Supply-side climate policy in Norway

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Abstract

It can be seen as a paradox that expensive measures are taken to reduce demand for fossil fuels in Norway, while an important share of Norwegian national income comes from export of fossil fuels. This paper reviews relevant parts of the economics literature and discusses the effects of a shift in Norwegian climate policy towards reduced oil extraction. Both the theoretical and the empirical literature suggest that the optimal combination of supply- and demand-side policy in Norway would include reduced extraction as an important component. In the short run, the optimal combination of supply- and demand-side climate policy is determined by the costs of domestic emission reductions on either side together with the effect on global emissions of domestic reductions. In the long run, the effect of the different policies on technological development, international institutions and political processes are among the factors that should also be taken into account.

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1 Introduction

It can be seen as a paradox that relatively expensive measures are taken to reduce demand for fossil fuels in Norway, while at the same time, an important share of Norwegian national income is from export of oil and natural gas. This lack of coherence between demand-side climate policy and the role as an international supplier of fossil fuels has gained attention also internationally, see for example The Economist (2017) and New York Times (2017).

In this paper, I review the most relevant parts of the literature on supply-side climate policy, in order to assess whether a reduction in oil extraction in Norway would constitute effective and cost-efficient policy to reduce global emissions of greenhouse gases.

In order to determine the optimal combination of supply- and demand-side climate policy for a small country like Norway, the cost of reducing domestic emissions on either side, together with the respective effects on global emissions, must be determined. The literature reviewed in this paper suggests that the current Norwegian policy puts too little weight on supply-side climate policy, compared to an optimal combination.

In a global agreement on greenhouse gas emission reductions, the distinction between demand- and supply-side climate policy would not be important. A reduction in supply would translate into the same reduction in demand and vice versa. International cooperation has, however, proven difficult to achieve. The Paris agreement from 2015 can be considered the end of the long-lasting attempt to achieve a global top-down agreement. Participation in the Paris agreement is based on each country independently determining their targets for emission reduction.

When a single country shall determine its climate policy, it must take into account potential reactions abroad to its domestic policy. Domestic policy might affect prices, technological development or even political pressure internationally, and hence the global effect on emissions might not be the same as the domestic effect.

Markusen (1975) showed how emission reductions in one country affects emission levels in other countries through changing international prices. Policy instruments – such as a carbon tax – that reduces emissions through lowering demand for fossil energy will decrease international fossil energy prices. The price decrease results in an increase in demand and consumption abroad, reducing the initial effect of the policy. Similarly, policy instruments that reduce the supply of fossil energy – for example a tax on extraction – will increase the price resulting in increased supply abroad. This counter-reaction is referred to as *carbon leakage*. See also Rauscher (1997).

The issue of carbon leakage has given rise to a literature in economics emphasizing the need for policies limiting both demand and supply when there is not full cooperation on climate policies internationally. Hoel (1994) shows that a combination of a tax on production and a tax on consumption is optimal (see also Bohm (1993)). Fæhn et al. (2017) consider specifically the Norwegian setting, and confirms this finding. Harstad (2012) further develops the arguments made by Hoel (1994) and shows that supply-side carbon leakage can be avoided completely if fossil energy resources can be bought internationally and conserved.

Despite these findings, climate policy has mainly been focused on the demand side, both in Norway and internationally, with initiatives aimed at reduced deforestation as an important exception.

The paper is written as follows. In Section 2.1, I discuss the theoretical literature on the optimal combination of supply- and demand-side climate policy. I then move on to the specific Norwegian case in Section 2.2. In Section 2.3, I discuss how supply-side policy might affect technological development, while I discuss some aspects of optimal supply-side policy in Section 2.4. Finally, in Section 2.5, I briefly discuss distributional aspects of supply-side policy, and I conclude in Section 3.

2 Norwegian oil extraction and global emissions

The decision to open up new oil fields in Norway is made by the government, while the decision of how much to extract from fields that are already opened up is generally made by private firms. A political process determines the decision of whether to open new fields for exploration. In this process, all costs and benefits, including externalities, should ideally determine the outcome. When an area is open for exploration, private firms are granted licenses, and they weigh the cost of exploration against expected future profits from possible findings. When oil or gas is discovered, the extraction costs together with the resource price determine the level of extraction.

A stylized version of the decision of how much to explore and extract is illustrated in Figure 1. The horizontal curve depicts the expected price, while the three remaining curves depict three different marginal extraction cost curves. The solid line is the private marginal cost of extraction – the only thing that will be taken into account by a profit-maximizing firm if there is no regulation or taxation. The extraction level resulting from the decision taken by a firm in this case is given by $x^{private}$.

In the first best, environmental costs are incorporated in the extraction decision, resulting in lower extraction. The curve denoted *Low env. costs* is the social marginal cost curve

