The producer benefits of implicit fossil fuel subsidies in the United States

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This paper estimates the financial benefits accruing to fossil fuel producers (i.e., the producer incidence) that arise because of implicit fossil fuel subsidies in the United States. The analysis takes account of coal, natural gas, gasoline, and diesel, along with the implicit subsidies due to externalized environmental damages, public health effects, and transportation-related costs. The direct benefit to fossil fuel producers across all four fuels is estimated at $62 billion per year, a sum calculated due to the higher price that suppliers receive because of inefficient pricing compared to the counterfactual scenario where environmental and public health externalities are internalized. A significant portion of these benefits accrue to relatively few companies, and specific estimates are provided for companies with the largest production. The financial benefit because of unpriced costs borne by society is comparable to 18% of net income from continuing domestic operations for the median natural gas and oil producer in 2017–2018, and it exceeds net income for the majority of coal producers. The results clarify what the domestic fossil fuel industry has at stake financially when it comes to policies that seek to address climate change, adverse health effects from local pollution, and inefficient transportation.

energy subsides | externals costs | efficient pricing | distributional consequences

Fossil fuels underlie much of the world's economic activity, in addition to many of the greatest environmental and public health challenges. The sudden, unexpected, and significant fall in demand for energy brought about by the novel coronavirus has spurred policymakers to consider financial assistance to fossil fuel companies in order to mitigate damage to the industry. This comes at a time when there otherwise has been growing and more enduring concerns about fossil fuel subsidies around the world and a recognition of the benefits and challenges to phasing them out (1–5). While the prospects and duration of any pandemic-induced bailouts remain uncertain, debates about fossil fuel subsidies and subsidy reform will continue—especially in light of their close connection to climate change, adverse health effects from local pollution, and transportation-related costs.

This paper's findings inform debates about fossil fuel subsides along two dimensions. The first is a quantification of the financial benefits to fossil fuel producers of implicit subsidies already in place. Using data for the United States from 2010 to 2018, the estimates provide insight into the distributional consequences of implicit fossil fuel subsidies between producers and consumers during typical economic conditions. The analysis considers coal, natural gas, gasoline, and diesel, along with the implicit subsidies for each that arise because of the external costs borne by society due to environmental damages, public health effects, and traffic-related conditions.

The producer benefits of interest—i.e., the producer incidence (PI)—are based on the higher price that suppliers receive because of inefficient pricing compared to the counterfactual scenario where environmental and public health externalities are internalized. The direct financial benefit to fossil fuel producers of inefficient pricing across all four fuels is estimated at $62 billion per year on average, representing 11% of the total annual subsidy of $568 billion. The total subsidy is equivalent to an average of 3% of US Gross Domestic Product and equals the estimated value of the environmental, public health, and transportation-related externalities on an annual basis. To be clear, the focus here is not on direct subsidy payments that reduce the costs of fossil fuels, but rather on the implicit subsides that arise because of inefficient pricing that gives rise to social costs (1, 2, 6). While direct subsidy payments are common in many countries (7–9), they are not in the United States.

The second set of findings are based on attribution of the subsidy benefits to specific fossil fuel companies. Because of high concentration in the supply of fossil fuels, the producer benefits accrue to a relatively small number of coal, gas, and oil companies. Many are found to benefit by hundreds of millions of dollars per year—with some exceeding one billion. When compared to a company's reported net income from continuing operations, the importance of these subsidies to company bottom lines becomes clear. The benefit exceeds net income for more than half of the coal companies over the most recent 2-y period, and in many cases by a wide margin. For natural gas and oil producers with the largest US production, the benefit constitutes a median of 18% of net income from domestic operations. The world's largest, foreign oil producers are also found to benefit by hundreds of millions, or even billions, per year.

This paper also makes two methodological contributions to the literature on fossil fuel subsidies. First is a generalization and implementation of the standard International Monetary Fund (IMF) framework (1, 2, 6, 10) to separately estimate the PI and consumer incidence (CI). A key feature of existing studies—which focus on economic efficiency, environmental and health impacts, and government revenues—is the simplifying assumption of perfectly elastic supply (1, 6, 8–10). This implicitly assumes away fundamental concerns about the extent to which the fossil fuel industry benefits from subsidies and may therefore seek to prevent

Significance

There are real and substantial financial implications to fossil fuel producers of policies that seek to correct market failures brought about by climate change, adverse health effects from local pollution, and inefficient transportation. The producer benefits of the existing policy regime in the United States are estimated at $62 billion annually during normal economic conditions. This translates into large amounts for individual companies due to the relatively small number of fossil fuel producers. This paper provides company-specific estimates, and these numbers clarify why many in the fossil fuel industry oppose more efficient regulatory reform; they may also shape the way policymakers view the prospects for additional subsidies going forward.

