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Can a Global Oil Royalty Help to Limit Climate Change?

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Introduction

This paper discusses whether a global oil[1] royalty could help to limit climate change. It starts by summarising the Paris Agreement and by discussing whether the world is currently on course to achieve its goal of limiting the increase in global average temperature to well below 2 degrees Celsius above pre-industrial levels. The relationship between prices and the demand and supply of oil is then discussed, and it is argued that a global oil royalty could reduce the production and consumption of oil. This paper concludes by modelling the global oil royalty rate that would cause oil production to fall to a level consistent with achieving the Paris Agreement's temperature goal.

What does the Paris Agreement say?

The Paris Agreement commits 194 countries to combating climate change. The overarching goals of the Paris Agreement are to limit the increase in global average temperature to well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the increase to 1.5 degrees Celsius.[2]

Is the world currently on course to limit climate change to well below 2 degrees Celsius above pre-industrial levels?

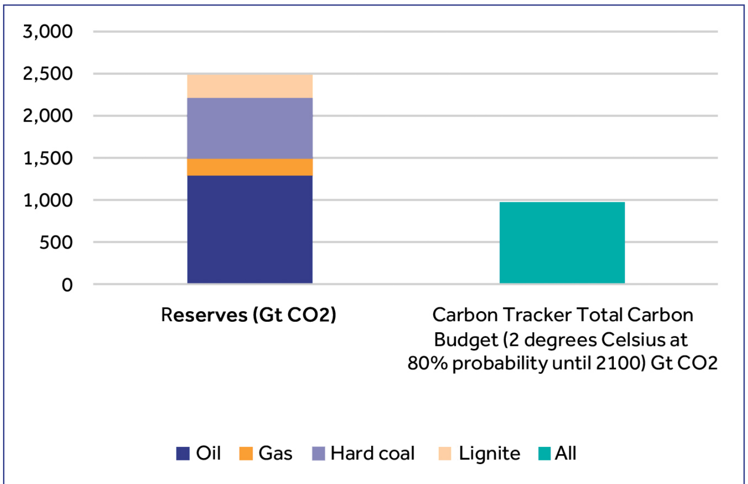
Climate change is partly caused by greenhouse gas emissions,[3] which include carbon dioxide. Restricting climate change to a specific level can only be achieved if the total amount of carbon dioxide released into the atmosphere is limited.[4] Fossil fuels (such as coal, oil and natural gas) release carbon dioxide when they are burned.

Past trends in carbon dioxide emissions provide an indication that it will be difficult to limit climate change to well below 2 degrees Celsius above pre-industrial levels. According to some estimates,[5] approximately two-thirds of the total available carbon dioxide emissions consistent with keeping climate change below 2 degrees Celsius above pre-industrial levels have already been emitted. It has also been argued[6] that the current trend in rising carbon dioxide emissions from some sources needs to be reversed in the short-term, and that technologies for removing greenhouse gases from the atmosphere will become indispensable, if there is to be a reasonable chance of meeting the goal of limiting climate change to well below 2 degrees Celsius above pre-industrial levels. Other studies[7] have argued that given past carbon dioxide emissions, it may already be too late to limit climate change to 1.5 degrees Celsius.

The goal of limiting climate change to well below 2 degrees Celsius above pre-industrial levels can thus only be achieved if carbon dioxide emissions are sharply reduced going forward. This was implicitly recognised in the Paris Agreement's commitment to the need for global greenhouse gas emissions to peak as soon as possible, to thereafter rapidly reduce, and to achieve a balance between anthropogenic emissions and removals in the second half this century.[8] Achieving this target will require public policies to reduce the consumption and supply of fossil fuels.

A detailed review of all the public policies aimed at reducing the production of fossil fuels is well beyond the scope of this paper. An analysis of fossil fuel reserves and oil companies' share prices can, however, provide an indication of market expectations regarding future fossil fuel production. The expectation of market participants can be reasonably assumed[9] to take account of current, and known future, public policies for limiting climate change. Estimates of future fossil fuel production from leading forecasters can also provide an indication of the expected impact of current public policies on the production of fossil fuels.

Graph 1 Gigatonnes[14] carbon dioxide in reserves and carbon budgets[15]



What do fossil fuel reserves imply for future production?

Fossil fuel reserves include only fossil fuels that are technically and economically recoverable. A fossil fuel is economically recoverable only if, at current and expected future market prices, it is profitable to mine that resource.[10] If fossil fuel companies' expectations of future prices sharply decline, then some existing reserves would become uneconomical to recover and would cease to become reserves. A corollary is that if current fossil fuel reserves exceed the level of total production consistent with achieving the Paris Agreement goals, then the price signals being given to companies in the fossil fuel market and their expectations concerning future production are not consistent with limiting climate change to well below 2 degrees Celsius.

A recent analysis[11] demonstrates that in order to have an 80 per cent probability of limiting climate change to 2 degrees Celsius, then carbon dioxide emissions cannot exceed 975 gigatonnes from 2013 to 2100.[12] The combined carbon dioxide emissions in current reserves of oil, gas, hard coal and lignite amount to 2,490 gigatonnes (see graph 1). Thus, the reserves of these fossil fuels are more than double the amount that can be consumed by 2100 if the world hopes to achieve the Paris Agreement's goal.[13] As it seems unlikely that companies would value, book and continue to explore for reserves that they did not intend to mine until the next century, this also provides an indication that current market expectations are that fossil fuel production will exceed the amount consistent with limiting climate change to well below 2 degrees Celsius.