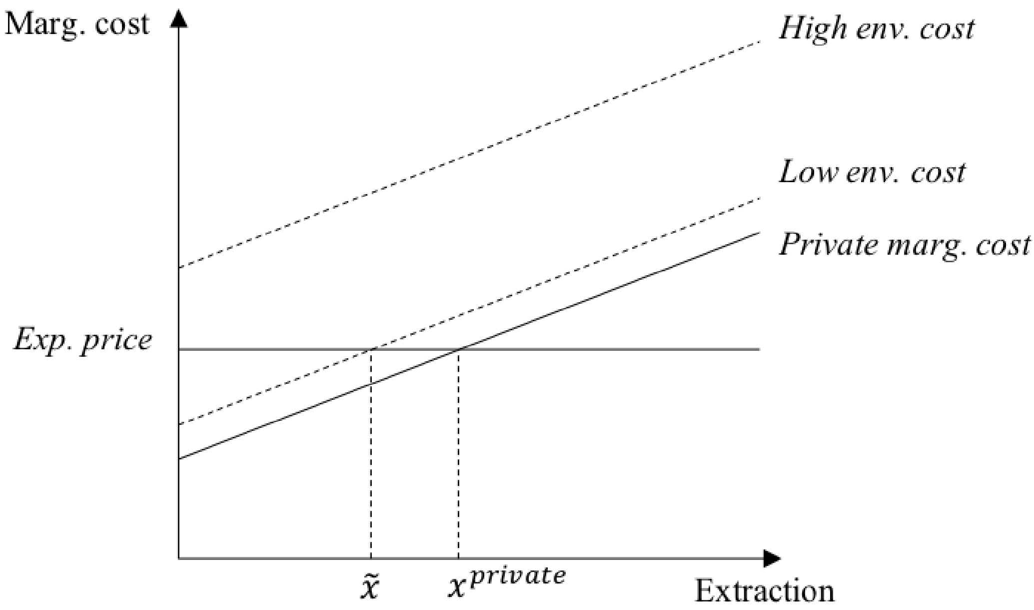

Figure 1: Optimal extraction with environmental externality

given that there are environmental costs from extraction, but these are relatively low. This environmental cost implies that the socially optimal extraction level, $\tilde{x}$, is lower than $x^{private}$. Finally, the curve denoted *High env. costs* represents the marginal extraction costs in a case where the environmental costs resulting from extraction are high. This cost curve exemplifies a situation where there should be no extraction from this field.

There are potentially important local environmental consequences of oil extraction in Norway, mostly connected to the potential for large oil spills and the effect that such spills could have on fish stocks, birds and biodiversity in general. For certain fields, with the areas of Lofoten, Vesterålen and Senja as the most prominent examples, it is clear that environmental-protection concerns have been consequential in postponing exploration, perhaps hindering exploration altogether.

The question that I will attempt to answer in this paper is whether the greenhouse gas emissions that are caused globally by extraction of Norwegian oil imply that some reserves that would otherwise have been exploited should not be. [1]

[1]This paper will focus on supply-side policy limiting *oil* extraction. There is also substantial extraction of natural gas in Norway, which is left out of this analysis. There are two reasons for this choice. First, Norwegian gas exports are mainly used in the European market, and thus covered by the EU emission trading system (ETS). This means that a reduction in gas exports to the EU can generally not be expected to affect global emissions. Second, the emissions from combustion of gas are relatively low compared to emissions from the main competitor, coal.

As is clear from the illustration in Figure 1, the answer to this question crucially depends on how the costs associated with an increase in the atmospheric stock of greenhouse gases are evaluated. I will not answer that question in this paper, but I briefly discuss this side of the equation in Section 2.4.

The main focus of this paper will be whether – or to what extent – reductions in Norwegian oil extraction will reduce global emissions, and how the costs of these emission reductions compare to the costs of measures taken on the demand side. I will discuss several issues that are important when supply-side policies and demand-side policies are compared. I will not focus on the exact choice of policy instrument.[2]

2.1 Supply-side versus demand-side policy in theory

In a global climate agreement, the difference between supply- and demand-side policies would not be relevant. The same emission reduction would be obtained either by reducing global extraction of fossil fuels, or by lowering consumption.

As long as there is no such global agreement, there can be important differences between the two approaches. In this situation, each country considering unilateral emission reductions must take into account potential changes in fossil fuel consumption outside its own boarders when the global effect of domestic policies is calculated. There is *carbon leakage* when emissions abroad increase as a consequence of domestic emission reductions.

Supply-side carbon leakage – leakage resulting from reduced domestic extraction of fossil fuels – is illustrated in Figure 2. A negative shift in supply in one country, shifting the global supply curve will be followed by increased supply in other countries, as long as the supply curve is not vertical. This happens because the domestic reduction in supply results in a price increase. The global equilibrium reduction in oil consumption will thus be smaller than the initial shift in supply. In the example in the figure, the initial negative shift in supply is from x^0 to $\hat{x}$, while the net reduction in the equilibrium quantity consumed is from x^0 to x^1.

The key determinants of the importance of carbon leakage are the slopes of the demand and supply curves. The steeper the global supply curve, the smaller the supply-side leakage illustrated in Figure 2. A very steep supply curve means that there are not many fields globally with marginal production costs close to the marginal field in the current

[2]A tax on extraction would be an effective instrument to internalize the externality caused by the effect of greenhouse gas emissions on the climate. A tax would affect the decision of exploration as well as the decision of extraction. For further discussion of the choice of instrument in supply-side policy, see Fæhn et al. (2017) and Fæhn et al. (2018).