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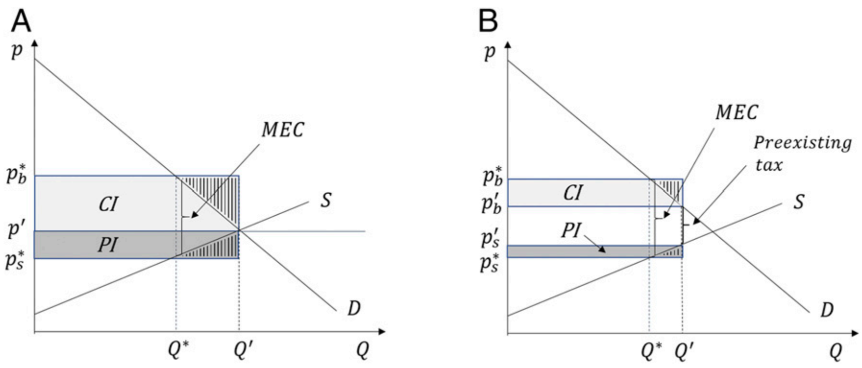

Fig. 1. The PI and CI of an implicit fossil fuel subsidy. MEC represents the marginal external cost associated with each unit of Q. (*A*) The presence of no preexisting tax is assumed. The total implicit subsidy is the area MEC×Q'. The incidence measures capture the gain in producer and consumer surplus from inefficient pricing, i.e., the respective shaded areas excluding the vertically hashed triangles. (*B*) A case with a preexisting tax; the net corrective tax is the difference between the MEC and the preexisting tax.

reform. The approach taken here uses empirically based estimates of supply elasticities to examine distributional implications, with a focus on PI.

The second methodological contribution is rough estimates of cost pass-through rates along different stages of fossil fuel supply chains. The estimated ranges, combined with company-specific production data, enable a further partition of PI into the benefits accruing to a subset of individual fossil fuel companies. These estimates shed light on what fossil fuel companies have at stake with policies that seek to address climate change, protect public health through the control of local pollution, and promote more efficient transportation.

Conceptual Framework

Implicit fossil fuel subsidies represent a hybrid of the standard tax and subsidy scenarios. This follows because externality-based, fossil fuel subsidies arise because of failure to implement efficient pricing, which confers an implicit subsidy. While different mechanisms are possible to establish efficient pricing, the most straightforward to illustrate the key points is Pigouvian taxation. Consider the market for a particular fossil fuel, characterized by the supply and demand curves in Fig. 1*A*. The initial equilibrium occurs at price p' and quantity Q', which is not efficient because of external costs in the form of environmental damages and adverse health effects. Assume for simplicity that the marginal external costs, denoted MEC, are constant. A Pigouvian tax equals the MEC and places a wedge between the supply and demand curves. If implemented, the Pigouvian tax would establish the efficient quantity Q^* as the equilibrium and the prices buyers pay and sellers receive as p_b^* and p_s^*, respectively.

The implicit fossil fuel subsidy is defined as the sum of all shaded areas in Fig. 1*A*; i.e., the rectangle equal to $\mathrm{MEC} \times Q'$. This is an effective subsidy because it represents real costs borne by society—through environmental damages and adverse public health effects or foregone tax revenue—but not reflected in the market (1, 10). Of central interest here is the way that the total subsidy differentially benefits consumers and producers (i.e., the measures of incidence). The CI captures the change in net benefits to consumers (i.e., consumer surplus) because of the lower price they pay, and the PI captures the change in net benefits to producers (i.e., producer surplus) because of the higher price they receive. These measures are illustrated in Fig. 1*A* as the shaded areas labeled CI and PI, respectively, which do not include the vertically hashed triangles. The two regions represent the net gain to consumers and producers of maintaining inefficient pricing.

