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A Simple Methodology for Calculating the Impact of a Carbon Tax

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Abstract

This technical note discusses how to implement a carbon tax at the national level. A carbon tax is a tax on fossil fuels, such as coal, natural gas, and crude oil (including fossil fuel products such as gasoline), that is imposed according to the carbon dioxide (CO_2) each fuel emits when burnt. The rate at which this CO_2 is taxed is known as the carbon tax rate or "carbon price". This paper uses simple numerical calculations to model the effect of a carbon tax on fuel prices, fuel use, fiscal revenue, and CO_2 emissions. A carbon tax would also have a substantial beneficial effect on local air pollution, although this is not explicitly modelled in this note.[1]

Adopting substantial carbon price reforms[2] is often perceived as a major policy decision, and proposed carbon taxes can face powerful opposition from entrenched interests. To overcome political challenges, and to allow economic agents to adjust their behavior, governments typically impose a very low carbon price initially and declare their intention to increase it gradually over time. However, many of these prices have not been significantly altered since they were introduced, and most are below US$10 per ton of CO_2,[3] even though "the explicit carbon-price level consistent with achieving the Paris temperature target" is, according to the High-Level Commission on Carbon Prices, "at least US$40-80/tCO2 by 2020 and US$50-100/t$CO_2$ by 2030, provided a supportive policy environment is in place" (Stiglitz & Stern, 2017). Based on the range proposed by Stiglitz and Stern, the note models a carbon tax of US$70/t$CO_2$.[4]

This note adopts a simplified 'isoelastic'[5] approach to approximate the effect of a carbon tax on fuel consumption and emissions in 2030. The advantage of the isoelastic approach is that it provides reasonable estimates even for large relative changes in fuel prices. The assumed US$70/t$CO_2$ carbon tax would substantially alter the price of coal, and reliable estimates of large price effects will be vital to enable policymakers to properly calibrate carbon tax rates and develop effective energy-transition strategies.

Taxing the carbon content of bulk coal, crude oil, and natural gas at the point of extraction, refining, or importation will reduce greenhouse-gas emissions, cut air pollution, and raise revenue. Data for India are used to illustrate the calculations. The model estimates that, for India, a carbon tax of US$70/t$CO_2$, implemented by 2025, would lower CO_2 emissions by 19 percent relative to a scenario without the tax. By 2030, it is estimated that the tax would provide US$162 billion (over 2% of projected GDP) in annual tax revenue (prior to compensatory spending) and that CO_2 emissions would be 45 percent lower than baseline.

[1] See Parry et al. (2014, 2015). Many countries also have substantial fossil fuel subsidies. The estimate of fossil fuel subsidies is even higher once underpriced local pollution and other externalities are accounted for (Coady et al., 2019).
[2] Increasing the implicit or explicit carbon price can be achieved through imposing carbon taxes or emissions trading schemes, removing fossil fuel subsidies, or imposing other types of fossil fuel taxes to account for all the effects of fossil fuels (including local air pollution). This paper focuses on the imposition of a carbon tax.
[3] See State and Trends of Carbon Pricing (World Bank, 2020b)
[4] Carbon taxes are usually measured in currency units (e.g. U.S. dollars) per ton of CO_2. Since one ton of carbon produces 3.67 tons of CO_2, when fully combusted, a tax of US$70 per ton of CO_2 is equivalent to US$257 per ton of carbon present in the underlying fuels.
[5] The 'isoelastic' model used here is a simplified version of the IMF model (International Monetary Fund, 2019) but using IEA projections (IEA, 2019) for baseline ('BAU') fuel use. See Part B of this paper for more information.

The note is divided into four parts. Part A describes the upstream approach to implementing a carbon tax, in which the carbon price is applied to fossil-fuel extraction or importation. Part B outlines the methodology. Part C goes through the calculations, step-by-step. Part D summarizes the results.

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Stephen Stretton

Part A: Implementing a Carbon Tax

1. Introduction

This technical note discusses the process for implementing a national-level carbon tax and estimates the results of such a tax on consumer prices, greenhouse gas emissions, environmental externalities, and fiscal revenue.[7] The estimations use data for India to illustrate the methodology, highlight analytical challenges, and present indicative results for a large emerging economy.

Carbon taxes are a key element of environmental tax reform (ETR). *Fiscal Policies for Development and Climate Action* (Pigato, 2018) identified three core benefits of ETR in developing countries. ETR improves market efficiency by charging for external costs that agents impose on others, minimizes economic costs for a given level of environmental stringency, and raises revenue to fund public goods. ETR also generates local environmental benefits and positive externalities, such as reduced air pollution, road congestion, and accident rates, and it can provide a valuable source of fiscal revenue. Local environmental benefits tend to be highly significant in developing countries, which often suffer from high rates of air pollution due to the heavy use of coal and/or a lack of enforceable emissions standards.

This note does not cover in detail transitional, distributional, incidence, or competitiveness issues. The introduction of a substantial carbon tax in any developed or developing country would need to deal with these matters through various measures. Since these matters are beyond the scope of this note and are a key part of any carbon tax reform, the note does not advocate any specific policy. The overall impact of these taxes on long-term industrial competitiveness tends to be relatively modest, and most adverse effects are concentrated in emissions-intensive, trade-exposed (EITE) sectors.[8]

This paper focuses on carbon taxes on fossil fuel consumption (implemented 'upstream' – see next section). This means that the exports of fossil fuels are not covered. However, there are reasons for taxing fossil fuel extraction – specifically to limit environmental damage and to capture resource rents for public purposes. So, while a tax on extracted and exported fossil fuels is not formally part of the scope of the carbon tax considered here, it may also be desirable. A carbon tax could be integrated into a system of licensing fees, royalties, and other taxes levied on the extractive industries.

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[7] The note builds on recent work on carbon taxation, carbon pricing, and environmental tax reform published by the World Bank and other sources. For example, the Carbon Tax Guide (World Bank, 2017) offers guidance on how to implement carbon taxes; the annual publication *State and Trends of Carbon Pricing* (World Bank, 2020b) examines the current state of emissions-trading schemes and carbon taxation worldwide; and a recent paper by the International Monetary Fund estimates the benefits generated by introducing carbon taxes and eliminating fossil-fuel subsidies.
[8] Exemptions and reduced rates have been used historically in such sectors, but these come at high losses in terms of efficiency and effectiveness. Better approaches include Output Based Rebating, Border Tax Adjustments or Consumption based Taxation (see Heine & Black, 2018).

2. Upstream Carbon Taxes

An upstream carbon tax is levied at the point of extraction, refining, or importation.[9] Rather than attempting to identify and monitor all sources of emissions in an economy, upstream carbon taxes apply the carbon price to fossil fuels as they are extracted or imported, which greatly simplifies tax administration while encouraging compliance. By contrast, downstream carbon pricing schemes put a price on carbon nearer to the point of emission. Under a cap-and-trade system, emitters such as coal- or gas-fired power plants are required to purchase emissions permits. Due to the inherent difficulty of measuring the complete emissions of every person and company, the coverage of downstream carbon pricing schemes tends to be limited. For example, the European Union's Emissions Trading Scheme (ETS) covers only large point-source emitters of CO_2 (only around 45% of total greenhouse gas emissions).[10]

The theory of upstream carbon taxes relies on one property from chemistry and one from economics. Due to the equivalence between the carbon content of a fuel and the CO_2 emissions produced by combusting it, taxing the carbon content of fuels at the point of extraction or importation ("upstream") is equivalent[11] to taxing their final ("downstream") emissions. Meanwhile, the economic theory of tax incidence implies that, in competitive markets, a tax on fossil fuels will tend to be passed on down the supply chain, incentivizing both production and consumption activities to become more climate friendly. Whilst situations of imperfect pass through are more complicated, the basic advantages of an upstream tax remain. Upstream carbon taxes are functionally similar to downstream taxes, but they tend to be more comprehensive, easier to administer, and harder to evade.