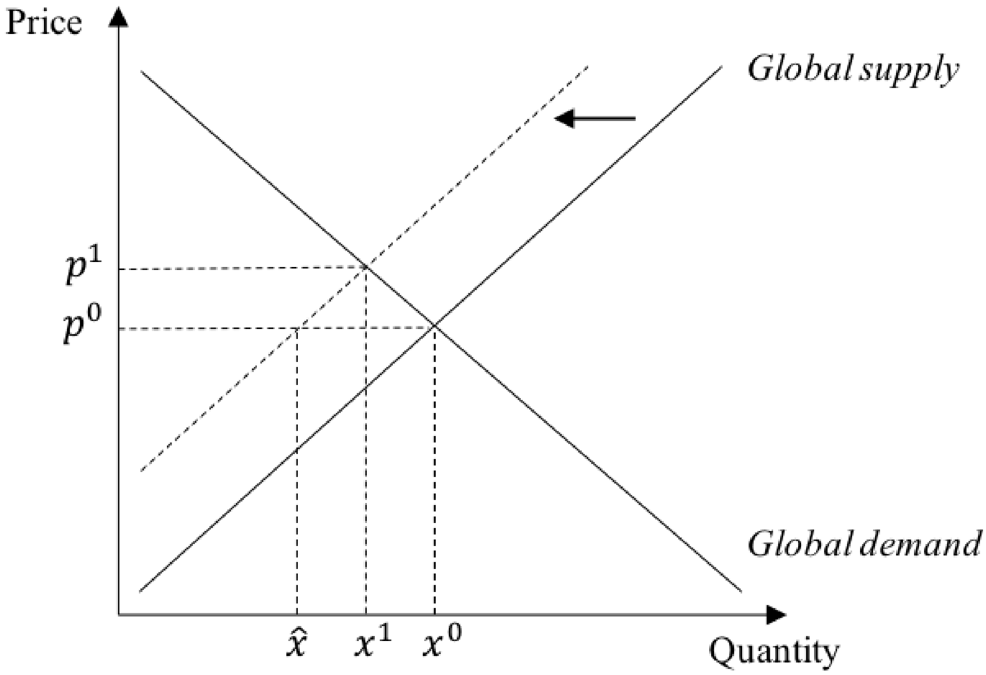

Figure 2: Supply-side carbon leakage.

equilibrium. Very elastic supply means that a small price increase triggers a large increase in global supply. If this is the case, the supply-side carbon leakage will be large. On the other hand, a steep demand curve means large supply-side leakage because a shift in supply affects the price strongly. On the other hand, an elastic demand curve means that a negative supply shift results in a very small price increase and thus weak incentives for other producers to increase supply, meaning low leakage.

One can also get carbon leakage through other channels. Price changes for factors of production used in the oil industry could trigger increased extraction abroad because of lower domestic extraction, and similar mechanisms are in play on the demand side, as one example. Furthermore, firms that are subject to strict climate policy can relocate to other countries.

The elasticity of global supply and demand for fossil fuels – determining the carbon leakage on both the demand side and the supply side – is crucial for the optimal combination of demand-side versus supply-side climate policy. . Hoel (1994) develops a theoretical framework and shows that there are three elements determining this optimal combination.

First, it is the cost of reducing demand and supply, respectively. However, it can be argued that the value of fossil fuel consumption and fossil fuel extraction are the same on the margin – it is reflected in the fossil fuel price. Consequently, the two other elements determine the relative cost of climate polices on the demand side and the supply side. For reductions in supply or demand that are not marginal, this is clearly no longer the case.

The second element in Hoel's framework is whether the country in question is a net importer or a net exporter of fossil fuels. For a net importer, the price decrease that will follow from demand-side policy is beneficial, while the price increase following supply-side policy is costly. In contrast to this, for a net exporter the price change from supply-side policy is beneficial while the effect of demand-side policy is costly. In this paper, I will not focus on the importance of the price changes generated from the different types of policy. However, it is worth keeping in mind that to the extent that these price changes are important, the channel supports supply-side policy over demand-side policy for a net exporter such as Norway.

The third element in the trade-off between supply- and demand-side policies in Hoel's framework is the size of the carbon leakage on either side. Hoel (1994) shows exactly how the carbon leakage is determined. As already discussed, it depends on the elasticity of supply and demand. If the global supply is relatively elastic compared to demand, the supply-side leakage will be more severe than the demand-side leakage. This will push the optimal combination of supply- and demand-side policy towards more reduction on the demand-side.

The size of the carbon leakage for supply-side policy versus demand-side policy is an empirical issue. This issue is investagated by Fæhn et al. (2017) in the Norwegian setting.

2.2 Supply-side versus demand-side policy in Norway

Fæhn et al. (2017) investigate the size of the carbon leakage following both on the supply- and demand-side policy in Norway. They also investigate the costs of reduced extraction and compare these to the costs of reduced demand for fossil fuels. They can thus compare the costs of reducing global emissions by the same amount using demand- and supply-side policy, respectively.

The theoretical framework in Fæhn et al. (2017) follows the lines of Hoel (1994). The authors consider the markets for oil, gas and coal. Consumers in all countries are assumed to be price takers, and demand is decreasing in the price in all three markets. In their main specification of the model, thy consider OPEC (Organization of the Petroleum Exporting Countries) a strategic player maximizing profits, while the remaining suppliers in the oil market and the suppliers in the other two markets act competitively.

They let a single country consider supply-side versus demand-side climate policy, taking the global climate policy as given. They assume that this country's government chooses policy to maximize welfare – consumer and producer surplus – given a target for global emission reductions that the country wants to meet. The target can be met by reducing demand or supply in any of the three markets, or by combining the different policies.

The conclusions from the theoretical model are in line with those of Hoel (1994). The authors show that the share of the emission reduction target that should be made by reductions on the supply-side depends three main factors. Firstly, the abatement cost curve for supply- and demand-side reductions, respectively. Secondly, the net exports (or imports) of the country in question in combination with the price change following changes in supply and demand. However, this factor is disregarded in the numerical analysis because the effect is considered very small. Finally, the optimal share of supply-side policy is determined by the relative carbon leakage from demand- and supply-side reductions.

In the numerical analysis, the authors consider the specific Norwegian case, and the purpose is to determine the abatement cost curves and the size of the carbon leakage, to be able to deduce the optimal combination of supply- and demand-side climate policy. On the demand side, reduction in consumption of all fossil fuels is considered, while on the supply side the authors focus on oil extraction (see footnote in Section 2 of this paper).