Previous research nevertheless implicitly assumes the PI is zero, which follows because of the simplifying assumption of perfectly elastic supply (1, 2, 6, 8–10). The assumption is reasonably motivated

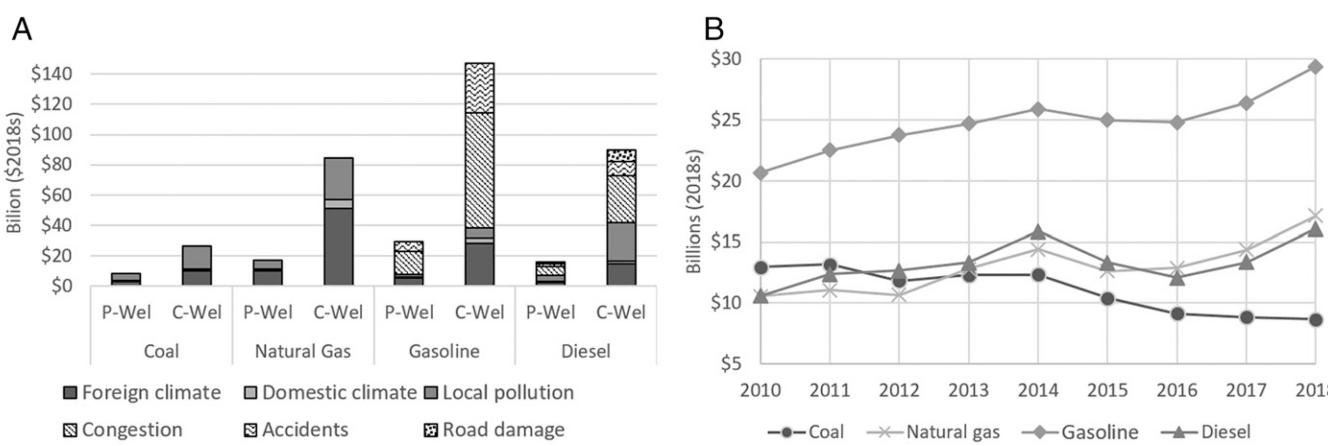

Fig. 2. The PI and CI of the subsidy for all fuels. (*A*) The measures of PI and CI for all four fuels (coal, natural gas, gasoline, and diesel) for the most recent year, 2018. Data for all other years are available in *SI Appendix*. Each measure is further partitioned into the underlying externalities, which are proportionally the same between both measures of incidence for each fuel (*SI Appendix*, Fig. S1). (*B*) The trend in PI over time for each fuel. While the producer benefits to coal have decreased 33%, those for all other fuels have increased substantially: 42% for gasoline, 52% for diesel, and 63% for natural gas.

Table 1. Sensitivity analysis on incidence and pass-through rates for 2018, in billions of dollars

	Coal			Natural gas			Gasoline			Diesel		
Year	CI ($)	PI ($)	Pass-through	CI ($)	PI ($)	Pass-through	CI ($)	PI ($)	Pass-through	CI ($)	PI ($)	Pass-through
Baseline	27	9	0.86	85	17	0.84	147	29	0.83	90	16	0.85
MEC												
50% decrease	21	8	0.78	43	11	0.80	46	11	0.81	31	7	0.83
50% increase	29	9	0.90	121	21	0.86	239	42	0.85	143	22	0.87
Implicit pass-through												
High	55	6	0.93	104	7	0.94	174	12	0.94	105	6	0.94
Low	16	13	0.83	63	35	0.65	110	64	0.64	68	35	0.66

Baseline corresponds to the numbers in Fig. 2*A*. The pass-through rates for each fuel are the ratio $(p_b^* - p_b^{'})/(\mathrm{MEC} - t)$ in each case. MEC scenarios are an overall 50% decrease or increase in the MEC for each fuel in 2018. The implicit pass-through high scenario is based on a simultaneous 50% decrease in the demand elasticity and 50% increase in the supply elasticity. The implicit pass-through low scenario corresponds to 50% changes in the opposite directions for both the demand and supply elasticities. All dollar values are reported in 2018 dollars.

in previous analyses because of the focus on efficiency rather than distributional concerns between producers and consumers. The assumption is also reasonable in cases where the focus is on relatively small countries subject to the global supply of fossil fuels. The assumption does not, however, fully characterize markets in the United States, especially when it comes to coal and natural gas, which are less interconnected in a global market compared to oil. While less is known about supply elasticities compared to those for demand, existing research does provide a basis for informed assumptions that push away from the limiting case of perfect elasticity, especially for the United States.

A final piece of the model to consider is the possibility for preexisting subsidies or taxes. An explicit, preexisting subsidy would be a direct government payment to reduce the producer or consumer costs of fossil fuels, but as mentioned previously, these are not common in the United States. Instead, implicit market subsidies do arise because of existing tax preferences for oil and gas firms, which have been estimated to cost the US government roughly $4 billion annually in foregone revenue (11). These subsidies are not accounted for in the present analysis because of the focus on nonmarket implicit subsidies. There are, however, preexisting taxes that affect the immediate applicability of Fig. 1*A*, and these must be taken into account to get an accurate measure of the fossil fuel subsidy in each case. Fig. 1*B* generalizes the framework to show how existing tax revenue associated with the initial equilibrium at $Q^{'}$ is not included in the overall subsidy. In this case, the implicit subsidy is based on the net corrective tax (i.e., MEC minus the preexisting tax). The measures of incidence differ as shown but still represent the difference in the respective surplus measures.