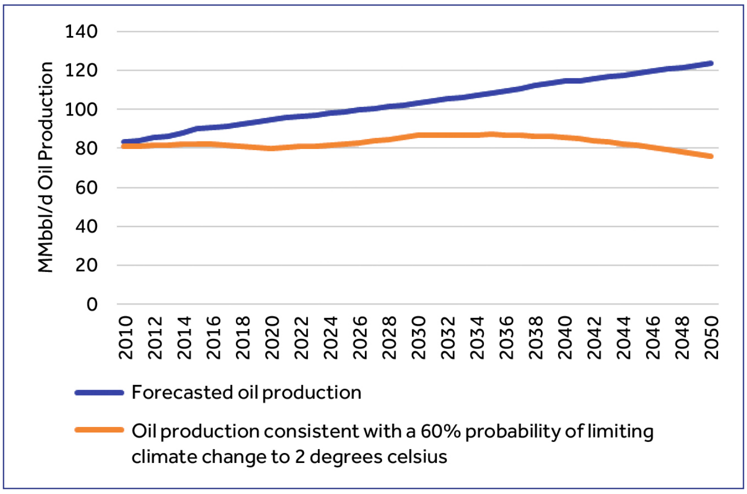
Recent studies[16] have also argued that if the Paris Agreement's goal is to be achieved, then up to 80 per cent of the booked reserves of listed fossil fuel companies cannot be mined and that their share prices may be overpriced by up to

60 per cent. In addition, many listed companies continue to invest significant amounts in exploring for new reserves, when an optimal strategy in a low carbon dioxide emissions future would be to maximise profits and increase dividends by cutting back on exploration and development expenditure. The market, therefore, seems to be pricing in future oil production that exceeds the amount consistent with achieving the Paris Agreement's goals. This is presumably because market expectations, based on current and known future public policies, are that fossil fuel production will continue to exceed the level consistent with achieving the Paris Agreement's goals.[17]

Current forecasts also demonstrate fossil fuel production well in excess of the level consistent with meeting the Paris Agreement's goals. For example, as shown in graph 2, the Energy Information Administration currently forecasts oil production that is well above the amount consistent with there being a 60 per cent probability of limiting the increase in global temperatures to 2 degrees Celsius.

Overall, market expectations and forecasts indicate that future fossil fuel production will likely exceed the amount consistent with achieving the Paris Agreement's goals.

Graph 2 Oil production [18]



Why might future fossil fuel production exceed the amount consistent with achieving the Paris Agreement's goals?

At current and expected future prices, there is likely to be a higher demand for, and supply of, fossil fuels than is consistent with the Paris Agreement's goals. There is high demand for gas, partly because it is a cost-effective fuel for generating electricity, and there is high demand for oil, mainly because it is a cost-effective fuel for powering vehicles. There is a high supply of oil, because at current and likely future prices it is profitable to produce. This paper illustrates these points by examining the costs of electricity generation, the costs of electric and internal combustion engines, the costs of producing oil, and the overall supply and demand curves for oil.

The market seems to be pricing in future oil production that exceeds the amount consistent with achieving the Paris Agreement's goals

The costs of electricity generation

This paper uses levelised costs to examine the cost of electricity generation from fossil fuels and renewable sources. The levelised cost of energy is the present discounted value of all costs divided by the present discounted value of production (see equation one overleaf). It can be thought of as the long-run average cost of the energy source, accounting for all costs and the time value of money.[19]

Levelised costs offer a fair way of comparing costs from energy sources with different cost profiles over time. Renewable power plants, for

Equation One: Levelised cost of energy

$$LCOE = \frac{\sum_{t=0}^{T} d^t C_t}{\sum_{t=0}^{T} d^t Q_t}$$

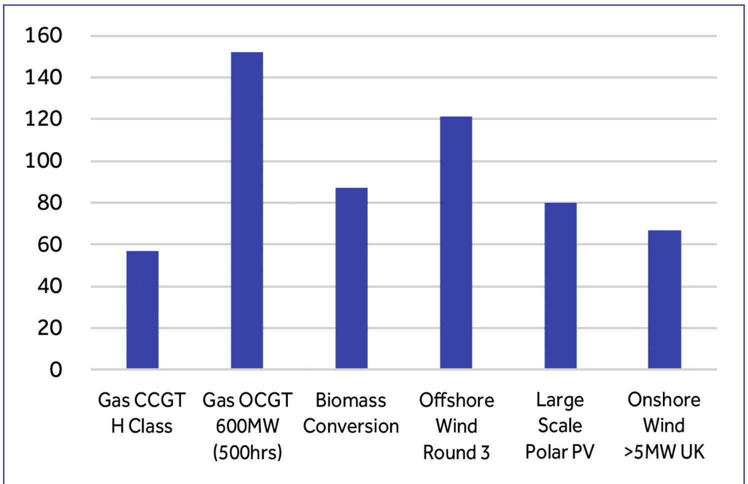
Where LCOE = levelised cost of energy and

T = lifetime of system; t = time;
d = discount rate; C = cost;
Q = production (e.g. Mega Watt Hours)

example, have high up-front capital costs, but relatively low operating costs (because their fuel is effectively free). In contrast, fossil fuel power plants have higher operating costs as their fuel has to be continually purchased. It is, therefore, only through a measure, such as levelised costs, that accounts for all costs over time and appropriately discounts future costs, that the costs of renewable and fossil fuel power plants can be fairly compared.