The abatement cost curve for demand-side policy is given by the marginal consumer surplus from fossil fuel consumption. In Fæhn et al. (2017), this curve is calculated by the use of a computable general equilibrium (CGE) model for Norway.[3] The authors consider implementation of uniform emission pricing across all sectors that are not covered by the European emission trading system (EU ETS), taking the already implemented Norwegian climate policy instruments as given. To provide a marginal cost curve for demand-side emission reductions, they set the price on emissions at different levels.

They estimate the following marginal abatement cost curve, where A_D denotes the domestic demand-side emission reduction, measured in million tons of CO_2: $MC_D = -2.5A_D^2 + 86.6A_D + 23.4$.[4].

On the supply-side, the abatement cost curve is given by the marginal producer surplus – the oil price minus the marginal extraction cost.[5] This curve is estimated by using data on extraction costs for nine Norwegian fields over the period of 2009 to 2011. The authors have considered all fields in production over the time period and identified the chosen nine

[3]The model that is used is the MSG-TECH, see Fæhn and Isaksen (2016) for description.

[4]Equation (22) in Fæhn et al. (2017)

[5]Fæhn et al. (2017) consider only fields that are already open, and the costs of exploration and opening up of new fields are therefore not included. This suggests that the abatement cost curve found in the paper is higher than the actual long-term abatement costs on the supply side.

fields as marginal in terms of profits. All the nine marginal fields were in or close to the final stages of extraction, where the profits are typically relatively low. For the nine selected fields, they use data from Statistics Norway on the produced volumes and the costs that would have been avoided if production had been terminated. The price used is the average oil world market price from 2009 to 2011, USD 84.5.[6]

They estimate the following marginal abatement cost curve, where A_S, measured in million tons of CO_2, denotes the domestic supply-side emission reductions: $MC_S = -0.7A_S^2 + 19.6A_S - 6.1$.[7] The authors argue that there is reason to believe that this is a relatively high estimate of the marginal abatement cost curve.

The marginal costs curves are both illustrated in Figure 3. The demand-side abatement cost is substantially higher, for all domestic abatement levels.

Next, the paper considers the effect on global emissions of cuts in consumption or in oil extraction. Here, they construct a model of the global fossil fuel market, and calibrate it based on data from 2011. The main drivers of the results regarding the size of the carbon leakage are the elasticities of supply and demand for each fuel. In the main simulation, the price elasticity of oil demand is assumed to be -0.5, while the cross-price elasticities to gas and coal are assumed to be 0.08. The supply elasticity for non-OPEC suppliers is set at 0.5. As OPEC optimizes profits, the central parameter is the marginal production cost, which is set at 45 % of the oil price.

When the global emission reductions following Norwegian cuts in supply or demand are calculated, emissions from extraction are also included. The extraction emission intensities, measured in tons of CO_2 equivalents per 1,000 toe hydrocarbon produced, are set at 90 for Norway, 76 for OPEC and 300 for other non-OPEC suppliers.

Table 1 summarizes the findings on carbon leakage of Fæhn et al. (2017), both for the case where OPEC is assumed to be a dominant producers and the case where OPEC is assumed to act competitively. The first and third columns consider the effect of supply-side reduction in Norway, whereas the second and forth column show the results for demand-side reduction. The *Net emission reduction* gives the global emission reduction following a one unit reduction of CO_2 emissions in Norway. When OPEC is assumed a dominant producer it is 0.353 for a supply-side reduction, while it is almost the double, 0.676, for a demand-side reduction.

To summarize, Fæhn et al. (2017) find that the carbon leakage is substantially higher on the supply side than on the demand side. However, they also show that the marginal

[6] Today's somewhat lower oil price would give a lower marginal abatement cost curve.

[7] Equation (23) in Fæhn et al. (2017). Note that the first units of emission reduction are actually profitable. There is no explanation for this finding provided by Fæhn et al. (2017).

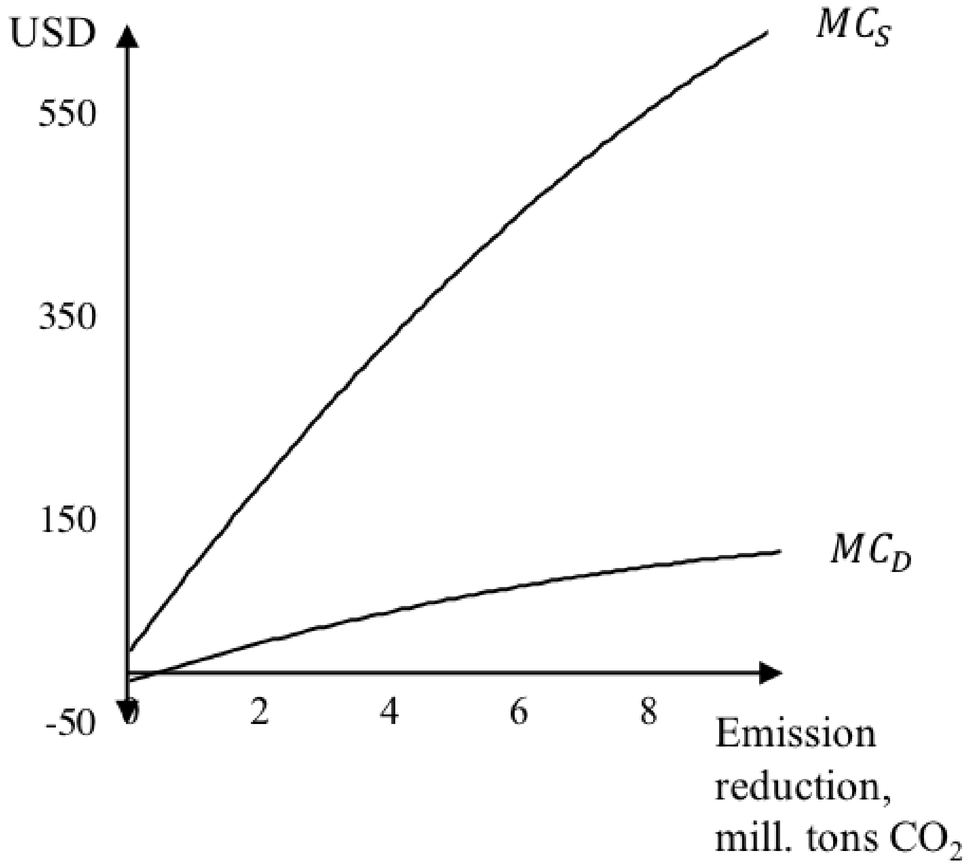

Figure 3: Abatement cost curves calculated by Fæhn et al. (2017).