Overall Producer Incidence

The methodological approach for estimating the incidence of fossil fuel subsidies requires several steps, all of which are described in detail in *SI Appendix*. First is obtaining price and quantity data for the different fuels. Second is estimating the MEC associated with each fuel. Third is obtaining information on preexisting taxes in order to calculate the net corrective taxes. Fourth is an approach for generating counterfactual prices that would emerge with efficient pricing. Last is obtaining estimates of supply and demand elasticities.

Total Subsidy. The results indicate a total subsidy across all four fuels of $592 billion in the most recent year, 2018. This number represents the external costs borne by society or foregone government revenue from inefficient pricing. Included in the external costs is the value of climate damages reflected in the social cost of carbon and adverse health effects from local pollution (*SI Appendix*, Fig. S1). The external costs for gasoline and diesel also include the value of congestion-based travel delays and accident fatalities, along with wear and tear on the roadways from heavy-duty, diesel fuel vehicles (*SI Appendix*, Fig. S1).

It is worth noting that the inclusion of transportation costs as part of the efficient gasoline and diesel taxes is a second-best policy approach. That is, it would be more efficient to implement a more direct vehicle miles traveled (VMT) tax. In the absence of VMT taxes, however, including the external costs of transportation in fuel taxes is reasonable and the standard approach in the literature as a feasible policy alternative. In the event that VMT taxes are eventually implemented, the externality associated with transportation fuels would need adjusting.

In 2018, the majority of the subsidy is for gasoline ($198 billion), followed by coal ($149 billion), natural gas ($126 billion), and diesel ($119 billion). The total amount does not vary much year to year (*SI Appendix*, Fig. S2), with a range between $538 and $592 billion and an average of $568 billion per year. Over the 8-y period, the subsidy for coal has declined 29%, while the subsidy for natural gas has increased 58%. Those for gasoline and diesel have increased 17% and 20%, respectively.

Incidence. Fig. 2*A* shows estimates of the PI and CI for each fuel in 2018, and data for all years are included in *SI Appendix*. The CI far exceeds the PI for all four fuels, reflecting the greater relative elasticity of supply. Fig. 2*A* also illustrates the proportional amounts of the incidence attributable to the different externalities, which are the same across the two measures of incidence for each fuel (*SI Appendix*, Fig. S1). Local pollution constitutes the greatest share for coal, climate change the greatest for natural gas, and transportation costs the greatest for gasoline and diesel.

The primary focus here is the PI. Although the magnitudes are substantially smaller than the CI, the dollar amounts that benefit a relatively small number of producers are substantial. In 2018, the PI across all four fuels was $71 billion, with an average of $62 billion per year since 2010. To be clear, this amount represents the financial benefit to fossil fuel suppliers in the United States of higher prices they receive because of inefficient policy that does not take account of external costs. The average amounts for coal, natural gas, and diesel are between $11 and $13 billion, with gasoline receiving the highest average of $25 billion. Fig. 2*B* shows the trend in PI for each fuel since 2010. While the producer benefits to coal have decreased 33%, those for all other fuels have increased substantially: 42% for gasoline, 52% for diesel, and 63% for natural gas.

External Validity and Sensitivity. Examination of the implied pass-through rates provides a source of external validation for the measures of incidence. The pass-through rate for each fuel is the share of costs that would be passed through to consumers if corrective taxes were implemented. Referring back to the prices shown