The levelised costs of electricity generation from gas, biomass, offshore wind, onshore wind and solar in the UK for 2016 are shown in graph 3.[20]

Graph 3 Levelised costs of electricity, pound sterling (GBP) per MWH in the UK [21]



As can be seen, electricity generated from Gas CCGT H class generators is cheaper than from any other source.

In addition, this comparison may understate the cost advantage gas has over renewable energy sources for two main reasons. First, the levelised cost of renewable energy varies by location. For example, it is cheaper to generate wind power in windy locations. It might thus be expected that investors would initially build wind turbines in the most favourable and cheapest locations, but as more and more generation capacity is built, construction will also have to take place in more expensive locations. This implies that, all else being equal, as more generation capacity is constructed the levelised costs of renewable energy will increase.

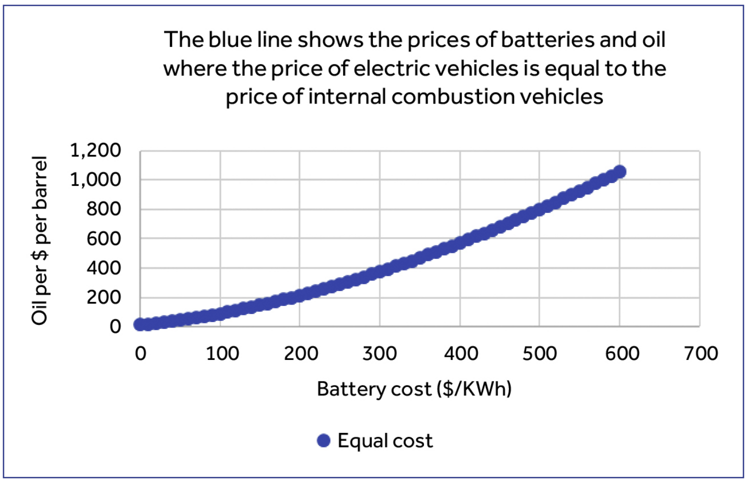
Second, solar and wind energy are intermittent. Thus, they require increases in back-up generation (often from gas generators) or increases in energy storage that are not fully reflected in reported levelised costs. Such additional costs will vary based on how much of total electricity is supplied by renewable sources and the correlation across time in generation from different renewable sources. However, a leading study[22] concludes that such additional costs are significant.

Overall, natural gas is a cost-effective way of generating electricity. This is reflected in the fact that electricity generation accounts for approximately 40 per cent of the demand for natural gas.[23]

Comparing the costs of electric and internal combustion engines

Approximately 65 per cent[24] of the current demand for oil comes from the transportation sector. This demand for oil is driven by the cost-effectiveness, at current and likely future oil prices, of internal combustion engines compared to electric engines. This point is illustrated in graph 4, which repeats the results of a recent

Graph 4 Cost of electric and internal combustion vehicles [25]



study comparing the costs of internal combustion engines and electric engines. The calculations underlying graph 4 assume a 3,000-pound vehicle which is driven 15,000 miles a year and a discount rate of 5 per cent. The internal combustion engine is assumed to get 30 miles per gallon. The electric engine is assumed to consume 0.3 kilowatt hour of electricity per mile and the price of electricity is assumed at $12.2 Kwh. The electric engine is also credited with $1,000 due to its lower cost of production compared to an internal combustion engine.

The line in graph 4 shows the different oil and battery prices at which the overall costs of electric and combustion engines are equal. At the current battery price of 325 US dollars ($) per kilowatt hour, oil prices would have to be $420 per barrel for electric engines to be price competitive. In actuality, as of the 3rd of April 2017, the oil price was $53.16 per barrel.[26] In addition, even in the long term the price of oil is not forecast to reach anywhere near $420 dollars per barrel. For example, the EIA reference case forecast for Brent Crude in nominal terms is only $236 per barrel in 2050.[27] At current oil prices, electric battery prices would have to fall to $60 per kilo watt hour to be competitive. So, based on current prices, internal combustion engine vehicles are much more cost-effective than electric vehicles.

The cost of electric batteries may of course fall in the future as technology increases. However, internal combustion engines may also (as they have done in the past) become more fuel efficient in the future. There is little reason to assume a priori that in the long-term technological change will improve the cost-effectiveness of electric engines compared to internal combustion engines. Moreover, studies that do forecast changes in battery prices and miles per gallon conclude that electric vehicles will continue to be relatively expensive over the next 10 to 15 years.[28]

Electric and internal combustion engines also compete on quality as well as price. Presently, internal combustion vehicles have a much longer range than electric vehicles. In addition, the existing infrastructure for internal combustion engine vehicles (refuelling stations, mechanics etc.) is better established than for electric vehicles. This implies that even if the overall costs of electric engine and internal combustion engine vehicles were similar, there would still be significant demand for internal combustion engine vehicles. In addition, electric vehicles would have to be cheaper than internal combustion engine vehicles by some margin to significantly reduce demand for oil.