abatement cost is lower on the supply side than on the demand side. In sum, they show that reduction in oil extraction constitutes an important share in the optimal combination of supply- and demand-side policy in Norway. In the paper, this result is summarized by the following example: Say Norway were to reduce emissions globally by 5 Mt of CO_2 by 2020, corresponding to about 10 % of Norway's present domestic greenhouse gas emissions. Then, the cost-effective combination of supply- and demand-side emission reduction would be that approximately 2/3 of the reduction should be done by lower oil extraction, while the remaining 1/3 should be made on the demand side. In this example, the total abatement cost would more than double if the whole abatement load were to be made on the demand side.

These results are striking, even though there is clearly considerable uncertainty regarding the size of all the effects found in the paper, and hence regarding the overall conclusion. The analysis in the paper suggests that even with quite conservative assumptions regarding the effects of unilateral reduction in extraction on global emissions, supply-side policy plays

	OPEC: Dominant producer		OPEC: Competitive producer	
	Supply side	Demand side	Supply side	Demand side
Gross emission reduction	1	1	1	1
Oil market leakage	-0.546	-0.454	-0.507	-0.493
Coal/gas market leakage	-0.088	0.088	-0.096	0.096
Domestic extraction	0.028	0	0.028	0
Foreign extraction	-0.041	0.041	-0.043	0.043
Net emission reduction	0.353	0.676	0.383	0.646

Table 1: Emission reduction following domestic cuts. From Fæhn et al. (2017)

a significant role in a cost-effective Norwegian climate policy.

There are also other papers looking at the effect on global emissions of unilateral supply-side policies. Metcalf (2016) and Erickson and Lazarus (2018) consider reduction in the US oil production, and their findings are in line with those of Fæhn et al. (2017).

There are papers suggesting that the assumptions regarding the behavior of OPEC in the oil market are more important than what is suggested by Fæhn et al. (2017). The main conclusion in Fæhn et al. (2017) does not change depending on whether they consider OPEC to behave competitively or not, as is illustrated in Table **??** above. This is partly contrasted by the findings of Böhringer, Rosendahl and Schneider (2013) and Bohringer, Rosendahl and Schneider (2018).

These papers both consider the effect on carbon leakage from demand side policies, taking into account the strategic behavior of OPEC in the oil market. They show that OPEC's response to EU's climate policy can be large, and hence including these responses can be important for the results. These papers show that if OPEC believes the EU is pursuing a quantity target, they will counteract a European carbon price by reducing production. By doing this, the producers shift the rents from taxation from the EU to themselves. The authors show that the response might be sufficiently strong for the carbon leakage to be negative. In Bohringer, Rosendahl and Schneider (2018), the authors show that these results do not necessarily pull through when the size of the group of countries pursuing the climate policy changes. Moreover, they demonstrate that the results depend on the composition of these countries, and on the share of emission cuts that are done by reducing use of coal versus oil.

Although these results suggest that taking the strategic behavior of OPEC into account is important, the findings rest on specific assumptions regarding the beliefs that OPEC have about other countries' policies. Moreover, the findings do not suggest that OPEC will counteract supply-side policies in the same way. supply-side policies raise the price, and although that can give OPEC a somewhat stronger incentive to reduce production, it does not provide the same incentive to change the volume in order to seize rents.

The model of Fæhn et al. (2017) is static, and the results might be different in a dynamic framework. Hagem and Storrøsten (fourthcoming) consider carbon leakage in a dynamic framework. They show that when intertemporal carbon leakage is taken into account, the case for supply-side policy is strengthened. The reason is that commitment to future reductions in extraction by one country provides incentives for producers in other countries to delay extraction to increase overall profits. This is the opposite of the green paradox that can result from demand-side policies. Hoel (2013) also argues that supply-side policies that reduce extraction from high-cost reserves will not create a green paradox. There is a large literature in economics on the «green paradox», which is the situation that might arise when policies that are aimed at reducing emissions result in earlier – and potentially higher – extraction. The term was originally used by Sinn (2008), who argued that an increase in the carbon tax over time gives owners of a non-renewable fossil resource an incentive to increase extraction.

Finally, Fæhn et al. (2017) does not consider potential effects of demand- and supply policy on the technological development. I will look closer into this in the next section of this paper.

2.3 Can supply-side policy change the technological development?

In this section, I will discuss some important insights from the economics literature that are relevant for understanding how a shift from demand-side to supply-side climate policy can potentially affect technological development over time. If the development of either renewable or fossil technologies are affected by changes in the global demand or supply of fossil fuels, the long-run consequences of demand- and supply-side climate policy can be different from the short-run consequences discussed so far in this paper. *Carbon lock-in* is a term referring to the possibility that technological, institutional and economic factors prevent shifts from carbon-intensive to low-carbon systems. If production methods require large up-front investments, for example in infrastructure, but are subsequently very cheap to use in production, it can create such a lock-in situation. See for example Erickson et al. (2015) or Unruh (2000) for discussion of carbon lock-in.