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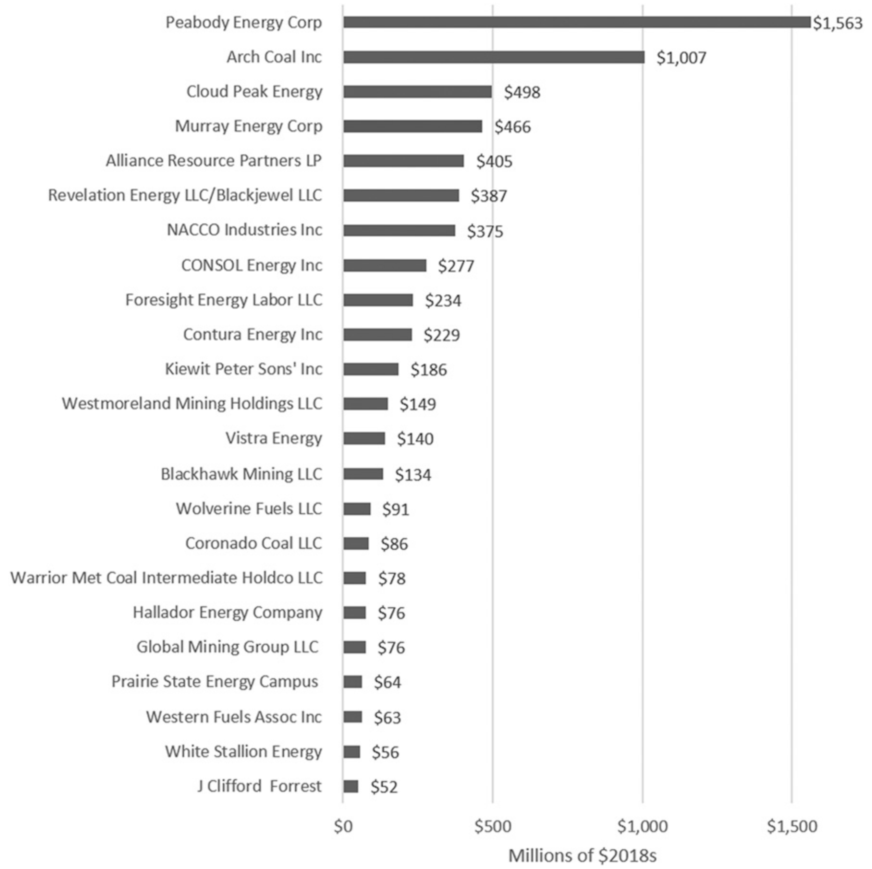

Fig. 3. Estimates of the company-specific benefit of the implicit subsidies to coal in 2018. The 23 companies listed are those that produced the greatest amounts domestically in 2018 and account for 88% of US production. The numbers are the midpoint estimates of the approach described in *SI Appendix*. They are derived using each company's production as a proportion of total supply and estimates of the pass-through rate within the coal supply chain.

in Fig. 1, the pass-through rate is equal to the ratio $(p_b^* - p_b')/(\text{MEC} - t)$, where t is the preexisting tax, so the denominator is the net corrective tax. For all four fuels, the implied pass-through is close to 0.85 in 2018 (see the "Baseline row" in Table 1), and the estimates vary little from year to year. A growing number of studies estimate pass-through rates for fossil fuels as a measure of incidence without needing to make assumptions about elasticities (12–20). Although none are directly comparable to the setting under study here, the range of estimates provides useful points of comparison that reinforce the reasonableness of the underlying elasticity assumptions (*SI Appendix*).

As noted above, key parameters for estimating the PI are the MEC for each fuel, in addition to the demand and supply elasticities. Although based on existing literatures, uncertainties about the estimates are inherent. Sensitivity analysis helps to evaluate the ways in which the incidence estimates depend on a range of alternative assumptions (Table 1).

The first set of results examines the effects of a 50% decrease or increase in the MEC estimate for each fuel. Because the total subsidy for each fuel is simply the product of the net corrective tax and the observed equilibrium quantity, the result is a 50% decrease or increase in the total subsidy, respectively. However, the same proportional adjustments do not map into the CI and PI. Focusing on changes to the PI, the sensitivity analysis on the MECs finds the estimate to range between $8 and $9 billion for coal, between $11 and $21 billion for natural gas, between $11 and $42 billion for gasoline, and between $7 and $22 billion for diesel.

The second set of results examines the effect of simultaneous changes to the demand and supply elasticities that push pass-through rates and therefore estimates of the PI in the same direction. The first case (the high pass-through scenario) is based on a simultaneous 50% decrease in the demand elasticity and 50% increase in the supply elasticity. These changes increase the effective pass-through rates for all fuels to between 0.93 and 0.94, thereby lowering the PI. The second case (the low pass-through scenario) is the reverse, and this substantially reduces the effective pass-through rates to between 0.64 and 0.66, with the exception of that for coal at 0.83. The range of results based on changes in the elasticities encompass those for changes in the MECs. Estimates of the PI now range between $6 and $13 billion for coal, between $7 and $35 billion for natural gas, between $12 and $64 billion for gasoline, and between $6 and $35 billion for diesel.

Despite the wide range of estimates the sensitivity analysis produces, focusing on only the most conservative scenarios still provides useful insight. Even the lower-bound estimates imply a combined benefit to fossil fuel suppliers of $31 billion in 2018 alone. Existing studies that assume perfectly elastic supply obscure this important distributional result.