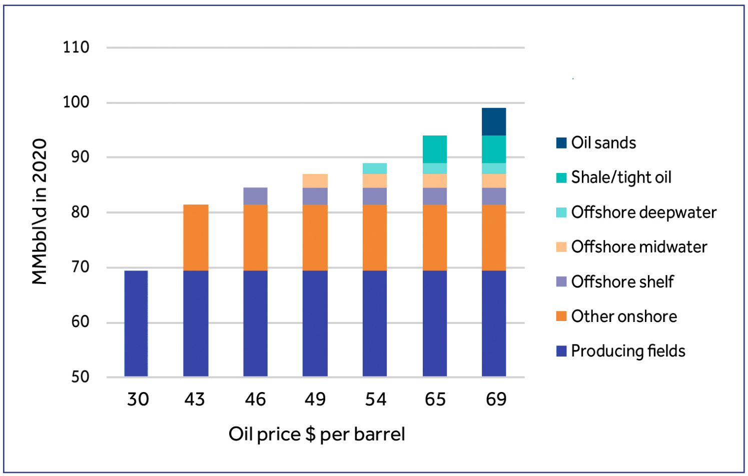
To summarise, there is much evidence that at current and likely future oil prices internal combustion engines will continue to be a cost-effective way of powering vehicles and that this will lead to substantial future demand for oil.

The costs of supplying oil

This paper uses a stylised oil field to examine whether at current and likely future prices it is profitable to produce oil. This paper modelled a stylised offshore oil field with production of 931 million barrels in total over 26 years and total costs of $12.6 billion broken down into exploration, development, operating and decommissioning costs.[29] With a conservative[30] future average international oil price of $60 per barrel, the field would make a pre-tax profit of $43.2 billion[31] and have a pre-tax internal economic rate of return of 52 per cent. These profits are well in excess of those required to motivate production. Assuming that the investor has to pay a tax of 62 per cent of profits,[32] the post-tax internal economic rate of return would still be 35 per cent, well above the hurdle rate of 12 per cent commonly required by international oil companies to develop fields. So even with a conservative estimate of future prices, it will likely remain profitable to supply oil going forward.

The costs of supplying oil are of course not identical across all fields. This is demonstrated by graph 5, which shows how the cumulative supply of oil increases for 2020 as the price of oil increases. For example, if the oil price is $30 per barrel, it is only profitable to extract oil from producing fields and the supply of oil would be just 69.5 million barrels per day (MMbbl/d) in 2020. In contrast, at an oil price of $54 a barrel, it is profitable to extract oil from producing fields and new onshore, offshore shelf, offshore mid-water and offshore deep-water fields, and the total supply of oil would be 89 MMbbl/d in 2020.

Graph 5 Oil production in 2020 from different categories of oil field at various oil prices [34]



Therefore, at recent oil prices of approximately $55 a barrel, it is profitable to supply more than 89 MMbbl/d of oil. This is well in excess of the 80.2 MMbbl/d for 2020 that is estimated to be consistent with limiting global climate change to 2 degrees Celsius.[33] So overall there is much evidence that at current and likely future oil prices, the supply of oil is likely to exceed the amount consistent with the principal goal of the Paris Agreement.

The overall demand and supply of oil

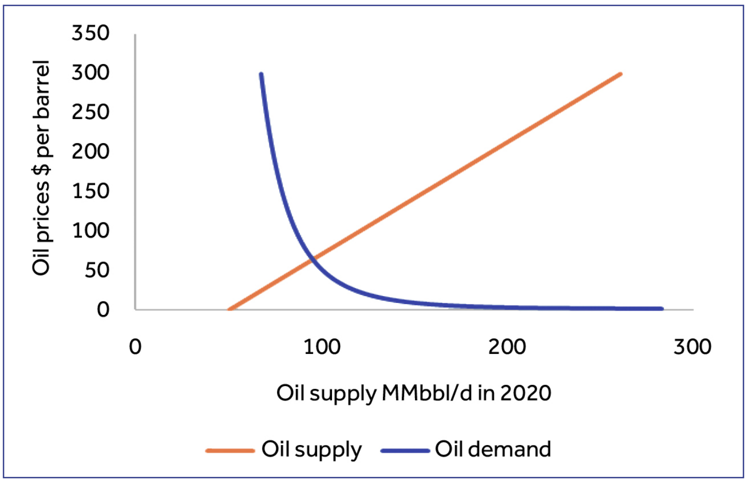
This paper constructs demand and supply curves to show the overall relationship between oil production and prices (see graph 6).

The demand curve is drawn based on a constant price elasticity of demand of -0.22. This demand elasticity is the average of the results of previous econometric studies into the price elasticity of demand.[35] A price elasticity of demand of -0.22 means that for each 1 per cent increase in the price of oil, there is only a 0.22 per cent decrease in demand for that fossil fuel. There is only a moderate fall in demand due to higher prices because, at least in the short term, consumers have little choice but to continue purchasing petrol for essential transport. In addition, for the reasons discussed earlier, even at very high oil prices, consumers may continue to purchase vehicles that use internal combustion engines fueled by petrol.

The supply curve is drawn based on the equation $Q_S = 50.8 + P*0.7$ (when Q is MMbbl/d and P is the oil price per barrel). This equation was estimated based on empirical data of the overall oil supply from different categories of oil field at different prices.[36]

Demand and supply are in equilibrium in 2020 at an oil price of $64 per barrel and quantity supplied of 95.6 MMbbl/d.[37] The quantity of oil supplied is significantly above the 80.2 MMbbl/d of supply for 2020 that is consistent with a 60 per cent probability of limiting the increase in global temperatures to 2 degrees Celsius.[38]

Graph 6 Oil demand and supply curves for 2020



There is therefore substantial evidence that oil production is above the amount consistent with limiting climate change to 2 degrees Celsius for the following reasons. First, at current and expected future oil prices, there is significant demand for oil because it is a cheap and effective fuel to power motor vehicles. Second, at current and expected future oil prices, it is profitable to produce and supply oil in large quantities.

Could a global oil royalty reduce oil production and limit climate change?