Upstream carbon taxes are a relatively cost-efficient method of raising revenue. Such taxes often require relatively little administration; they apply to the informal as well as the formal sector;[12] and they are resistant to tax avoidance and evasion. Fossil fuels are bulky physical commodities that require commercial-scale transportation, and smuggling is only viable in extreme circumstances. For fossil-fuel imports, administering a carbon tax would be incorporated into the normal functions of the customs service. The points at which fossil fuels are extracted (e.g., oil wells, coal mines) or imported (e.g., overland borders, seaports) tend to be readily identifiable and much easier to monitor than the numerous and diffuse points at which fossil fuels are consumed.

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[9] Strictly speaking, taxing fossil fuels after refining is a 'midstream' approach. At present, carbon taxes are mostly implemented midstream (i.e., after fuel refining/processing rather than at the well head/coal mine) as an extension of fuel excise duties. This retains most of the advantages of a fully upstream approach (so long as fossil fuel carbon is taxed once and only once – i.e. no double counting or exemptions).

[10] See https://ec.europa.eu/clima/policies/ets_en

[11] The share of fossil fuels that are not combusted completely is relatively small: it includes byproducts of incomplete combustion, such as soot and carbon monoxide, as well as non-combustible fossil-fuel-derived products, such as plastics. The lifetime environmental costs of these products and byproducts are comparable to, or greater than, those produced by fossil-fuel combustion and applying a carbon tax to the fossil-fuel inputs used by the plastics industry would have positive environmental effects in its own right, though estimating such effects is beyond the scope of this analysis.

[12] Developing countries often have large informal sectors that are not well covered by income tax, VAT and corporation tax. An upstream carbon tax can cover the informal sector at a low administrative cost (Heine & Black, 2018).

3. Additional Emissions Sources, Other GHGs, Ancillary Costs and Benefits

To achieve its full effect, a carbon tax must account for CO_2 produced by means other than fossil-fuel combustion, as well as for greenhouse gases other than CO_2, such as methane (CH_4) and nitrous oxide (N_2O).[13] Fossil-fuel extraction itself produces CO_2 emissions, which would not be captured by a tax that solely focused on the amount of fuel extracted. Moreover, fossil-fuel extraction also produces emissions of other greenhouse gases, such as CH_4. Other economic activities, including agriculture and land-use changes, can involve significant emissions of CO_2 and often CH_4 and N_2O. Such emissions should be identified and taxed at rates that reflect the established carbon price. Taxes on CH_4, N_2O, and other greenhouse gases should be based on their CO_2 equivalent as defined by the Intergovernmental Panel on Climate Change (IPCC, 1995).[14]

In addition to lowering CO_2 emissions, carbon taxes can reduce other negative externalities associated with the consumption of fossil fuels. The local benefits of a carbon tax include its impact on air pollution, traffic congestion, vehicle fatalities, and road damage, inter alia. All fossil fuels create local pollution; by reducing the consumption of fossil fuels, a carbon tax will limit the adverse health and environmental consequences associated with that pollution. While each fuel's carbon content is not always proportionate to its impact on local pollution, coal is both the most carbon-intensive fuel and the most polluting, as coal combustion produces large amounts of particulates and other air pollutants such as SO2. In addition, a carbon tax that reduces the number of vehicles in use will have a positive impact on local air quality while also mitigating the individual and social costs of traffic congestion, vehicle accidents, and damage to roads.

An efficient carbon price should account for externalities other than climate change, such as local air pollution, traffic congestion, and road accidents. While the impact of a carbon tax on these and other externalities will be determined by each local context, an efficient tax rate should reflect the totality of the harms caused by fossil-fuel consumption (Parry et al., 2014). Because these harms vary by fuel, the efficient tax rates for coal and vehicle fuels are often higher than those for industrial fuel oil and natural gas. Parry et al (2014) describe a methodology for corrective taxes that fully account for other externalities. We do not however model any additional taxes, apart from those that are already integrated into existing transport fuel prices.

Imports of fossil fuel products such as gasoline and diesel should also be taxed in a manner that reflects their carbon content, making their carbon price equivalent to that of other fossil fuels. For analytical purposes, gasoline and diesel are considered separately in the modelling from other petroleum products with respect to their fuel-price elasticities.

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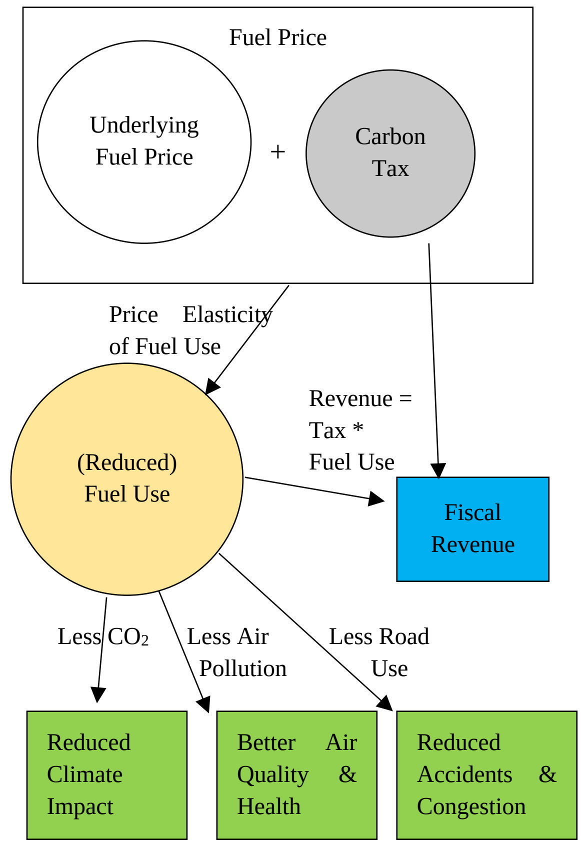
[13] Non-CO_2 pollutants often carry non-climate social damages that are often significantly higher than the carbon tax considered here. Hence efficient Pigouvian taxes require that they be taxed separately at rates commensurate to their climate + non-climate externalities (Parry et al., 2014). In general, an approximate approach is better than no taxes at all, and these tax rates could be updated as more information becomes available. On the other hand, it is not clear how carbon pricing would cover land use, land use change and forestry (LULUCF): other approaches are needed.

[14] See https://www.ipcc.ch/site/assets/uploads/2018/06/2nd-assessment-en.pdf. Other GHGs have different atmospheric lifetimes than CO_2, so a time period must be chosen for averaging the relative warming effect of non-CO_2 GHGs. It is usual to use the GWP100, i.e. the Global Warming Potential averaged over 100 years. Over this time period, the GWP of a ton of methane is 28-34 times that of a ton of CO_2

Part B: Modelling the Effects of a Carbon Tax – Methodology

1. Introduction

Figure 1: The Effects of a Carbon Tax



The rest of the paper estimates the effects of a hypothetical carbon tax on fuel prices, fuel use, tax revenues, and CO_2 emissions. It also presents a brief discussion of some of the ancillary local benefits generated by a carbon tax. The hypothetical carbon tax rate is set at US$70/t$CO_2$, in line with the High-Level Commission on Carbon Pricing's recommendations for meeting the Paris Agreement target of keeping global warming below 2°C above preindustrial average temperatures by the end of the century (Stiglitz & Stern, 2017).

A high-enough carbon tax can influence fossil-fuel usage through the price elasticity of fossil fuel consumption.[15] The revenue raised by a carbon tax will equal the amount of fossil fuel used multiplied by the tax rate. If the introduced tax meaningfully increases the price of fossil fuel (by more than 20%), it will reduce usage of fossil fuel to an extent determined by its price elasticity. As fossil-fuel usage directly determines CO_2 emissions and local air pollution, the price elasticity of demand for fossil fuel will also determine its environmental impact. Similarly, increasing the price of gasoline and diesel will increase the cost of driving and thereby reduce road traffic, with positive implications for accidents, congestion, and air pollution (**Error! Reference source not found.**).

Many countries have substantial fossil fuel subsidies, including underpriced local pollution and other externalities (Coady et al., 2019). So that the effect of the carbon tax can be isolated, it is assumed that under the business as usual scenario fuel subsidies have been eliminated, and VAT imposed at the standard rate, and that this is consistent with the 'current policies' scenario used for projected fuel use.