Company-Specific Benefits

A further question that naturally emerges is how these measures of PI translate into direct financial benefits for specific fossil fuel producers. Such calculations depend on two key pieces of information. First are estimates of how the PI is distributed along the supply chains of each fuel type. This involves more links for gasoline and diesel than for coal and natural gas because gasoline and diesel are downstream products of oil, whereas coal and

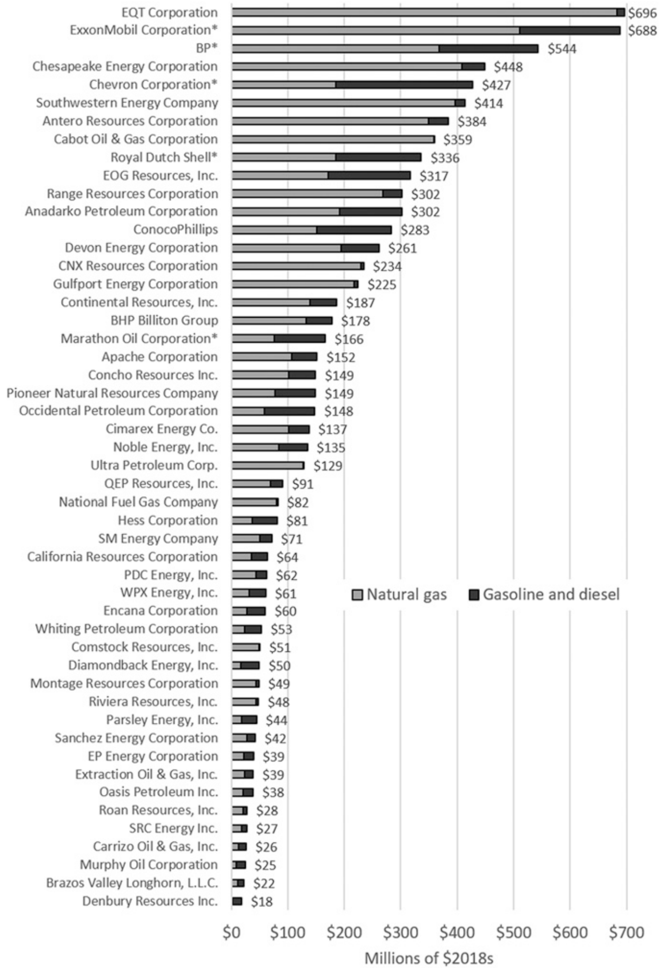

Fig. 4. Estimates of the company-specific benefits of the implicit subsidies to natural gas, gasoline, and diesel based on US production in 2018. The 50 companies listed are those with the largest US reserves in 2018. Based only on their US production, they account for 44% of the domestic natural gas supply and 7% of the global oil supply. The numbers are the midpoint estimates of the approach described in *SI Appendix*. They are derived using each company's production as a proportion of total supply and estimates of the pass-through rate within the supply chain for each fuel. Companies with an asterisk are those that are vertically integrated on the supply chain for gasoline and diesel and are therefore assumed to capture a greater share of the benefits.

natural gas are primary energy sources. Second is the production level of individual fossil fuel companies that comprise the upstream supply. Here again the approach differs somewhat for gasoline and diesel because the upstream supply of oil is integrated in a world market, unlike that for coal and natural gas. Details on the sources of data and approaches for making these calculations are described in *SI Appendix*.

The Largest Producers. The specific companies considered here are a subset of those that comprise the supply for US consumption. This means that estimates of the company-specific benefits that follow are only a fraction of the total PI discussed above. Companies of central interest initially are those with the greatest domestic production of coal or domestic reserves for natural gas and oil. Also considered are company-specific benefits to the 10 largest producers of oil world-wide, as a shift to more efficient pricing for gasoline and diesel in the United States would affect oil producers outside the United States because of changes in the world price of oil. The overall aim is to provide estimates of how much selected companies have at stake when it comes to the possibility for policies that impose efficient pricing on fuels in the United States.

Fig. 3 illustrates the midpoint estimates of the financial benefit in 2018 for each of the 23 largest coal companies operating domestically that year, which combined produced 88% of all domestic production. Seven of them received estimated benefits well above $300 million for the year. Indeed, the two largest, Peabody Energy and Arch Coal, received annual benefits of $1.56 and $1.01 billion, respectively. Even the lowest estimate among companies indicates benefits in excess of $52 million. These magnitudes illustrate how large financial benefits accrue to a small number of companies because the majority of coal produced in the United States is concentrated among relatively few producers. In particular, the subsidy benefits reported in Fig. 3 account for 77% of the coal PI in 2018, with the remaining unaccounted for benefits going to smaller producing companies and the downstream rail transportation of coal to electric power plants.