This paper investigates whether a global oil royalty would be an effective fiscal instrument to reduce oil production. By 'global oil royalty' this paper means:

A payment from the company that is producing oil to the government of the country where the oil field is located. The payment is set at a fixed percentage of gross oil revenues. The global oil royalty would be applied at the same rate by all countries with oil reserves.

In the literature,[39] such a charge is referred to as a 'royalty', as opposed to a 'tax', as it is theoretically paid by the company to the government for the right to produce oil that belongs to the state.

The theoretical impact of a global oil royalty on demand and supply is relatively simple. The royalty increases the cost of producing oil and therefore pushes the supply curve upwards and to the left. This occurs because for any given price, oil companies now receive less net revenue (because the royalty results in revenue for the government) and therefore for any given price, there are fewer oil fields that are profitable. By pushing the supply curve to the left, the royalty results in a new equilibrium between demand and supply, where the oil price is higher and the amount of oil produced is lower. For any given royalty rate, the relative impact on price and quantity depends on the slope (elasticity) of the demand curve. The steeper (more inelastic) the demand curve is, the larger the impact of any given royalty rate on prices and the lower the impact on quantity.

Overall, there is a strong economic argument that a global oil royalty could reduce the supply of oil

Overall, there is a strong economic argument that a global oil royalty could reduce the supply of oil. The oil taxation literature has long recognised that such a royalty could lead to marginal fields not being developed.[40] Indeed, the literature[41] often sees this as a weakness of a royalty compared to more neutral profits and excess profits based taxes.

There is also sometimes a concern that a high oil royalty in one country might lead to companies choosing to invest in the development of fields in lower tax/royalty jurisdictions. This may be a concern for the tax policy of a single country; however, this paper is proposing a global oil royalty that is implemented at the same rate by all countries. Companies could not, therefore, choose to invest in a low royalty/tax jurisdiction.

Despite the strong theoretical argument that a global oil royalty could reduce oil production, there has been almost no discussion of the impact of a global oil royalty on climate change. This lack of discussion is surprising, given that a royalty has many advantages over other economic instruments that can also be used to limit the consumption and production of fossil fuels and which have been extensively discussed in the literature (see annex 1).

The global oil royalty would likely lead to reductions in oil production from marginal high-cost fields

One important advantage of a global oil royalty is that it would be relatively easy to administer. A global oil royalty would be levied on upstream revenues, which are dependent on oil prices and production. Oil prices are easy to audit, as the actual price that an upstream oil operator sells oil at should differ little from published international benchmarks (e.g. Brent Crude). Oil production can also be easily physically monitored and measured by the authorities. In addition, oil production takes place at a relatively small number of fields operated by large companies. The number of sites and companies that the royalty would be applied to is thus relatively small. This contrasts with the complexities of administering many of the alternative economic instruments that could be used to limit the production and consumption of fossil fuels. For example, a tax which is levied on carbon emissions would have to be applied to millions of vehicle owners. Moreover, such a tax requires the accurate measuring and auditing of emissions from vehicles and manufacturing companies.

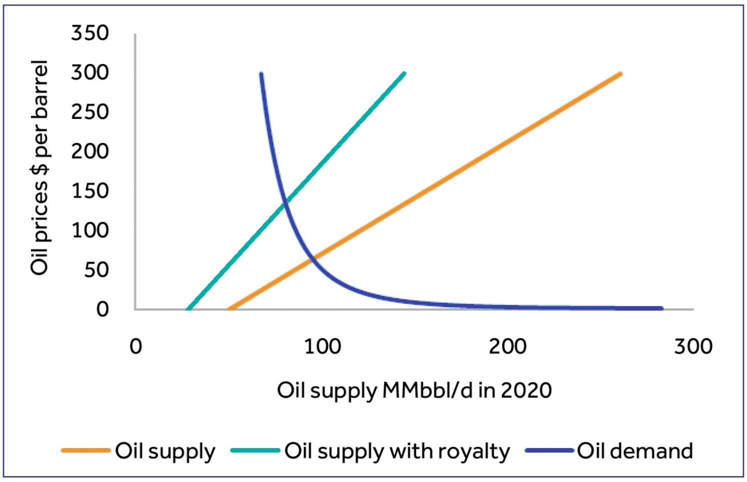
Another potential advantage of a global oil royalty is that it would lead to revenue occurring in countries where oil is produced.[42] In contrast, most other economic instruments that could be used to reduce carbon dioxide emissions lead to revenue being collected in the country where emissions occur.[43] As gross domestic product (GDP) per capita is more strongly positively associated with carbon dioxide emissions per capita than oil production per capita across countries,[44] the distribution of revenue from a global oil royalty may be more equitable than from a global carbon dioxide emissions tax.

More detailed research should, however, be conducted to calculate the distribution of revenues from the global oil royalty across countries. The global oil royalty would likely lead to reductions in oil production from marginal high-cost fields. Such marginal high-cost fields (such as deep-water offshore fields) may be concentrated in certain countries. These countries would likely see significant reductions in oil production and limited revenues from the global oil royalty. In contrast, countries with low costs of oil production and few marginal fields would see little reduction in oil production and significant revenues from the global oil royalty.[45] If these low-cost oil producers are on average richer than high-cost oil producers, then the distribution of revenues from the global oil royalty maybe inequitable.