Carbon taxes need not harm economic growth. Only fossil fuel consumption is modelled in this paper, as this is the main source of CO_2 emissions. Long-term elasticities implicitly include a response from the supply side (e.g. increased efficiency of the capital stock and increased use of renewable energy). However, implementing a carbon tax of $70/t$CO_2$ is a political challenge. The effects on the prices of fossil fuels, particularly coal, are substantial. Such a tax would need to be accompanied by substantial compensatory spending (see this Part B, section 3). Output-based rebating is a desirable alternative to tax exemptions for emissions intensive trade exposed sectors (Heine & Black, 2018).

[15] The price elasticity of fuel use includes energy supply effects, e.g. substitution of renewables for fossil fuels in electricity production.

2. Methodology

The simple modelling approach in this paper does not distinguish between different trajectories of carbon price. It merely assumes that the tax rate reaches \$70/tCO_2 before 2025 and stays at that level in real terms until 2030. At what date and what level, the tax is introduced, and how it is raised over 2020-2025 from perhaps an initially lower level, is not explicitly specified. The modelling results are thus approximate.

We use an isoelastic model, which is appropriate both for small and large changes in price. Using this assumption, the proportional change in consumption is related to the (not necessarily small) change in price by the formula:

$$\mathbf{Q_{Ctax,i} = Q_{BAU,i} * (P_{Ctax,i} / P_{BAU,i})^{\varepsilon_i}}$$

where $P_{BAU,I}$ is the price under the BAU scenario, $P_{Ctax,i}$ is the price with Carbon tax, $Q_{BAU,i}$ is the quantity of fuel i used under the BAU scenario, $Q_{Ctax,i}$ is the quantity of fuel i consumed under the carbon tax scenario, and ε_i is the price elasticity of fuel i.[16]

Note that we do not include cross-price elasticities, for simplicity sake. A more realistic model would involve some fuel switching from coal to natural gas at low and moderate carbon prices. Nevertheless, we believe the model presented here gives a good approximation, given other uncertainties such as in baseline energy demand.

In comparison to a linear model, this simple model is intended to be more appropriate for large price changes. The calculations are closely related, but simplified and more aggregated, compared to those of the IMF model (International Monetary Fund, 2019).

The price elasticity of fuel use, ε_i is the responsiveness of fuel i consumption[17] to prices. It can be defined, for small changes, as the percentage change in fuel consumption divided by the small change in price that

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[16] This footnote demonstrates that ε_i is an elasticity. Our model with simplified notation (where P_0 is the price in the absence of a carbon tax and Q_0 is the fuel consumption expected in that case) is:

$$Q = Q_0 \left(\frac{P}{P_0}\right)^{\varepsilon_i}$$

Differentiating, with respect to the price P, we get:

$$\frac{dQ}{dP} = \frac{\varepsilon_i}{P} Q_0 \left(\frac{P}{P_0}\right)^{\varepsilon_i}$$

By the definition of an elasticity, and substitution for Q:

$$Price\ Elasticity\ of\ Fuel\ Use = \frac{dQ}{dP} \cdot \frac{P}{Q} = \frac{\varepsilon_i}{P} Q_0 \left(\frac{P}{P_0}\right)^{\varepsilon_i} \frac{P}{Q} = \varepsilon_i \left(\frac{P}{P_0}\right)^{\varepsilon_i} \frac{Q_0}{Q} = \varepsilon_i$$

This demonstrates that we have defined an 'isoelastic' (i.e. constant elasticity) model.

[17] These are price elasticities of fuel use rather than price elasticities of fuel demand since they encompass both demand-side responses and supply-side alternatives (e.g. renewables).

induces that change. Price elasticity is normally negative, reflecting the fact that price and demand move in opposite directions – i.e. a rise in price causes a fall in demand. Demand is said to be relatively inelastic if the price elasticity has a magnitude less than 1. Fuel demand tends to be relatively inelastic, as some uses are difficult to avoid or are not very price sensitive (see below).

In practice, the price elasticity in the long run is greater than in the short run. This is simply another way of saying that some of the reduction in usage resulting from a price rise happens only after some time has passed. For example, a carbon tax might make wind power a more attractive investment, which will then reduce demand for fossil fuels – but it takes time for the new capacity to be built and come online, so this is a long-run price response.

The price elasticities of fuel consumption are based on a review of previous studies (Labandeira, Labeaga and López-Otero 2017). Our assumptions are shown below. For natural gas, gasoline, and diesel, we use fuel-specific elasticities.

Whilst there are many studies for elasticities of transport fuels, and a few for natural gas, there are relatively few studies for coal. A study for China in 2012 suggests "a range of -0.3 to -0.7 for elasticity when responses over two years are considered" (Burke & Liao, 2015). For coal (and other oil products), non-fuel specific values are used (i.e. overall by fuel averages), according to the meta-analysis (so, for example, -0.6 for the long-term elasticity).

Table 1: Assumed Price Elasticities of Fuel Consumption

	Short Term (<1y) Assumed Elasticities	Long Term (>5y) Assumed Elasticities
Coal	-0.2	-0.6
Natural Gas	-0.18	-0.68
Gasoline	-0.29	-0.77
Diesel	-0.15	-0.44
Other Oil Products	-0.2	-0.6

Source: Based on (Labandeira, Labeaga and López-Otero 2017)

Note that these are economy-wide elasticity estimates; depending on a certain country's residential and industrial structures (household and firm energy consumption), they might vary across countries.

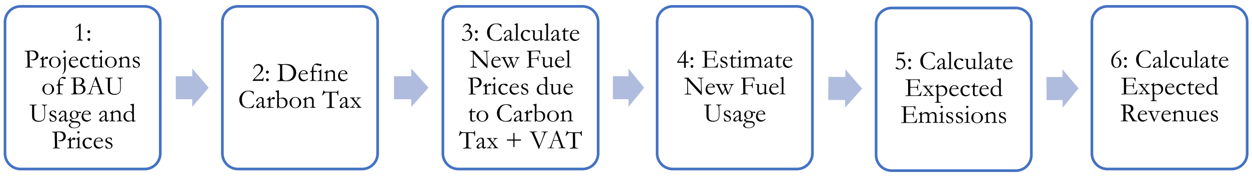
The paper uses constant 2020 USD for calculations and results.

The values in this written note are rounded. The derived results quoted here are based on unrounded calculations rather than rounded ones.

3. Procedure

This section describes the main steps used to calculate how fossil-fuel use and emissions respond to a carbon tax. We identify six main steps (Figure 2) in estimating the emissions and revenues from each fuel type (coal, natural gas, gasoline, diesel, and other oil products). The results are then aggregated.

Figure 2: Summary of Procedure for Calculating Core Results



Data from India are used to illustrate the calculations. We give example calculations for the long-term response of coal use and emissions to a carbon tax of $70/t$CO_2$, using the following assumptions:

Assumptions and Abbreviations (Coal, India):

	Abbreviation	**Value**	**Unit**
Fuel Type	i	Coal	
Projected fuel (coal) consumption (2030)	$Q_{BAU,i}$	28,925	PJ/y
Projected pre-VAT fuel price	$P_{BAU,Pre\text{-}VAT,i}$	1.99	$/GJ
Emissions factor	EF_i	0.0946	tCO_2/GJ
Carbon tax per ton CO_2	t	70	$/t$CO_2$
VAT Rate	v	18%	
Price elasticity of fuel consumption	ε_i	-0.6	(Long term)

Part C: Modelling the Effects of a Carbon Tax – Calculations

1. Define Projections of Business-As-Usual Fuel Consumption and Prices

Business-As-Usual (BAU) projections are defined as a carbon price of zero (with no fossil fuel subsidies and a VAT system without exemptions or reduced rates on fossil fuels or their use) and are taken from the *Current Policy Scenario* from the latest International Energy Outlook (IEA, 2019).[18]

Table 2: BAU Estimates for Fuel Consumption and Prices; and Emissions Factors by Fuel

India, BAU Projections, 2030	Projected pre-VAT Fuel Prices $P_{BAU,Pre\text{-}VAT}$	Projected Fuel Consumption $Q_{BAU,i}$	Emissions Factors EF_i
	2030 Price (2020$/GJ)	2030 Current Policy Scenario (PJ/y)	tCO_2/GJ (= $MtCO_2/PJ$)
Coal	1.99	28,925	0.0946
Natural Gas	4.35	5,530	0.0561
Crude Oil	9.97	15,775	0.0733
Gasoline	27.74	2,244	0.0693
Diesel	23.35	6,499	0.0741
Other Oil Products	(Same as Crude Oil)	7,031	

Sources: IPCC (2006), IEA (2018), IEA (2019), World Bank (2020).