Fig. 4 illustrates the results for natural gas, gasoline, and diesel combined for each of the 50 companies with the largest US production of natural gas and oil in 2018, and it includes benefits based on domestic production only. As described in *SI Appendix*, the subsidy benefits stemming from gasoline and diesel are followed upstream to oil producers, who in all cases produce natural gas as well. Twelve companies have benefits greater than $300 million, and the largest is EQT Corporation, with an annual benefit of $696 million, followed closely by ExxonMobil at $688 million. The lowest estimate is $18 million for the year.

The majority of benefits accounted for in Fig. 4 are for natural gas rather than gasoline and diesel. The reason is that the 50 producers supplied 44% of domestic natural gas production, which is used entirely to meet domestic consumption. With gasoline and diesel, however, the upstream oil is supplied in a world market, and the 50 producers only account for 7% of global production in 2018. Quantifying the benefits to these companies is compelling because it shows how efficient pricing of gasoline and diesel would affect the returns to US oil production.

Also of interest is how the same change in US policy would affect returns to the world's largest oil producers because of the consequent reduction in the world price of oil. These results are shown in Fig. 5 for the world's 10 largest oil producers in 2018. All companies have benefits above $500 million for the year. The largest by a wide margin is Saudi Aramco, the world's largest producer, at $3.09 billion. The magnitudes in Fig. 5 for

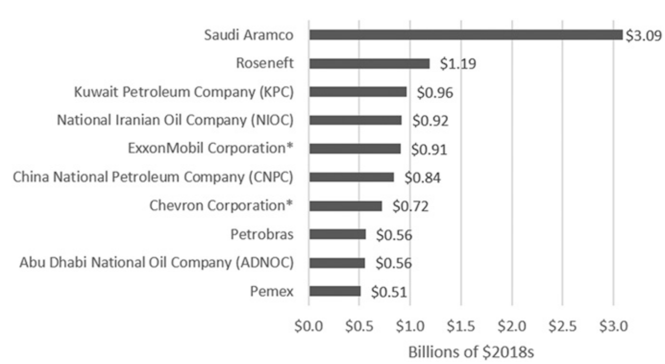

Fig. 5. Estimates of the benefits to the world's largest oil producers due to implicit subsidies for gasoline and diesel in United States in 2018. The 10 companies listed are those with the greater production in 2018, and combined they account for 34% of the global supply. The numbers are the midpoint estimates of the approach described in *SI Appendix*. They are derived using each company's production as a proportion of total supply and estimates of the pass-through rate within the supply chain for each fuel. Companies with an asterisk are those that are vertically integrated on the US supply chain for gasoline and diesel and are therefore assumed to capture a greater share of the benefits.

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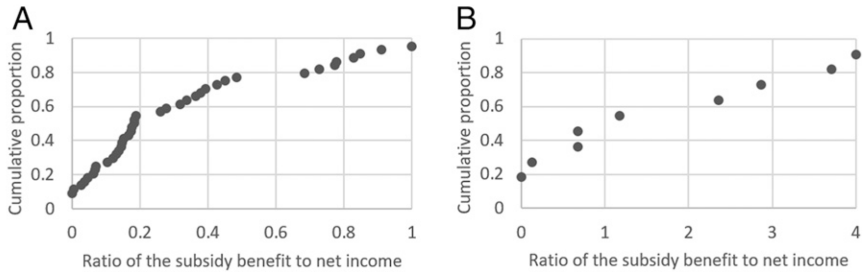

Fig. 6. Distribution of the ratio of company-specific benefits to net income, 2017–2018. (*A*) The ratio of the subsidy benefit to net income from domestic continuing operations for the natural gas and oil producers. The benefits are those reported in Fig. 4, and net income comes from company annual reports. The graph is censored such that four companies report negative net income, and three companies have ratios greater than one. (*B*) The same ratios for the 11 publicly traded coal companies for which data are available. Two companies report negative net income, and two companies have ratios that far exceed 4 (at 6 and 10.6). See *SI Appendix* for more details.

ExxonMobil and Chevron include the gasoline and diesel estimates already reported in Fig. 4. The full subsidy benefit for these two companies in 2018 is the sum of those for natural gas in Fig. 4 and those for gasoline and diesel in Fig. 5, totaling $1.4 billion for ExxonMobil and $908 million for Chevron.