Overall, there is a strong theoretical argument that a global oil royalty could reduce oil production and limit climate change.[46] This paper undertakes some preliminary calculations to ascertain the rate of the global oil royalty that would cause oil production to fall to a level consistent with there being a 60 per cent probability of limiting climate change to 2 degrees Celsius. These calculations use the empirical supply and demand curves estimated earlier (in graph 6) and assume that oil production of 80.2 MMbbl/d in 2020 is consistent with limiting climate change to 2 degrees Celsius.[47]

According to this modelling, a 46 per cent global oil royalty would lead to oil prices increasing to $141 in 2020 (see graph 7). At this price, demand and supply are in equilibrium with oil

Graph 7 Oil demand and supply curves for 2020 with a 46% global oil royalty



production of 80.2 MMbbl/d in 2020. This level of production is consistent with there being a 60 per cent chance of limiting climate change to 2 degrees Celsius. The global oil royalty would also result in total global government revenue of $1.9 trillion in 2020. A global oil royalty rate of 46 per cent is thus potentially a powerful public policy for achieving the Paris Agreement.

This global oil royalty rate should, however, be interpreted cautiously, as numerous uncertainties underpin its calculation. The exact value of the elasticity of demand is one such uncertainty. In the econometric literature, oil price elasticities of demand ranging from -0.03 to -0.66 are reported. If the true price elasticity of demand for oil is at the lower end of this range, then a much higher global oil royalty rate would be required to reduce oil production to a level consistent with limiting climate change to 2 degrees Celsius. In contrast, if the price elasticity of demand is as high as -0.66, then a global oil royalty of just 11 per cent would reduce oil production to 80.2 MMbbl/d in 2020.

A further uncertainty is the impact the global oil royalty would have on the production of other fossil fuels such as coal. This paper calculated the global oil royalty and oil production that would with a 60 per cent probability limit climate change to 2 degrees Celsius, assuming that the production of other fossil fuels also falls, due to public policies that have not been explicitly modelled by this paper, to a level consistent with limiting climate change to 2 degrees Celsius. This assumption maybe problematic for two reasons. First, public policies are not currently resulting in the production of other fossil fuels falling to a level consistent with limiting climate change to 2 degrees Celsius. Second, an increase in the price of oil would make other fossil fuels relatively cheaper and might lead to their consumption increasing. Conversely, public policies that reduced demand for other fossil fuels might increase demand for oil. This suggests that it would be worthwhile to undertake further research to calculate the different global royalties required on different fossil fuels to simultaneously reduce the production of every fossil fuel to a level consistent with reducing climate change to 2 degrees Celsius.

Another constraint in this paper's model is that it calculated the global oil royalty rate consistent with oil production for a single year. In actuality, the price elasticity of oil demand is likely to be more elastic in the long term than the short term. This suggests that a global oil royalty rate of 46 per cent would have a lower impact on price and a larger impact on production in the long term (post 2020). In turn, this implies that a lower global oil royalty rate may be consistent with limiting climate change to 2 degrees Celsius in the long term.

There are also likely to be many scenarios for oil production until 2050 that are consistent with limiting climate change to 2 degrees Celsius. A scenario where oil production is higher than 80.2 MMbbl/d in 2020, but is then subsequently lower (than under the 80.2 MMbbl/d scenario), is possible.

For the reasons outlined above, this paper's calculation of the global oil royalty rate of 46 per cent should be regarded as illustrative and should be interpreted cautiously. Prior to any firm conclusions being drawn about the optimal rate of the global oil royalty for achieving the Paris Agreement's goal, this paper's model should be extended to include multiple fossil fuels[48] and years.

There may also be legal constraints to immediately implementing the global oil royalty on all oil fields in all countries. For example, some contracts between governments and oil companies for oil fields include fiscal stability clauses. These clauses sometimes commit governments to either not increasing (or compensating the oil company if they do increase) royalties and taxes for an oil field. Governments may, therefore, only be able to levy the global oil royalty on new fields and existing fields that do not have fiscal stability clauses; or alternatively levy the global oil royalty on all oil fields and compensate oil companies operating fields with fiscal stability clauses. The existence of fiscal stability clauses would thus reduce the impact of the global oil royalty on oil supply, climate change and government revenue. The magnitude of this impact would depend on the proportion of total oil supply from oil fields that have fiscal stability clauses. Further detailed research is required to understand exactly what proportion of oil supply is currently from oil fields with fiscal stability clauses and how this would change the impact of the global oil royalty on oil supply and climate change.

The global oil royalty would reduce oil production, but it would also increase oil prices and government revenue.

The implementation of a global oil royalty would also be complicated by the fact that royalties are implemented by individual countries. This paper, therefore, briefly discusses the impact the global oil royalty would have on oil producers and consumers and the motivation these two groups would have to agree to such a policy.

The policy of implementing a global oil royalty may meet some resistance from oil-consuming countries. The reason for this is that the global oil royalty would increase oil prices, but revenue would accrue where oil is produced and not where petrol and refined products are consumed. Oil-consuming countries might, therefore, prefer public policies to achieve the Paris Agreement, such as a global carbon dioxide emissions tax, where revenue accrues in the country where petrol and refined products are consumed.

There would be advantages to oil-producing countries as a whole to implementing the global oil royalty compared to other public policies for achieving the Paris Agreement. The global oil royalty would reduce oil production, but it would also increase oil prices and government revenue. Oil-producing countries would certainly be likely to favour a global oil royalty as a public policy compared to a global carbon dioxide emissions tax, as while both public policies would reduce oil consumption, the global oil royalty results in increased revenue for oil producers, while a global carbon dioxide emissions tax results in increased revenue for oil consuming countries.