Since the amount of CO_2 emitted is proportional to the amount of fuel used, the emissions generated by fuel consumption are calculated as:

$$\mathbf{E_{BAU,i} = Q_{BAU,i} * EF_i}$$

In all of our calculations, it is assumed that VAT is imposed on fuels at the standard rate.[19] The post-VAT BAU fuel price is:

$$\mathbf{P_{BAU,i} = (1 + v) * P_{BAU,Pre\text{-}VAT,i}}$$

Calculations:

BAU emissions	*Emissions Factor ($MtCO_2/PJ$)*		*Fuel Usage (PJ/y)*		*Emissions*	
	0.0946	*	28,925	=	2,736	*$MtCO_2/y$*
BAU VAT	*Pretax price ($/GJ)*		*VAT rate*		*VAT on Fuel*	
	$1.99	*	18%	=	$0.36	*$/GJ*
Projected post-VAT fuel price	*Pretax price ($/GJ)*		*VAT on Fuel*		*Price after VAT*	
	$1.99	+	$0.36	=	$2.35	*$/GJ*

[18] Alternatively, scale current fuel use by projected GDP to the power of income elasticity of fuel use (IMF, 2019).
[19] India's VAT is called the Goods and Services Tax (GST). The standard GST rate is 18 percent. Coal is subject to a reduced rate of 5 percent, as well as a dedicated coal tax of 400 rupees per ton. Under the BAU scenario, the standard GST rate is expected to replace the reduced GST rate and coal tax by 2030. The BAU post-VAT fuel price is therefore: P = post-VAT fuel price = (projected BAU pre-tax fuel price) * (1 + (standard VAT rate)).

2. Define Carbon Tax

The analysis assumes that the carbon tax will be implemented between 2020 and 2025. The rate is assumed to rise to US$70/$tCO_2$ by 2025 and to remain at that (real) level until 2030. The following calculations should be performed separately for each fuel i. The carbon tax of $70/$tCO_2$ is converted into a rate per GJ of fuel, using standard IEA emissions factors. If t is the carbon tax rate and EF the emissions factor, the carbon tax per unit energy of the fuel is:

$$\mathbf{EF_i * t}$$

Calculations:

Carbon tax per GJ fuel:	*Emissions Factor (tCO_2/GJ)*	*	*Carbon Tax (\$/tCO_2)*	=	*Carbon Tax on Coal (\$/GJ)*	
	0.0946	*	$70	=	$6.62	*$/GJ*
Carbon tax per ton coal:	*Carbon Tax on Coal ($/GJ)*	*	*Energy Content (GJ/ton)*	=	*Carbon Tax on Coal in physical units*	
	$6.62	*	16.68	=	$110	*$/ton (IND)*

For the purposes of implementation, the tax can be calculated in physical units of the underlying fuel. Since coal in particular varies in its energy content, the value of the tax in per ton of coal will be different in different locations.

Table 3: Carbon Tax in Physical Units

Fuel	Carbon Tax (\$/tCO_2)	Emissions Factor (tCO_2/GJ)	Carbon Tax per GJ	Conversion	Carbon Tax Per Physical Unit
Coal	$70	0.095	$6.62	16.68 GJ/ton-IND 25.12 GJ/ton-AUS	$110/ton-IND $166/ton-AUS
Natural Gas	$70	0.056	$3.93	1.06 GJ/MMBTU	$4.1/MMBTU
Crude Oil	$70	0.073	$5.13	5.86 GJ/bbl	$30.1/bbl
Gasoline	$70	0.069	$4.85	0.0331 GJ/l	$0.161/l
Diesel	$70	0.074	$5.18	0.0352 GJ/l	$0.183/l

Sources: IEA/IPCC; WB; Indian government.[20]

[20] *Units:* tCO_2 = ton of CO_2. GJ = Gigajoules. MMBTU=Million British Thermal Units, a unit of energy; bbl = Barrel of Oil; l = liter. *Note*: Energy units NCV (Net Calorific Value). The emissions factor is the CO_2 content of fuels per energy, which is quite constant across all fuels globally, but because Australian coal has a higher calorific value per ton than Indian coal, the tax needs to be higher per ton of coal for Australian coal. This example does not include VAT. *Assumptions:* Coal emissions factor: IPCC Bitumous coal, 2006 carbon content, 100% combustion. IND: Indian G-11 grade coal, 3984 NCV (4150kCal/kg GCV). AUS: Australian coal, Newcastle export: 6000kCal/kg NCV (6300kCal/kg GCV).

3. Calculate New Fuel Prices

Countries that use a VAT typically apply it to a product's final market price; for all products made with carbon-based fuels, the final price would include the cost of the carbon tax. To avoid creating implicit subsidies, VAT should be applied at a standard rate to the post-carbon-tax price of all VAT-eligible products. Consequently, the introduction of a carbon tax would indirectly boost VAT revenue by increasing the final price of VAT-eligible products that are produced, transported, or distributed using fossil fuels.

Since CO_2 emissions are part of the real cost of fossil-fuel production, the VAT (or equivalent tax) should be applied after the carbon tax. The post-carbon-tax fuel price is:

$$\mathbf{P_{WithCtax,i} = P_{BAU,i} + t * EF_i + v * t * EF_i}$$

where t is the carbon tax rate (in $/tCO_2$), v is the vat rate (in %), $\mathbf{EF_i}$ **is** the emissions factor for fuel i.[21]

Calculations:

New fuel price:	*BAU post-VAT price*	+	*Carbon Tax on Coal*	+	*VAT on Carbon Tax*	=	*Post-Tax Price*	
	$2.35	+	*$6.62*	+	*$1.19*	=	*$10.17*	*$/GJ*
Price rises by factor of:			*Price with C-Tax*	/	*BAU price*	=	*Price Change Factor*	
$(P_{Ctax,i} / P_{BAU,i})$			*$10.17*	/	*$2.35*	=	*4.32*	

[21] Or, put another way,

Post-tax fuel price = (Pre-tax fuel price + C-tax) * (1 + Standard VAT rate)

4. Estimate New Fuel Usage

After calculating the impact of the carbon tax on fuel prices, the next step is to estimate its effect on demand. Multiple methodologies can be used to estimate the effect of price changes on demand. Substitution is a key element in the price elasticity of demand, and in this case the substitutability of low-carbon or zero-carbon alternative energy sources influences the effect of the carbon tax on demand for fossil fuels. Over time, substitution effects would be expected to alter the supply of energy by increasing demand for low-carbon or zero-carbon energy sources, which would incentivize investment in the development and production of lower-carbon energy technologies. These changes are estimated based on the formula:

$$\mathbf{Q_{Ctax,i} = Q_{BAU,i} * (P_{Ctax,i} / P_{BAU,i})^{\varepsilon_i}}$$

where $P_{BAU,I}$ is the fuel price under the BAU (zero carbon price) scenario, $P_{Ctax,i}$ is the price after the carbon tax, $Q_{BAU,i}$ is the quantity of fuel i used under the BAU scenario, $Q_{Ctax,i}$ is the quantity of fuel i consumed under the carbon tax scenario, and ε_i is the price elasticity of fuel i. The assumed elasticities are presented below (Table 4), and more information can be found in the Appendix.[22]

Table 4: Assumed Price Elasticities of Fuel Consumption (ε_i)

	Short Term (1y) Assumed Elasticities	Long Term (5y+) Assumed Elasticities
Coal	-0.2	-0.6
Natural Gas	-0.18	-0.68
Gasoline	-0.29	-0.77
Diesel	-0.15	-0.44
Other Oil Products	-0.2	-0.6

Source: Based on (Labandeira, Labeaga and López-Otero 2017). See appendix for more information.

