steady per capita consumption is not reached.
- A long run capital intensity above the golden age capital intensity implies not only that the maximum per capita consumption is not realized but also that, due to the excessive production of machinery and equipment, there has been a waste of natural resources in both the production of that machinery and equipment on the one hand, while on the other hand the fossil fuel energy used for the production of the excess machinery and equipment as well as for running such machinery and equipment clearly means that there are unnecessary CO2 emissions and hence additional welfare losses – beyond missing the maximum per capita consumption.

If policymakers and firms, respectively, achieve r=a and if one assumes that that the progress rate in the oil sector is proportionate to the general progress rate, hence Z"= z"a (with 0<z"<1; the case z">1 also could be considered if there is empirical evidence for this) and in addition that the available amount of renewable energy is a positive function of the progress rate a (V" is a positive parameter), one can restate the above equation; and so we get:

(14)
$$p" = \frac{(1+z"a)\left[v'V'Y - v'R'R"\left(\frac{P'}{P} + V"a\right) + v's"S'\right]}{\left[\frac{r}{\pi"} - z"a + v'(1+z"a)h"\right]}$$

(15)
$$p" = \frac{v'V'Y - v'R'R"\left(\frac{P'}{P} + V"a\right) + v's"S'}{\frac{r/\pi" - z"a}{1+z"a} + v'h"}$$

(16)

$$\frac{dp"}{da} = -\left\{\frac{\left[v'V'Y - v'R'R"\left(\frac{P'}{P} + V"a\right) + v's"S'\right]\left[-\frac{z"(1+r/\pi")}{(1+z"a)^2}\right]}{\left(\frac{(r/\pi") - z"a}{1+z"a} + v'h"\right)^2}\right\} - \left[\frac{v'R'R"V"}{\frac{((r/\pi") - z"a)}{1+z"a} + v'h"}\right]$$

$$\frac{dp"}{da} < 0,\ if \left[\frac{v'R'R"V"}{\frac{(r/\pi") - z"a}{1+z"a} + v'h"}\right] > \{...\}$$

The latter condition is not fulfilled and indeed dp"/da>0 if the squared bracket term is negative which would occur if r is zero and $h" < \frac{v'}{\frac{1}{z"a} + 1}$; this is a requirement that refers to the demand parameter h" relative to cost and progress parameters. As one can see, the general progress rate has an ambiguous impact on the relative price of oil.

It should be noted that in an economy with a Cobb Douglas function $Y=K^{ß}(AL)^{1-ß}$ and (with τ denoting the income tax rate, K capital stock, A knowledge, L labor; 0<ß<1; y':=Y/(AL)) a savings function S=s(1-τ)Y long run output in the steady state is $y'\# = (s(1-\tau)/(a+n+\delta))^{ß/(1-ß)}$; δ is the capital depreciation rate, n the exogenous growth rate of labor. With a progress rate of knowledge a and a given negative population rate – with a equal to the absolute value of n - one could replace Y by the above equation and again a would have to be considered in an additional term.

The role for the use of renewable energy could be assumed to be mainly in consumption which still would have to be considered (with c'>0): e.g. a consumption function C=c(1-τ)Y + c'R which has implications for the savings function. Alternatively, R would be considered in the production function.

There is relatively little knowledge so far as to the extent to which general government promotion of research and development leads to innovation growth relevant to the oil and gas sector. There are clear arguments that government should specifically encourage green R&D and innovation, respectively.

To the extent that a reduction of the relative price p" leads to a rise of the general stock market price index – through lower costs of production and higher profits, respectively – all factors that lead to a lower p" imply a rise of the stock market price index. This index has to be distinguished from the energy (oil & gas) sector sub-index where the sign of the impact of those variables should be opposite.

3. Implications for Climate Policy Approaches and Economic Policy

Policymakers in the US, the EU and China, plus ASEAN, should take into account the links between innovation and climate policy and the relative price of oil which, in turn, has an impact on business cycle dynamics. A rise of the relative oil price raises exports to OPEC countries and other countries rich in oil and gas reserves; at the same time, the rise of the relative oil price dampens the overall stock market price index relative to the aggregate output price level – this ratio is Tobin's Q. A lower Q implies a dampening effect on aggregate investment and output in the medium term.