A potential contribution to carbon lock-in could be that there are learning by doing in exploration for and extraction of oil. The concept of learning by doing has been used and discussed in economics for many decades, see Arrow (1962) and Lucas (1988) for important early contributions. If knowledge and technology is developing more rapidly in the fossil energy sector the larger this sector is, this could over time make the shift to renewable energy more costly the higher the global extraction.

The relatively low emissions from oil extraction in Norway is likely due to the high emission prices facing the extracting firms. It might also reflect learning by doing processes in low-emission technologies used in extraction. When looking into the emission intensities in extraction for different oil producing countries, Fæhn et al. (2017) find that the emission intensity in Norway is below a third a third of the average for other non-OPEC producers. Similar conclusions are drawn by Masnadi et al. (2018). They compare emissions from extraction, transportation and refining of crude oil in different producer countries. According to their estimates, Norway is in the bottom six countries when measuring the volume-weighted average crude oil upstream greenhouse-gas intensities, with an intensity below one third of the countries at the top of the list (Algeria and Venezuela). See also Gavenas, Rosendahl and Skjerpen (2015) for a detailed account of emissions resulting from extraction of oil and gas in Norwegian fields. Over the years, it is possible that learning by doing has contributed to a decline in costs for the firms face of keeping the emission intensities low.

However, it is not obvious whether more rapid technological development in sectors with high fossil energy use leads to more or less dependence of fossil fuels, indenpendently of whether this development is due to learning by doing or has other causes. On the one hand, better technologies for using fossil fuels may result in fossil energy being used for new purposes, in new sectors of the economy etc., because it becomes a more competitive factor of production. Higher fossil fuel prices resulting from this process will increase global extraction, and the technological development results in higher emissions. On the other hand, the result of the technological development may as well be that fossil fuels become more redundant, prices fall and extraction and emission go down, due to increased energy efficiency.

One important element in understanding whether technological development within the fossil fuel sector leads to increased or decreased demand for fossil fuels is presented in Acemoglu (2002).

In his paper on directed technical change from 2002, Acemoglu shows that the key to understanding whether technological development within a given sector leads to increased or decreased demand for the factors of productions that are used in this sector is the potential for these factors to replace other factors in production. This is relatively intuitive: If a factor in production can be used more efficiently, demand for this factor will drop if the excess supply cannot easily be used in alternative ways. On the contrary, more efficient technologies can lead to a large increase in the use of this factor in the economy if the substitutability between this factor and others is high.

Acemoglu (2002) also considers the determinants of directed technical change. In a stylized model with two factors of production, he shows that increased access to one factor of production can lead to more rapid technological development for technologies used in combination with this factor, so-called complementary technology. But this is only the case if there is sufficient substitutability between the two factors. In the case where the two factors only to a small extent can replace each other in the production process, increased access to one factor will direct the technological development towards the other factor.

Acemoglu (2002) shows how the level of substitutability between the two factors of production determine the net effect of increased access to one factor of production on the direction of technological development. Increased access to one factor of production will – in equilibrium – increase the use of this factor. When a factor is more widely used, the expected profits from developing new complementary technologies for this factor will, all else equal, increase. However, the equilibrium price of the factor will decrease, which, again with all else equal, decreases the expected profits from developing complementary technology because it decreases the willingness to pay for more efficient use of the factor in production. If the two factors of production are close substitutes in the economy, the first effect will dominate, because only a small price decrease is necessary for the economy to increase the use of the factor that is now less scarce. In this case, increased access to one factor leads to more rapid development of its complimentary technologies. On the other hand, if the two factors cannot replace each other easily, the price decrease will be large, and the second effect will dominate. Increased access of one factor will in this situation lead to relatively more rapid development of the complimentary technologies for the other factor.

To summarize, one important finding in Acemoglu (2002) is that the technological development will over time contribute to lower demand – and thus a lower equilibrium price – for a factor that at some point becomes more scarce in the economy. If the two factors are close substitutes, this is due to slower technological development for technologies complimentary to the more scarce factor. In this case, slower technological development results in lower demand. If the two factors cannot easily replace each other, the result is due to more rapid technological development for the more scarce factor, which in this case is what leads to lower demand.

The short-run effect of lower access to one factor of production in the economy, say fossil fuels, is a price increase, but the long-run effect might not necessarily be the same. The short-run price increase is the cause of carbon leakage from supply-side policy, as discussed in the preceding sections. Acemoglu (2002)'s findings suggest, however, that this price increase will be counteracted over time as the direction of the technological development will go in favor of a lower price. Acemoglu (2002) even indicates that if the factors of production in the economy are sufficiently close substitutes, the long-run effect on the price of increased access to one factor might be positive.

Acemoglu (2002)'s results suggest that the long-run effect of unilateral supply-side climate policy can be stronger than what is indicated by looking only at the short-run, as in the analysis by Fæhn et al. (2017).

Acemoglu et al. (2012) develop the framework from the 2002 paper to explicitly investigate the effects of climate policy when the factors in production can be either clean or dirty. The central insight discussed above is confirmed here: Larger access to one factor – say fossil energy – will change the technological development in favor of higher demand for this factor. The authors find that as long as dirty and clean energy sources can substitute each other to a sufficient extent, traditional policy instruments such as carbon taxation and subsidies to technological development can switch the long-run equilibrium of the economy from one that is reliant on fossil energy to one that is not. This happens because these instruments contribute to a change in investments in new technologies that is amplified over time as more and more clean and less and less dirty energy is used in the economy.