Calculations:

Fuel use relative to baseline:	*Price Change Factor*	^	*Fuel Elasticity*	=	*Usage Change Factor*	
	4.32	^	-0.6	=	0.42	
Fuel use with carbon tax:	*Original BAU Fuel Use*	*	*Usage Change Factor*	=	*New Fuel Use*	
	28,925	*	0.42	=	12,021	PJ/y

[22] Note that our assumed elasticity is a long-term elasticity, and so implicitly it is assumed the carbon tax is in place well before 2030 (i.e. the carbon tax should be imposed in 2025 or earlier). Short term effects are estimated to be roughly a third of the long-term effects, as demonstrated by assumed price elasticities in the table below.

5. Estimate Emissions

Since the amount of CO_2 emitted is proportional to the amount of fuel used, the emissions generated by fuel consumption are calculated as:

$$\mathbf{E_{Ctax,i} = Q_{Ctax,i} * EF_i}$$

Calculations:

	Coal Use (PJ/y)	*	Emissions Factor (GJ/tCO_2)	=	Emissions	
CO_2 emissions:	12,021	*	0.0946	=	1,137	MtCO_2/y

6. Calculate Expected Revenues

The revenue raised by a carbon tax is simply the tax rate multiplied by the amount of carbon released, summed over all fuels:

$$\mathbf{Revenue = \Sigma_i\ t * E_{WithCtax,i}}$$

Calculations:

	Carbon Tax	*	Emissions	=	Revenue	
Carbon tax revenue:	70	*	1,172	=	$79,603	million

If, as proposed, VAT is charged on the value of fuel that includes the carbon tax, there will be both gains and losses in VAT revenues. The VAT revenue gains are due to the VAT on the carbon tax revenue itself. The VAT revenue losses will be caused by the reduction in fuel consumption caused by the tax (and can be estimated by the reduction in fuel consumption multiplied by the price of fuel multiplied by the VAT rate). Such effects are explicitly calculated in the overall summary in the next section. Since there are expected to be countervailing reductions in net revenues (e.g. due to compensatory spending) we do not include these revenues in the overall summaries at the end of the paper and focus instead on the carbon tax revenue alone.

7. Summary of Calculations for Coal

The calculations are summarized below for coal. Further calculations for natural gas and oil products, as well as an aggregation of oil product results, are available in the appendices.

Table 5: Long-term Effect of a Carbon Tax Example Calculations for India, Coal, 2030

Input Variables								
1 Projected year consumption							28,925	PJ/y
2 Projected Pre-VAT fuel price							1.99	$/GJ
3 Emissions Factor							0.09	tCO_2/GJ
4 Carbon tax per ton CO_2							70	$/t$CO_2$
5 VAT Rate							18%	
6 Price elasticity of fuel consumption							-60%	
7 Pretax fuel Price							1.99	
Calculations								
8 BAU Emissions			0.0946	*	28,925	=	2,736	MtCO_2/y
9 VAT			1.99	*	18%	=	$0.36	$/GJ
10 Projected post-VAT fuel price			1.99	+	0.36	=	$2.35	$/GJ
11 Carbon Tax per GJ fuel			0.0946	*	$70	=	$6.62	$/GJ
12 VAT on Carbon Tax			18%	*	6.622	=	$1.19	$/GJ
13 New fuel price	$2.35	+	$6.62	+	$1.19	=	$10.17	$/GJ
14 Price rises by factor of			$10.17	/	$2.35	=	$4.32	
15 Change in price relative to BAU			4.32	-	1	=	332%	
16 Fuel usage relative to baseline			4.32	^	-0.6	=	0.42	
17 Fuel Use with Carbon Tax			28,925	*	0.42	=	12,021	PJ/y
18 Change in fuel use relative to BAU			12,021	-	28,925	=	-16,904	PJ/y
19 CO_2 Emissions			12,021	*	0.0946	=	1,137	MtCO_2/y
20 Change in fuel use and emissions			0.42	-	1	=	-58%	
21 Carbon Tax Revenue (Emissions method)			70	*	1,137	=	$79,603	million
22 Carbon Tax Revenue (Energy price method)			$6.62	*	12,021	=	$79,603	million
23 Increase in VAT Revenue on Carbon Tax			79,603	*	18%	=	$14,328	million
24 Reduction in VAT Revenue from reduced Fuel Use	$1.99	*	18%	*	-16,904	=	-$6,068	million
25 Total Revenues	$79,603	+	$14,328	+	-$6,068	=	$87,863	million

Note: See Appendices for additional calculations for Natural Gas and Oil Products

Part D: Summary and Conclusions

1. Aggregation of all Fuel Types (Long Term Response, 2030)

Aggregation simply means summing up the emissions from all different fuel types. The table below sums up the calculations for coal (above) and for other fuel types (see Appendix). The impact on emissions is estimated to be substantially larger in the long term (-45%, relative to baseline) as opposed to the short-term effect alone (-19%, relative to baseline – see below).

Table 6: Aggregate Calculations for All Fuel Types (Long term, 2030)

	Coal		Natural Gas		Oil		Total	
BAU Fuel Consumption	28,925	+	5,530	+	15,775	=	50,230	PJ/y
BAU Emissions	2,736		310		1,153	=	4,199	$MtCO_2/y$
Total Fuel Consumption	12,021	+	3,572	+	13,413	=	29,006	PJ/y
Fuel Emissions with Carbon Tax	1,137	+	200	+	984	=	2,321	$MtCO_2/y$
Change in emissions	2,321	/	4,199	-	1		-45%	
Carbon Tax Revenues	$79,603	+	$14,025	+	$68,600	=	$162,228	million

2. Aggregation of all Fuel Types (Short Term Response, 2025)

We can also estimate the short-term effect of a carbon tax. The calculations are not set out explicitly in this paper, but follow the same principles as the long-term calculations, except the elasticities are much lower (about 1/3 of the long term – see page 9). For illustrative purposes here we assume that the carbon tax is introduced after 2020 and reaches $70/tCO_2$ shortly before 2025.

Table 7: Aggregate Calculations for All Fuel Types (Short Term, 2025)

	Coal		Natural Gas		Oil		Total	
BAU Fuel Consumption	23,479	+	3,955	+	13,227	=	40,661	PJ/y
BAU Emissions	2,221		222		970	=	3,413	$MtCO_2/y$
Total Fuel Consumption	17,722	+	3,458	+	12,410	=	33,591	PJ/y
Fuel Emissions with Carbon Tax	1,677	+	194	+	910	=	2,781	$MtCO_2/y$
Change in emissions	2,781	/	3,413	-	1		-19%	
Carbon Tax Revenues	$117,358	+	$13,579	+	$63,469	=	$194,407	million

3. Revenue Raised and Compensatory Spending

A comprehensive estimate of the fiscal effect of a carbon tax should incorporate implications for tax administration, its effect on other taxes, and its welfare impact. The cost of collecting a tax reduces the revenue it generates; among the advantages of an upstream carbon tax is its low administrative cost. The potential ramifications for other taxes are more complicated. For example, by reducing road traffic a carbon tax could diminish revenue from road tolls or vehicle-related duties. This effect can be estimated based on the projected reduction in road use while accounting for any behavioral changes that might boost revenue from other sources (e.g., the increased use of public transportation).[23]

Compensatory spending may be necessary to offset the cost of a carbon tax on vulnerable households. Some consumers will be able to avoid the tax by changing their behavior—indeed, disincentivizing carbon-intensive consumption is a key objective of the carbon tax—while others will be able to absorb the extra cost with no significant effect on their welfare. However, low-income households may be adversely impacted by higher consumer prices, and part of the revenue from the tax can be used to partially or wholly compensate these groups. Any such compensation should be implemented through the expenditure side of the budget—e.g., via transfer payments, increased social spending, or another mechanism unrelated to energy consumption. Attempting to carve out carbon-tax exemptions or deductions that will benefit vulnerable households will greatly complicate tax administration, distort relative prices, and likely entail substantial leakages to wealthier consumers, mirroring the typically regressive and inefficient distribution of fossil-fuel subsidies (IMF, 2010).[24]

[23] The direct effects of the carbon tax on VAT are not included in the main calculations, since these may be offset by other effects, but they are available in the appendices.