Policymakers should take into account the linkages between innovation, oil/gas prices and the stock markets where the link of the latter to CO2 mitigation innovation developments also have to be considered; and macroprudential supervisors certainly have to consider these dynamics. The new links in financial markets considered here will certainly play a critical role in the transition to climate neutrality and climate policymakers would be wise to have carefully studied the Schumpeterian dynamics of CO2 allowance prices and innovation dynamics plus stock market dynamics and the interrelationship between stock market intensity – as emphasized in the paper of DE HAAS/POPOV (2019) – and CO2-mitigation progress as well as climate-stabilizing innovation dynamics.

If national CO2 Emission Trading Systems are integrated internationally, there will be crucial global effects on climate neutrality, financial markets and output. For example, if the regional EU ETS – with a price of about €26/ton CO2 in 2019 – would be integrated with California's ETS (there the allowance price was about €14/ton CO2 in 2019) – there would be a common CO2 allowance price which would be around €20/ton CO2. An interesting question concerns the effect on the global oil price and the oil price indeed is a global price. One cannot rule out that the market integration of CO2 ETS of major G20 countries would transitorily lead to a lower average global CO2 allowance price so that the relative oil price could transitorily increase. This in turn means that for a certain transition period there would be an incentive for developing countries without much renewable energy capacity to use more fossil fuels, but one may expect this effect to be rather limited in time since the leading producers and exporters of machinery and equipment in the world economy are from G20/European countries and ASEAN countries. Once the new machines sold by producers in these countries are largely geared towards renewable energy use, the use of old machinery and equipment in poor developing countries would largely be a question of physical wear and tear – the physical depreciation of the old vintages of machinery will make a major global oil and gas rebound effect quite unlikely in the long run.

As regards the efficiency of ETS, there is little doubt that CO2 allowances are a highly efficient market institution unless there would be a lack of adequate financial market regulation, including the regulation of CO2 allowance markets in G20+ countries. Only a broader North-South cooperation which would bring about ETS systems in the G20 will allow an efficient climate change policy: The G20 accounted for 81% of global CO2 emissions in 2018. Moreover, reducing fossil fuel subsidization seems to be of prime importance for achieving lower CO2 emissions in the world economy and here again a G20 approach could be useful. This could include joint innovation projects for renewable energy whose prices in the end will be decisive in reducing oil and gas production. Once the energy price of renewables is lower than the variable cost of oil and gas production, one can expect that the production of fossil fuel will end – assuming that government subsidies for oil and gas production in OPEC countries will not artificially raise the volume of oil and gas production.

It should be emphasized that government R&D promotion is a natural element of rational economic policy. However, one should also carefully study the extent to which associated innovation amounts to technological progress in oil and gas exploration and production which, in turn, affects the modified Hotelling rule. The cross-sectoral innovation spillovers for the oil and gas industry have not been studied in any broad way in the literature so that there is room for further research. Prudential supervisors in the world economy, which include many central bankers, will have a natural interest in the theoretical and empirical analysis (WELFENS/CELEBI, 2020) on the topic presented here.

For EU countries as well as other net importers of oil and gas a long run decline of oil and gas imports will put new pressure on economic policy: Higher expenditures for promoting R&D in general and for CO2-mitigation technologies would be adequate. In the EU Germany, the Netherlands and Austria have a long history – dating back to the 1970s – of real appreciations of the currency and adequate innovation dynamics of industry. For other Eurozone countries/EU countries a long run appreciation pressure is a challenge that still has to be fully understood in the coming decades. Here a challenge for the EU Commission as well as national policymakers in the field of R&D promotion exists and naturally maintaining competition and global free trade should be crucial elements as well. These macroeconomic and structural challenges for the EU, ASEAN countries and China deserve special attention in future research. The US – a net exporter of oil and gas - in turn could face a problem in the context of a real depreciation.

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