Not included as part of the gasoline and diesel estimates in Figs. 4 and 5 are $33 billion of benefits (73% of the gasoline and diesel PI) to other oil producers and downstream suppliers of transportation fuels in US retail markets. It is also the case that the oil-based estimates are due only to consumption of gasoline and diesel and therefore do not reflect additional subsidies associated with other petroleum products such as heating oil and jet fuel. The producer-specific benefits, therefore, should be interpreted as an underestimate.

Relation to Net Income. How do the implicit subsidy benefits compare to company bottom lines? The final set of results compare the magnitude of the subsidy benefit for each company to the company's net income based on continuing operations in the United States. Net income is the standard measure of a company's bottom line, measuring total revenue from production minus all costs, including administrative and operating expenses, depreciation, interest, taxes, and other expenses. A useful way to express these results is the ratio of a company's subsidy benefit to its net income.

Given annual fluctuations in net income, one should not conclude that a ratio greater than one means that implementing efficient pricing would cause the company to go out of business, as levels of production would shift, costs would change, and many companies have additional operations outside the United States. Rather, the comparisons are useful to indicate whether the subsidy benefits are of a substantial magnitude compared to regular operations.

Fig. 6 reports the average ratios for 2017–2018, including all companies listed in Figs. 3 and 4 with a complete set of data (*SI Appendix*). The magnitudes illustrate the importance of the implicit subsidies. The median ratio among natural gas and oil producers is 0.18 (Fig. 6*A*). This means that the median implicit subsidy benefit to producers over the 2-y period was equal to 18% of reported net income based on domestic operations.

The picture that emerges for coal companies is more stark, although data on net income are available for fewer companies. The subsidy benefit exceeds net income for 6 out of the 9 companies reporting positive income. The median ratio is 1.2 for all 11 companies for which data are available. This means that the subsidy benefit is roughly equal to (though just over) net income for 2017–2018 for the median coal producer. Prior research finds that the environmental and health damages from coal-fired electricity generation exceed the sector's value added by a factor of 0.8–5.6 (21). The results here have a considerably narrower scope, focusing on a comparison of only the private benefits of the implicit subsidy to net income of individual companies. Given recent trends of declining demand for coal and the surge in bankruptcies among coal producers, these results at the very least raise questions about whether financial viability would continue for coal producers in the United States under efficient pricing.

Conclusion

Along with greater recognition of explicit and implicit fossil fuel subsidies has come growing concern about their distributional consequences. Who benefits? Who bears the costs? And how might a better understanding of the distributional impacts affect the political economy and feasibility of proposed reforms? While existing studies have focused on distributional impacts of efficient pricing among households (22–27), questions about how distributional burdens are split between producers and consumers have gone unstudied. Indeed, as discussed previously, the existing literature on fossil fuel subsidies, which focuses primarily on environmental consequences and efficiency implications, sidesteps the issue completely by assuming perfectly elastic supply and therefore zero PI.

Estimates of the PI are nevertheless critical for understanding what the fossil fuel industry has at stake when it comes to the potential for subsidy reform. There are real and substantial financial implications to fossil fuel producers of policies that seek to correct market failures brought about by climate change, adverse health effects from local pollution, and inefficient transportation. The producer benefits of the existing policy regime in the United States are estimated at $62 billion annually during normal economic conditions. This translates into large amounts for individual companies due to the relatively small number of fossil fuel producers and high pass-through rates within fuel supply chains. These numbers clarify why many in the fossil fuel industry oppose more efficient regulatory reform; they may also shape the way policymakers view the prospects for additional subsidies going forward.

Methods

The approach for estimating the PI of implicit fossil fuel subsidies is based on the conceptual framework in Fig. 1. Implementation proceeds in five steps: 1) price and quantity data for each of the four fuels, which were obtained from the Energy Information Administration; 2) MEC estimates for each fuel based on the IMF's methodology, with minor exceptions to update estimates for each year; 3) information on preexisting taxes in order to estimate the net corrective taxes; 4) a model based on constant elasticities of supply and demand for generating counterfactual prices that would emerge with efficient pricing; and 5) estimates of supply and demand elasticities based on a review of the literature.

Details on each of these steps are included in *SI Appendix*, along with a brief literature review on related pass-through estimates. Also included in *SI Appendix* are details on the methods employed for attributing portions of the estimated PI to the large domestic fossil fuel producers, along with the large global producers of oil listed in Fig. 5. It begins with a conceptual framework and empirical evidence in support of assumptions about supply chain pass-through rates, followed by company-specific data collection and benefit estimates in proportion to production.

Data Availability. All study data are included in the article and/or supporting information.

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