[24] A well-designed combination of carbon taxes and compensatory spending can be effective, popular, and affordable. A carbon tax in the Canadian province of British Columbia, in effect since 2008, was designed to be revenue neutral. The combination of measures has been popular, and the provincial economy is among the country's strongest.

4. Conclusions

Establishing a carbon tax can cut CO_2 emissions, raise fiscal revenue, and reduce local air pollution and other negative externalities associated with the consumption of fossil fuels. An upstream carbon tax is typically superior to a downstream tax, as it reaches all segments of the economy at a low administrative cost. In India, we estimate that a carbon tax rate of US$70/t$CO_2$ could, by 2025, reduce emissions by 19% and raise $194bn of revenue relative to the situation without a carbon tax. By 2030, such a tax would reduce emissions by 45% relative to the baseline, while raising US$162 billion in annual revenue.

An upstream carbon tax is an economically and administratively efficient way to raise revenue and to cut carbon emissions and other pollutants. It is particularly relevant to developing countries wishing to move to a cleaner development path.

Table 8: The Short-term Impact of a Carbon Tax on Emissions and Fiscal Revenue (in 2025)

Fuel	BAU Emissions ($MtCO_2/y$)	Emissions with Carbon Tax ($MtCO_2/y$)	Change from BAU	Direct Carbon Tax Revenue (US$ billions)
Coal	2,221	1,677	-25%	117
Natural Gas	222	194	-13%	14
Crude Oil & Oil Products	970	910	-6%	63
Total	3,413	2,781	-19%	**194**

Source: Author's calculations

Table 9: The Long-term Impact of a Carbon Tax on Emissions and Fiscal Revenue (in 2030)

Fuel	BAU Emissions ($MtCO_2/y$)	Emissions with Carbon Tax ($MtCO_2/y$)	Change from BAU	Direct Carbon Tax Revenue (US$ billions)
Coal	2,736	1,137	-58%	80
Natural Gas	310	200	-35%	14
Crude Oil & Oil Products	1,153	984	-25%	69
Total	4,199	2,321	-45%	**162**

Source: Author's calculations

Appendices

Appendix 1: Long-term (2030) Calculations for Other Fuel Types (other than coal)

Table 10: Calculations for Natural Gas

Input Variables								
1 Projected year consumption							5,530	PJ/y
2 Projected Pre-VAT fuel price							4.35	$/GJ
3 Emissions Factor							0.06	tCO_2/GJ
4 Carbon tax per ton CO_2							70	$/$tCO_2$
5 VAT Rate							18%	
6 Price elasticity of fuel consumption							-18%	
7 Pretax fuel Price							4.35	
Calculations								
8 BAU Emissions			0.0561	*	5,530	=	310	$MtCO_2$/y
9 VAT			4.35	*	18%	=	$0.78	$/GJ
10 Projected post-VAT fuel price			4.35	+	0.78	=	$5.14	$/GJ
11 Carbon Tax per GJ fuel			0.0561	*	$70	=	$3.93	$/GJ
12 VAT on Carbon Tax			18%	*	3.927	=	$0.71	$/GJ
13 New fuel price	$5.14	+	$3.93	+	$0.71	=	$9.77	$/GJ
14 Price rises by factor of			$9.77	/	$5.14	=	$1.90	
15 Change in price relative to BAU			1.90	-	1	=	90%	
16 Fuel usage relative to baseline			1.90	^	-0.18	=	0.89	
17 Fuel Use with Carbon Tax			5,530	*	0.89	=	4,926	PJ/y
18 Change in fuel use relative to BAU			4,926	-	5,530	=	-604	PJ/y
19 CO_2 Emissions			4,926	*	0.0561	=	276	$MtCO_2$/y
20 Fuel Use / BAU Fuel Use			0.89	-	1.00	=	-11%	
21 Carbon Tax Revenue (Emissions method)			70	*	276	=	$19,344	million
22 Carbon Tax Revenue (Energy price method)			$3.93	*	4,926	=	$19,344	million
23 Increase in VAT Revenue on Carbon Tax			19,344	*	18%	=	$3,482	million
24 Reduction in VAT Revenue from reduced Fuel Use	$4.35	*	18%	*	-604	=	-$1,535	million
25 Total Revenues	$19,344	+	$3,482	+	-$1,535	=	$15,015	million

Table 11: Calculations for Gasoline

Input Variables								
1 Projected year consumption							2,244	PJ/y
2 Projected Pre-VAT fuel price							27.74	$/GJ
3 Emissions Factor							0.07	tCO_2/GJ
4 Carbon tax per ton CO_2							70	$\$/tCO_2$
5 VAT Rate							18%	
6 Price elasticity of fuel consumption							-29%	
7 Pretax fuel Price							27.74	
Calculations								
8 BAU Emissions			0.0693	*	2,244	=	156	$MtCO_2/y$
9 VAT			27.74	*	18%	=	$4.99	$/GJ
10 Projected post-VAT fuel price			27.74	+	4.99	=	$32.73	$/GJ
11 Carbon Tax per GJ fuel			0.0693	*	$70	=	$4.85	$/GJ
12 VAT on Carbon Tax			18%	*	4.851	=	$0.87	$/GJ
13 New fuel price	$32.73	+	$4.85	+	$0.87	=	$38.46	$/GJ
14 Price rises by factor of			$38.46	/	$32.73	=	$1.17	
15 Change in price relative to BAU			1.17	-	1	=	17%	
16 Fuel usage relative to baseline			1.17	^	-0.29	=	0.95	
17 Fuel Use with Carbon Tax			2,244	*	0.95	=	2,142	PJ/y
18 Change in fuel use relative to BAU			2,142	-	2,244	=	-102	PJ/y
19 CO_2 Emissions			2,142	*	0.0693	=	148	$MtCO_2/y$
20 Fuel Use / BAU Fuel Use			0.95	-	1.00	=	-5%	
21 Carbon Tax Revenue (Emissions method)			70	*	148	=	$10,391	million
22 Carbon Tax Revenue (Energy price method)			$4.85	*	2,142	=	$10,391	million
23 Increase in VAT Revenue on Carbon Tax			10,391	*	18%	=	$1,870	million
24 Reduction in VAT Revenue from reduced Fuel Use	$27.74	*	18%	*	-102	=	-$1,308	million
25 Total Revenues	$10,391	+	$1,870	+	-$1,308	=	$10,040	million

Table 12: Calculations for Diesel

Input Variables								
1 Projected year consumption							6,499	PJ/y
2 Projected Pre-VAT fuel price							23.35	$/GJ
3 Emissions Factor							0.074067	tCO_2/GJ
4 Carbon tax per ton CO_2							70	$\$/tCO_2$
5 VAT Rate							18%	
6 Price elasticity of fuel consumption							-15%	
7 Pretax fuel Price							23.35	
Calculations								
8 BAU Emissions			0.0740667	*	6,499	=	481	$MtCO_2/y$
9 VAT			23.35	*	18%	=	$4.20	$/GJ
10 Projected post-VAT fuel price			23.35	+	4.20	=	$27.55	$/GJ
11 Carbon Tax per GJ fuel			0.0740667	*	$70	=	$5.18	$/GJ
12 VAT on Carbon Tax			18%	*	5.184	=	$0.93	$/GJ
13 New fuel price	$27.55	+	$5.18	+	$0.93	=	$33.67	$/GJ
14 Price rises by factor of			$33.67	/	$27.55	=	$1.22	
15 Change in price relative to BAU			1.22	-	1	=	22%	
16 Fuel usage relative to baseline			1.22	^	-0.15	=	0.97	
17 Fuel Use with Carbon Tax			6,499	*	0.97	=	6,307	PJ/y
18 Change in fuel use relative to BAU			6,307	-	6,499	=	-193	PJ/y
19 CO_2 Emissions			6,307	*	0.0741	=	467	$MtCO_2/y$
20 Fuel Use / BAU Fuel Use			0.97	-	1.00	=	-3%	
21 Carbon Tax Revenue (Emissions method)			70	*	467	=	$32,699	million
22 Carbon Tax Revenue (Energy price method)			$5.18	*	6,307	=	$32,699	million
23 Increase in VAT Revenue on Carbon Tax			32,699	*	18%	=	$5,886	million
24 Reduction in VAT Revenue from reduced Fuel Use	$23.35	*	18%	*	-193	=	-$2,307	million
25 Total Revenues	$32,699	+	$5,886	+	-$2,307	=	$34,098	million