In Acemoglu et al. (2016), a model similar to the ones used in the two previous papers is used to look into the mechanisms in more detail, both analytically and empirically. Again, the main result concerning the path-dependency of technological development is supported. The authors show again that the optimal mix of policy instruments consists of both subsidies to green energy development and of carbon taxes.

It is worth noting that the subsidy to green technology development in these models is not a consequence of a market failure in the way we usually understand it. There are no positive externalities from technology development in either technologies, but still the carbon tax is not a sufficient instrument. The reason is the path-dependency in the development – by using a subsidy, the economy is pushed towards a path that is less dependent on fossil energy. This is welfare increasing when there are negative externalities from consumption of fossil energy, even though fossil energy consumption is priced with an appropriate carbon tax.

A positive relationship between energy prices and the development of energy-saving technology is supported by several empirical findings, for example Newell, Jaffe and Stavins (1999) and Popp (2002). Newell, Jaffe and Stavins (1999) investigate the connection between the development of energy-saving technology for air-conditioners and energy prices. They show that when energy prices are higher there is a more rapid development in more energy-efficient technology. Similarly, Popp (2002) uses US patent data from 1979 to 1994 and shows that that there is more innovation in energy efficiency in periods with high energy prices. See also more recent empirical studies such as Hassler, Krusell and Olovsson (n.d.) and Aghion et al. (2016).

It is clear from the theoretical arguments presented by Acemoglu and his co-authors that supply-side polices may play an important role in directing technological change away from fossil energy and towards alternative energy sources and energy efficiency. It is also possible that there are other important path-dependencies that work in favor of supply-side policies. Fouquet (2016) argues that energy subsidies in general contribute to locking economies onto pathways with very high energy-intensity. This could also be the case for renewable energy subsidies. Therefore, if investments in new technologies can be shifted away from fossil energy technologies by the use of supply-side policies, this might come with an additional benefit compared to the situation if only green energy subsidies are used. This benefit is that the shift away from fossil energy is not translated only into investments in renewable energy, but into investment in all sorts of technologies that can compete with fossil energy technologies over time.

As the discussion in this section shows, the effect of different policies on the technological development could provide an additional argument in favor of using supply-side policies both globally and in a small country like Norway.

2.4 Optimal supply-side climate policy in Norway

So far, I have discussed the costs of global emission reductions, in the short and the long run, for demand- and supply-side climate policy. An important question for the policy makers is how large emission reductions it is optimal to do by use of supply-side policy. Although I will not answer this question, I will briefly discuss the important trade-offs in this section.

Ideally, the total cost of reducing extraction should be weighed against the sum of the value of reducing global emissions, other environmental effects of extraction and other potential externalities. Both the short- and long-run effect on global emissions of a domestic reduction in extraction should be taken into account.

A tax on oil extraction is an effective instrument for implementing the optimal supply-side policy, and it has the benefit that the exact cost of reducing domestic emissions does not have to be known by the policy maker.

According to the findings of Fæhn et al. (2017), a tax per ton of oil extracted should reflect the willingness to pay of the policy maker for a reduction of global emissions of about one ton. Here, however, none of the potential local environmental externalities from extraction are taken into account, neither are the potential long-run effects of reduced extraction discussed in Section 2.3.

The willingness to pay of the Norwegian policy makers for a reduction in global emissions is not obvious. However, it is clear that shifting Norwegian governments to some extent value reductions in greenhouse gas emission globally. As a starting point for measuring the size of this value, one could look at the carbon prices that are implemented on the demand-side in the Norwegian economy.[8] The carbon prices used in the different sectors in the Norwegian economy range from 0 to NOK 700 (including the EU ETS permit price), equivalent to USD 85. The highest prices are faced by domestic air traffic and offshore- oil and gas installations (Regjeringen (2018)[9]).

However, as is clearly illustrated by Fæhn et al. (2017), there is carbon leakage also on the demand-side. For a uniform tax on all sectors outside the EU ETS, they estimate the global emission reduction to be about 2/3 of the domestic reduction. It could therefore be argued that the implemented carbon pricing provides a lower bound for the willingness to pay for global emission reductions.

Finally, a number of the climate policy measures are taken on the demand-side in the Norwegian economy have costs that are estimated to be far above the highest implemented carbon prices. As one example, the cost of emission reductions as a consequence of the subsidies to electrical cars is calculated to be almost 600 USD, according to a Norwegian expert panel (Grønn Skattekommisjon (2015)).

In sum, the demand-side measures can be interpreted to imply that there is a substantial willingness to pay for global emission reductions. Moreover, investigations made by Greaker and Rosendahl (2017) suggest that there are non-negligible amounts of oil to be extracted in Norway in the coming years with relatively low profits. They investigate the Impact Assessment that was made before the Licensing Decision in 2016 for exploration in Barents Sea South-East and find that the economic profitability of exploration can turn out to be low. A tax on emissions reflecting the actual willingness to pay for emission reductions could therefore potentially mean a substantial reduction in reduction of Norwegian oil.

[8] Norway face commitments on domestic emission reductions according both towards the EU and according to the Paris agreement. The demand-side measures that are taken can be the result only of these commitments and supply-side policies will not – given the current systems – contribute to the fulfillment of these commitments. However, as Norway is already taking on costs to reduce global emission for example through the REDD initiative (initative for reducing emissions from deforestation and forest degradation in developing countries), it can be argued that international commitments does not seem to be the only reason for the measures.

[9] The Norwegian national budget for 2019.