There would, however, likely be a subset of oil-producing countries that have particularly high costs of production and many marginal oil fields. The decline in oil production due to the global oil royalty would be disproportionally borne by such countries, and thus they might resist such a policy.

It could also be argued that there are inherent difficulties in implementing a global oil royalty across all (or many) oil-producing countries. While this is a valid criticism, it applies to many public policies to reduce climate change and not just the specific policy of a global oil royalty. For example, the effectiveness of a carbon dioxide emissions tax would be very limited if it was only implemented in a single country with a small proportion of global emissions. Such a tax would be much more effective if it was implemented in every country.

An oil royalty might also have to be implemented by fewer countries than a carbon dioxide emissions tax to be effective. Oil production can only occur where oil reserves exist; in contrast, carbon dioxide emissions can occur in any country. So, there is an absolute limit to the total number of countries to which a global oil royalty would have to be applied, while no such limit exists with regards to a carbon dioxide emissions tax.[49] Overall, while a global oil royalty might be difficult to implement, concerted global action is required to combat climate change, and there are reasons to consider that a global oil royalty would have to be implemented in fewer countries than other public policies to effectively combat climate change.

Conclusion

To conclude, the world has committed to limiting climate change to 2 degrees Celsius. However, based on the current and expected future production of fossil fuels, this goal will not be achieved. The principal reason for this is that fossil fuels are a cheap way of generating electricity and fueling vehicles. Economic instruments like royalties and taxes are an effective way of increasing the price of fossil fuels and reducing their supply and consumption. A global oil royalty would be a relatively simple and easily administered way of increasing the price of oil and reducing its supply and production. Preliminary, illustrative calculations suggest that a global oil royalty rate of 46 per cent would reduce oil production to a level consistent with limiting climate change to 2 degrees Celsius.

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Annex 1: Global oil royalty compared to other economic instruments

Economic instrument	Disadvantages compared to a global oil royalty	Advantages compared to a global oil royalty
Global carbon dioxide emissions tax A tax levied on the actual amount of carbon dioxide emissions.	• Requires that the tax authorities can accurately measure and audit carbon emissions made by companies and households. This can be difficult and expensive. • Ideally, the tax is collected from all emitters. As there are many households and companies that emit carbon dioxide, this makes the tax relatively complicated and expensive to administer. • The tax can be levied on large emitters only. However, this reduces the economic efficiency of the tax. • Revenue is collected by the country where emissions occur. If the tax is levied in all countries, then the distribution of revenues between countries would vary according to their level of pollution. In contrast, under a global oil royalty revenue varies with production. To the extent that oil consumption is more positively strongly associated with per capita GDP than oil production, the oil consumption tax will be less equitable. • If implemented by a single country (as opposed to all countries), the tax would reduce the international competiveness of domestic companies that emit carbon dioxide.	• Potentially more economically efficient, as the tax is levied on emissions. In contrast, a global oil royalty is levied on each barrel of oil produced. A global oil royalty is therefore increasing the costs of production and reducing the consumption of refined oil products, such as lubricants, that do not result in carbon dioxide emissions. However, in reality, the vast majority of oil is used to create refined oil products such as petrol, which do result in carbon dioxide emissions.
Carbon content excise tax on refined products that emit carbon when consumed (e.g. petrol) A tax levied on domestic producers and importers of refined oil products, with the tax rate positively varying with the likely carbon emissions of the refined oil product.	• Revenue will accrue in those countries where consumption takes place and the distribution of revenue is therefore potentially less equitable than from a global oil royalty. • If implemented by a single country (as opposed to all countries), the tax will reduce the international competiveness of domestic companies that consume refined oil products. • If implemented at different rates by different countries, this tax would encourage smuggling from low-tax jurisdictions. • Complicates tax administration, as it implies monitoring of both importers and domestic refineries. • The tax rate should account for not only the carbon emissions of the refined oil product, but also the emissions associated with its production. This complicates the administration of the tax, as it requires that the tax authorities have detailed information on the carbon content of production and transportation of refined oil products that have been imported.[50]	• Potentially more economically efficient, as the tax rate varies according to likely emitted carbon content. Thus, the tax rate would be lower or zero for lubricants. However, in reality this economic benefit is likely to be small or marginal, as very little oil is refined into products such as lubricants that don't emit carbon dioxide when used.

Economic instrument	Disadvantages compared to a global oil royalty	Advantages compared to a global oil royalty
Domestic oil import and production tax A tax levied on all oil consumed in a country. This involves taxing domestic production of oil that is not exported and imports of oil that are for consumption in the country.	• If the tax is not implemented at the same rate by all countries, then this tax reduces the international competiveness of domestic companies that use oil in that country. • Complicates tax administration, as it requires the monitoring of whether produced oil is for export or the domestic market. • If the tax is not implemented at the same rate by all countries, then it encourages the smuggling of oil from low-tax jurisdictions. • Revenue will accrue in those countries where oil consumption takes place and the distribution of revenue is therefore potentially less equitable than for a global oil royalty.	
Cap and trade Licenses setting an absolute limit for emissions. Within this overall limit, companies buy and sell emission allowances as needed.	• It is not practical for all emitters to be covered by a cap and trade scheme. Households and small commercial emitters are therefore normally excluded, which reduces the economic efficiency of such schemes. • Requires monitoring and verification of actual emissions compared to licenses for each emitter. This can be expensive. • If allowances are initially distributed for free, then revenue from selling licenses accrues to companies that can reduce historically high emissions at a low cost.	

Notes

1 The definition of oil used in this paper includes crude oil, condensate and natural gas liquids, but does not include other liquids such as biofuels, coal-to-liquids fuel and/or gas to liquids.