Table 13: Calculations for Other Oil Products

Input Variables								
1 Projected year consumption							7,031	PJ/y
2 Projected Pre-VAT fuel price							9.97	$/GJ
3 Emissions Factor							0.07333	tCO_2/GJ
4 Carbon tax per ton CO_2							70	$\$/tCO_2$
5 VAT Rate							18%	
6 Price elasticity of fuel consumption							-21%	
7 Pretax fuel Price							9.97	
Calculations								
8 BAU Emissions			0.07333	*	7,031	=	516	$MtCO_2/y$
9 VAT			9.97	*	18%	=	$1.79	$/GJ
10 Projected post-VAT fuel price			9.97	+	1.79	=	$11.77	$/GJ
11 Carbon Tax per GJ fuel			0.07333	*	$70	=	$5.13	$/GJ
12 VAT on Carbon Tax			18%	*	5.1331	=	$0.92	$/GJ
13 New fuel price	$11.77	+	$5.13	+	$0.92	=	$17.82	$/GJ
14 Price rises by factor of			$17.82	/	$11.77	=	$1.51	
15 Change in price relative to BAU			1.51	-	1	=	51%	
16 Fuel usage relative to baseline			1.51	^	-0.21	=	0.92	
17 Fuel Use with Carbon Tax			7,031	*	0.92	=	6,444	PJ/y
18 Change in fuel use relative to BAU			6,444	-	7,031	=	-587	PJ/y
19 CO_2 Emissions			6,444	*	0.07333	=	473	$MtCO_2/y$
20 Fuel Use / BAU Fuel Use			0.92	-	1.00	=	-8%	
21 Carbon Tax Revenue (Emissions method)			70	*	473	=	$33,078	million
22 Carbon Tax Revenue (Energy price method)			$5.13	*	6,444	=	$33,078	million
23 Increase in VAT Revenue on Carbon Tax			33,078	*	18%	=	$5,954	million
24 Reduction in VAT Revenue from reduced Fuel Use	$9.97	*	18%	*	-587	=	-$2,783	million
25 Total Revenues	$33,078	+	$5,954	+	-$2,783	=	$30,412	million

Table 14: Aggregation

Oil Products Aggregation, 2030

	Gasoline		Diesel		Other Oil			
Total Oil Consumption	1,982	+	5,951	+	5,480	=	13,413	PJ/y
Carbon Tax Revenues Fuel Price Method	$9,617	+	$30,852	+	$28,132	=	$68,600	million
Change in VAT Due to VAT on Carbon Tax	$1,731	+	$5,553	+	$5,064	=	$12,348	million
Change in VAT Due to Reduced Fuel Use	-$1,308	+	-$2,307	+	-$2,783	=	-$6,398	million
Total Revenues	$10,040	+	$34,098	+	$30,412	=	$74,550	million
Oil Emissions			13,413	*	0.0733	=	984	$MtCO_2$/y

Aggregation of All Fossil Fuels, 2030

	Coal		Natural Gas		Oil		Total	
BAU Fuel Consumption	28,925	+	5,530	+	15,775	=	50,230	PJ/y
BAU Emissions	2,736		310		1,153	=	4,199	$MtCO_2$/y
Total Fuel Consumption	12,021	+	3,572	+	13,413	=	29,006	PJ/y
Fuel Emissions with Carbon Tax	1,137	+	200	+	984	=	2,321	$MtCO_2$/y
Change in emissions	**2,321**	**/**	**4,199**	**-**	**1**		**-45%**	
Carbon Tax Revenues	**$79,603**	**+**	**$14,025**	**+**	**$68,600**	**=**	**$162,228**	**million**
Change in VAT Due to VAT on Carbon Tax	$14,328	+	$2,525	+	$12,348	=	$29,201	million
Change in VAT by Reduced Fuel Use	-$6,068	+	-$1,535	+	-$6,398	=	-$14,000	million
Total Revenues	$87,863	+	$15,015	+	$74,550	=	$177,429	million

Appendix 2: Assumptions

In this case study we have made some assumptions as to what fuel consumption and prices would be in 2030 in the absence of a carbon tax. These are our 'business as usual' (BAU) projections. All prices are expressed in constant (mid-year) 2020 USD, with exchange rates of USD 0.0132 per Indian Rupee correct as of 19th May 2020.

Unit conversions were taken from UN data (United Nations, 2018). We use two standard sets of units i.e. GJ and PJ. The conversions between the units and the non-SI equivalents one million times bigger are the same. We use Net Calorific Value (NCV) throughout.

Table 15: Conversions (GJ-sized units)

From\Into	GJ
Million BTU	1.05506
GigaCalorie	4.19
MWh	3.6
TOE	41.868

Source: (United Nations, 2018)

Table 16: Conversions (PJ-sized units)

From\Into	PJ
Trillion BTU	1.05506
PetaCalorie	4.19
TWh	3.6
MTOE	41.868

The International Energy Agency World Energy Outlook (IEA, 2019) 'Current Policy Scenario' was used for projected energy consumption. Gasoline and diesel proportions of total oil use were kept constant based on mid-2019 proportions (Ministry of Petroleum & Natural Gas (India), 2020).

The World Bank's estimates for real energy prices were used, converted into constant 2020 US dollars per GJ (World Bank, 2020a)**.** BAU gasoline and diesel end consumer prices were kept constant in real terms based on latest Indian data.

Table 17: World Bank Commodities Price Forecast (nominal US dollars) as of Apr 23, 2020

Fuel	Unit	2019	2020	2025	2030
Coal, Australia	$/t	77.9	65.0	64.3	60.0
Crude oil, avg	$/bbl	61.4	35.0	52.7	70.0
Natural gas, Europe	$/mmbtu	4.8	3.1	5.2	7.0
Natural gas, US	$/mmbtu	2.6	2.0	2.9	4.0
Liquefied natural gas, Japan	$/mmbtu	10.6	8.7	8.7	8.5

Source: World Bank (2020)

The Manufacture Unit Value (MUV) Index was used to index to constant 2020 prices for this study.

Table 18: Manufacturing Unit Value (MUV) Index of Inflation

Inflation index 2010=100	2010	2019	2020	2025	2030
MUV index	100	99.5	99.0	107.8	118.6

Source: World Bank (2020)

Note that WB real prices are USD2010 so need to be updated to USD2020 for our purposes, using the MUV index. Thus, our prices are now expressed in constant USD 2020 thusly.

Table 19: World Bank Commodities Price Forecast (real 2020 US dollars) as of Apr 23, 2020

Fuel	Unit	2019	2020	2025	2030
Coal, Australia	$/mt	77.5	65.0	59.1	50.1
Crude oil, avg	$/bbl	61.1	35.0	48.4	58.4
Natural gas, Europe	$/mmbtu	4.8	3.1	4.8	5.8
Natural gas, US	$/mmbtu	2.6	2.0	2.7	3.3
Liquefied natural gas, Japan	$/mmbtu	10.5	8.7	8.0	7.1
Natural gas, Avg US & EU	$/mmbtu	3.7	2.6	3.7	4.6

Source: World Bank (2020)

Ideally, local prices would be used for natural gas and coal, but we also wish the methodology to be internationally applicable using easily available WB forecasts. Thus, we choose standard coal and oil prices and we choose a gas price forecast to be applicable to local prices (in this case the average of US and EU prices is closer to Indian local prices than Japanese LNG prices, so we use this – compare current average US and EU natural gas prices in Table 19 with Indian prices in Table 20 below). In the case of coal, we in effect use international prices, approximately correct for fuel costs after transportation in India once we convert to GJ terms (Kamboj & Tongia, 2018; Tongia & Gross, 2019; Vishwanathan et al., 2018).