2.5 Distributional effects of supply-side climate policy

Distributional aspects of different policies can be considered at least along two dimensions – across individuals or groups at one point in time and across generations. Furthermore, there will be distributional impacts of supply-side climate policy both within Norway and in the rest of the world. There might also be links between distributional consequences – or perceived distributional consequences – of different policies, and the political feasibility of these policies. More generally, there are ethical aspects to climate policy that have not been discussed in this paper. In this section, I will briefly discuss the distributional aspects of supply-side climate policy, political feasibility of supply-side policy in Norway, and finally how a stronger focus on supply-side policy can potentially strengthen international cooperation on climate policy.

demand-side climate policy will lower global fossil fuel prices, benefiting countries that import fossil fuels, or more generally, consumers of fossil fuels. Lowered Norwegian oil extraction, on the other hand, will increase the global oil price, and to some extent also the prices of gas and coal. This benefits oil-exporting countries and harms consumers. It can be argued that these global distributional effects are more favorable for demand-side climate policy.

However, if a larger weight on supply-side climate policy can lower the overall cost of emission reductions and therefore results in a larger and more rapid decline in emissions, the overall distributional effect can also go in the opposite direction. This is because the most dramatic consequences of climate change are likely to face poor countries with much weaker ability to adapt to the changes.

Within Norway, there will also be differences between the distributional consequences of supply- and demand-side policy. Through the tax system, a large share of the reduction in profits from the oil sector would go to the Norwegian state. Thus, the distribution of this cost cannot be expected to be very different from that of other climate policy instruments that are paid over the state budget, such as green technology subsidies. However, lower extraction will to a larger extent than demand-side policies hit a specific group, namely thos employed in the oil sector. At the same time, a larger share of the burden of supply-side policies is put on firms.

These differences in distributional consequences, or even the mere perception of the distributional consequences of the different policies, might act in favor of supply-side policy. Green and Denniss (2018) argue that supply-side climate policy will be more politically feasible, and hence applied to a larger extent, than demand-side policy. Firstly, they argue that the benefits from supply-side policies are more easily seen and accepted by voters, partly because there are clear co-benefits such as less local air pollution, in addition to the climate benefit. The benefit from less climate change can be difficult to apprehend because it is spread out both geographically and across generations. Secondly, the authors argue that the costs of supply-side policy are likely to be perceived as both smaller and more fairly distributed than the costs from demand-side policy. The argument is that voters believe the fossil fuel firms themselves are taking a larger part of the total cost.

It can also be argued that a stronger focus on supply-side policy could improve on the current situation in the international cooperation on climate policy. Collier and Venables (2014) argue that a planned and sequenced closing of global coal industry, where the richest countries move first, could create sufficient moral pressure on countries and governments to induce much more stringent climate policy worldwide. They argue that for countries to be affected by such moral pressure, there must be a mechanism in play that puts the moral responsibility on only one or a few countries at any point in time. As soon as these countries comply with the closing scheme, the responsibility is moved. The sequence must be perceived as fair, and it could be important that rich countries are first on the list. Although these authors consider closing of the coal industry, the same argument could potentially be made for oil.

A somewhat similar argument is put forward by Green (2018), who argues that reduced extraction in some countries can contribute to the strengthening of *global moral norms* that can in turn induce other countries to strengthen their climate policies.

Finally, if a rich and well-functioning state like Norway is not willing to bear the cost of reducing its oil extraction, it would clearly to some extent relief the existing moral pressure – if any – on other countries to do so. Moreover, it seems intuitively clear that it will be especially difficult to raise the necessary political support to implement large and disruptive changes in energy use globally if the international distribution of costs are perceived as very unfair by many. Rich countries – such as Norway – taking on higher costs, for example through strong supply-side measures can potentially reduce this unfairness. See Kartha et al. (2018) for further discussion.

3 Conclusion

In this paper, I have reviewed relevant parts of the economics literature, and discussed the effects of a shift in Norwegian climate policy towards reduced oil extraction. Both the theoretical and the empirical literature suggest that the optimal combination of supply- and demand-side policy in Norway would include reduced extraction as an important component.

In the short run, the optimal combination of supply- and demand-side policy is determined by the costs of domestic emission reductions on either side together with the respective degrees of carbon leakage.

In the long run, the effect of the different policies on technological development, international institutions and political processes are among the factors that should also be taken into account. Furthermore, there are different distributional aspects of the different policies.

There are other possible approaches to reduction in global supply of fossil fuels than the approach that has been studied in this paper. One of them is the possibility of leasing or buying fossil fuel reserves abroad to conserve them. There are at least two benefits to this approach. Firstly, because the total number of reserves that can be preserved is larger than the number of domestic reserves alone, the abatement cost curve on the supply side will be less steep. Secondly, as is demonstrated by Harstad (2012), by removing the right segment of reserves from the global supply curve, the problem of carbon leakage can be eliminated. If the global supply curve for fossil fuels is partly vertical due to preservation of all reserves with costs within a given range, changes in domestic emissions will not result in increased supply even if the price increases. Some important challenges to international trade in conservation of fossil fuels, are discussed by Harstad (2016), and more research is needed to overcome these and other challenges.

For Norway, oil reserves in the Arctic can be well-suited for preservation. Arctic oil will be expensive to find and extract, hence the profits cannot be expected to be very high. Furthermore, it is likely that there are more severe local environmental risks associated with Arctic oil extraction compared to other areas. Finally, there will be need for new and better technologies to be able to operate in the extreme conditions in the Arctic. The effect of Norwegian oil extraction on technological development that are discussed in Section 2.3 can therefore be more important in the Arctic than in other areas. Similar mechanisms, and the consequences for exploration for fossil fuels in the Arctic, are discussed by Leroux and Spiro (2018).

The mechanisms and trade-offs discussed in this paper are not unique for Norway. Similar arguments for supply-side climate policy can be made for any supplier of fossil fuels that puts a positive value on reduction in global greenhouse gas emissions.

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