2 United Nations Framework Convention on Climate Change (2015).

3 Intergovernmental Panel on Climate Change (IPCC) (2013).

4 Clarke et al. (2014).

5 Friedlingstein et al. (2014).

6 IPCC (2013); Clarke et al. (2014).

7 Rogelj et al. (2016).

8 United Nations Framework Convention on Climate Change (2015).

9 McGlade and Ekins (2015); van der Ploeg and Rezai (2017).

10 McGlade and Ekins (2015).

11 Carbon Tracker & The Grantham Research Institute (2013)

12 This is also in the absence of cost effective negative emissions technologies.

13 In this Paper, unless otherwise stated, reference to the Paris Agreement's goal should be taken to refer to the goal of limiting the increase in global average temperatures to well below 2 degrees Celsius of pre-industrial levels.

14 Gt stands for Gigatonnes in the graph

15 The data on Carbon Dioxide emissions in current reserves is taken from McGlade and Ekins (2015). The data on the Carbon Dioxide budget consistent with a 50% probability of limiting the rise in global temperatures to 2 degrees Celsius or less is taken from Carbon Tracker & The Grantham Research institute (2013).

16 Carbon Tracker & The Grantham Research Institute (2013).

17 In this paper, unless otherwise stated, reference to the Paris Agreement's goals should be taken to refer to the goal of limiting the increase in global average temperatures to well below 2 degrees Celsius of pre-industrial levels and the goal of limiting the increase to 1.5 degrees Celsius above pre-industrial levels.

18 The data on forecasted oil production is taken from the reference case for oil and other liquids production from the EIA (2016). This paper adjusts the EIA (2016) forecast downwards to account for the fact that the EIA's forecast includes other liquids (such as biofuels, coal-to-liquids fuel and gas to liquids) that are not included in this paper's definition of oil.
The data on oil production that is consistent with global temperatures increasing by 2 degrees Celsius is taken from McGlade and Ekins (2015), who use the TIAM-UCL model under a 2oC scenario with carbon capture and storage.

19 Covert et al. (2016).

20 See Department of Business, Energy & Industrial Strategy (2016) for more details on how the levelised cost of energy (LCOE) was calculated.

21 This data is taken from Department of Business, Energy & Industrial Strategy (2016).

22 Joskoaw (2011).

23 See: https://www.iea.org/about/faqs/naturalgas/; https://www.eia.gov/coal.

24 IEA (2016).

25 This graph is based on an economic model constructed by Covert et al. (2016).

26 Brent Crude price taken from Bloomberg, available at: https://www.bloomberg.com/energy [accessed 03 April 2017].

27 EIA (2017), available at: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=1-AEO2017&region=0-0&cases=ref2017~ref_no_cpp&start=2015&end=2050&f=A&linechart=ref2017-d120816a.3-1-AEO2017~ref_no_cpp-d120816a.3-1-AEO2017&sourcekey=0 [accessed 11 June 2017].

28 Covert et al. (2016); Newbery and Strbac (2016); Simmons et al. (2015).

29 Assumptions are taken from Daniel et al. (2016) and internal Oceans and Natural Resources Advisory Division models.

30 This is conservative in that it is well below the EIA's forecast of nominal long-term oil prices.

31 For ease of reading, this paper has used the term 'profits', although strictly speaking the term 'net cash flows' would be more accurate.

32 This is the average 'State Take' across a range of fields, as calculated in Oceans and Natural Resources Advisory Division benchmarking reports.

33 Rogelj et al. (2016).

34 Data taken from Rystad Energy (2016), available at: https://www.rystadenergy.com/NewsEvents/PressReleases/global-liquids-supply-cost-curve-shale-and-oil-sands [accessed 11 June 2017].

35 For details of this review, see: Caldara et al. (2016).

36 More specifically: a) the ordinary least squares estimation technique was used; b) a linear functional form was used; c) the dependent variable was oil supply in MMbbl/d; d) the independent variable was the oil price; e) the adjusted R-Squared was 0.96 and the intercept, coefficient and overall regression (f-test) were all significant at the 1% level; f) a visual review of the predicted values and residuals demonstrated an absence of heteroscedasticity and this was confirmed by the Breusch–Pagan test; and g) the data used was that shown in graph 2.

37 More specifically, the oil supply of 95.60 MMbbl/d is based on forecasted oil production from the EIA. The price that is consistent with this quantity of supply, given the slopes of the demand and supply curves, was then calculated.

38 McGlade and Ekins (2015).

39 See, for example, Baunsgaard (2001).

40 Ibid.

41 See, for example, Baunsgaard (2001) and Nakhle (2008).

42 Eisenack et al. (2012).

43 Lazarus et al. (2015).

44 More specifically, this paper calculated the correlation coefficient between GDP per capita and carbon dioxide emissions per capita as being 0.53 across countries, while the correlation coefficient between oil production and GDP per capita was 0.33 across countries.

45 For such countries, it is even possible that the decline in government revenues from existing taxes on oil production would outweigh the revenue from the global oil royalty.

46 See, for example, Baunsgaard (2001) and Nakhle (2008) for evidence that a royalty can reduce oil production.

47 This assumption is based on detailed modelling by Rogelj et al. (2016).

48 This could include research on the demand elasticities of other forms of carbon fuel, such as coal. The oil supply curve used in this paper could also be re-estimated using more detailed data on individual petroleum fields.

49 Other than the total number of countries in the world.

50 Pearson and Smith (1993).