Table 20: Local Natural Gas Prices (for comparison only, these are not used directly)

24. Domestic natural gas price and gas price ceiling (GCV basis)		
Period	**Domestic Natural Gas price in US$/MMBTU**	**Gas price ceiling in US$/MMBTU**
November 2014 - March 2015	5.05	-
April 2015 - September 2015	4.66	-
October 2015 - March 2016	3.82	-
April 2016 - September 2016	3.06	6.61
October 2016 - March 2017	2.5	5.3
April 2017 - September 2017	2.48	5.56
October 2017 - March 2018	2.89	6.3
April 2018 - September 2018	3.06	6.78
October 2018 - March 2019	3.36	7.67
April 2019 - September 2019	3.69	9.32
October 2019 - March 2020	3.23	8.43
April 2020 - September 2020	2.39	5.61

Source: (Ministry of Petroleum & Natural Gas (India), 2020)

Prices are converted to GJ terms using standard conversion factors based on standard calorific values.

Table 21: Assumed calorific values (converted to GJ terms)

Fuel	Calorific Value (NCV)	Source
Bituminous coal	29.00 GJ/ton	UN (2018)
Indian Coal (G11 Steam coal)	16.68 GJ/ton	Coal India ltd midpoint (Government Of India, 2020) NCV/GCV assumption 0.96
Australian Coal (Newcastle Std)	25.12 GJ/ton	GlobalCoal Newcastle standard; (World Bank, 2020a)
Crude Oil	5.8615 GJ/bbl (NCV)	UN (2018)
Gasoline	0.033148 GJ/liter (NCV)	Eurostat/IEA (2004)
Diesel	0.035249 GJ/liter (NCV)	Eurostat/IEA (2004)
Natural gas	1.055 GJ/MMBTU	Standard unit conversion.

Sources: (Eurostat et al., 2004; Government Of India, 2020; United Nations, 2018; World Bank, 2020a)

This produces our commodity price forecasts in real US dollars and GJ.

Table 22: World Bank Commodities Price Forecast (real 2020 US dollars) as of Apr 23, 2020

Fuel	Unit	2019	2020	2025	2030
Coal, Australia	$/GJ	3.1	2.6	2.35	
Crude oil, avg	$/GJ	10.4	6.0	8.26	9.97
Natural gas, avg US & EU	$/GJ	3.5	2.4	3.54	4.35

Source: Author calculation based on above data.

In other countries, when projections of energy demand or local fuel prices are not available, or consistency between projections and projected prices is a concern, an alternative approach is recommended. To calculate expected energy consumption in 2030, we can project forward energy demand from the most recent data based on GDP growth and estimated income elasticities, in line with the approach outlined in the IMF mitigation model (International Monetary Fund, 2019). That model uses income and price elasticities to project forward expected energy consumption.

Emissions factors were calculated from carbon content based on 2006 IPCC guidelines by the IEA (IEA, 2018).[25] Note that the unit tCO_2/GJ is exactly equivalent to $MtCO_2/PJ$.

[25] The IPCC emissions factors assume 100% oxidation of carbon. These emissions factors do not include the carbon footprint of energy used in the extraction or transportation of fossil fuels, nor of leaks of other greenhouse gases, such as methane. Losses in refinement are counted only (and imperfectly) in the overall use of oil, rather than in that attributable to gasoline or diesel specifically.

Table 23: Assumed Emissions Factors

Fuel	kgC/GJ	tCO_2/GJ	$kgCO_2$/liter
Bitumous Coal	25.80	0.0946	
Natural Gas	15.30	0.0561	
Crude Oil	20.00	0.0733	
Motor Gasoline	18.90	0.0693	2.30
Diesel	20.20	0.0741	2.61

Source: Author calculations based on IEA (2018), itself based on IPCC (2006) assumptions.

Transport Fuels: Assumptions about Local Prices, Consumption and Emissions Factors

First, in the absence of alternative information, we assume that the post-tax real price of gasoline and diesel, before any carbon tax, will stay at current levels (in real terms) in 2030.

Table 24: Latest local Gasoline, Diesel Post-tax prices and Exchange Rates

Quantity	Rate	Unit
Exchange Rate	75.68	INR/USD (19^{th} May 2020)
Post-tax Gasoline	69.59	INR/liter
Post-tax Diesel	62.29	INR/liter
Post-tax Gasoline	0.92	$/liter
Post-tax Diesel	0.82	$/liter
Post-tax Gasoline	27.7	$/GJ
Post-tax Diesel	24.8	$/GJ

Sources: Author calculations; Google (Exchange rate); (Ministry of Petroleum & Natural Gas (India), 2020)

Second, we assume that the proportions of gasoline and diesel (measured by energy content) as a proportion of total crude oil consumption will stay at current levels in 2030.

Third, for calculating the fuel price increase implied by the carbon tax (and the revenue from it), we use gasoline and diesel-specific emissions factors, with other crude oil products taking the aggregate emissions factor of crude oil (i.e. the carbon dioxide emitted per GJ of energy).

However, to calculate total emissions we do not directly have the emissions factor for 'other crude oil products', because the emissions factor of this 'residual' is not fixed. To calculate total emissions, we sum the total energy consumption (gasoline, diesel, and other oil products), and then multiply this figure by the aggregate emissions factor for crude oil.

Table 25: Local Road Fuel Prices (Original Data)

Price buildup of petroleum products (Rs./litre/Cylinder)		
Particulars	**Petrol***	**Diesel***
Price charged to dealers (excluding Excise Duty and VAT)	28.28	31.78
Excise Duty	22.98	18.83
Dealers' Commission (Average)	3.54	2.49
VAT (incl VAT on dealers' commission)	14.79	9.19
Retail Selling Price	**69.59**	**62.29**

Source: Ministry of Petroleum & Natural Gas (India), 2020

Appendix 3: Acronyms and Abbreviations

2020$: Constant 2020 US dollars – equivalent in purchasing power to this amount in $ in 2020
BAU: Business as Usual, e.g. projections in the absence of a carbon tax
BTU: British Thermal Unit. a unit of energy equal to 1.05506 GJ
CH_4: Methane, a greenhouse gas
CO_2: Carbon Dioxide, a greenhouse gas
C-Tax: Carbon Tax
Gcal: Gigacalorie; one million kilocalories. A unit of energy equal to 4.1868 GJ
GCV: Gross Calorific Value (Higher Heating Value): A different convention for measuring energy content
GEPR: Getting Energy Prices Right, an IMF book (Parry et al., 2014)
GJ: Gigajoules. A unit of energy. 1 GJ = 1 billion Joules
GST: Goods and Services Tax, a form of VAT adopted in India
IEA: International Energy Agency
IMF: International Monetary Fund
LNG: Liquid Natural Gas (composed mostly of methane)
LPG: Liquid Petroleum Gas – a distillate of crude oil, containing ethane and butane etc
MMBtu, mmbtu: Million British Thermal Units. A unit of energy equal to 1.05506 PJ
Mt: Million tons
Mtoe, MTOE: Million tons of oil equivalent
MUV: Manufacture Unit Value – an index of prices of internationally traded goods, used to track inflation
MWh: Megawatt-hour. A unit of energy (used for measuring electricity). 1 MWh = 3.6 GJ
NCV: Net Calorific Value (Lower Heating Value): A convention for measuring energy content
N_2O: Nitrous Oxide, a greenhouse gas
NO_x: Collective term for pollutants NO (Nitric Oxide) and NO_2 (Nitrogen Dioxide), local air pollutants
OBR: Output Based Rebating: refund of carbon tax based on physical output e.g. of electricity or aluminum
Pcal: Petacalorie; one million Gigacalories.
PJ: Petajoules. A unit of energy. 1PJ = 1 million GJ
PM2.5s: Atmospheric particulate matter with diameter less than 2.5 micrometers, a measure of air pollution
SO_2: Sulfur Dioxide, an air pollutant
t: Ton: A metric ton (tonne) = 1000kg. Also called *mt* (metric ton) in WB price forecasts
tC: Tons of carbon
tCO_2: Tons of carbon dioxide
Toe, TOE: Ton of Oil Equivalent. A unit of energy equal to 41.868 GJ
VAT: Value Added Tax, a tax on consumption
VOCs: Volatile Organic Compounds – a category of pollutants arising from evaporation of hydrocarbons, including from the fuel tanks and combustion products of vehicles
WB: World Bank; **WBG:** World Bank Group
WTO: World Trade Organization

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