Macroeconomics of Climate Change: Mitigation Strategies

IMF course

(notes by Leonarda Srdelić)

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Contents

1. Designing Mitigation Policies

1.1 Introduction to Mitigation

Definition 1 *Mitigation is the stabilisation of global temperatures to internationally agreed targets of between 1.5 and 2 degrees.*

This implies cutting global greenhouse gas emissions 25% to 50% below 2019 levels by 2030 and progressing to zero net emissions by around mid-century. In turn, this will require additional measures equivalent to a global carbon price exceeding $75 per ton by 2030.

There is currently an ambition gap, because even if fully achieved, current pledges would cut global emissions in 2030 by only 2/3 of what is needed even for a 2 degrees Celsius target. And the policy gap is much larger because the current *global average carbon price* is only $3 per ton.

Energy-related emissions, which are 78% of total global greenhouse gases (Fig 1), are the most practical to tax. Power, transport, buildings, and industry account for 33%, 17%, 6%, and 13% of global emissions of fugitive emissions, mainly methane leaks from extractive industries, another 6%. In turn, coal, oil, and natural gas combustion account for 33%, 21%, and 18% of global emissions. Other emissions sources include agriculture, industrial process emissions, and waste, which are 12%, 6%, and 4% of emissions, and land - use emissions, which are more difficult to measure.

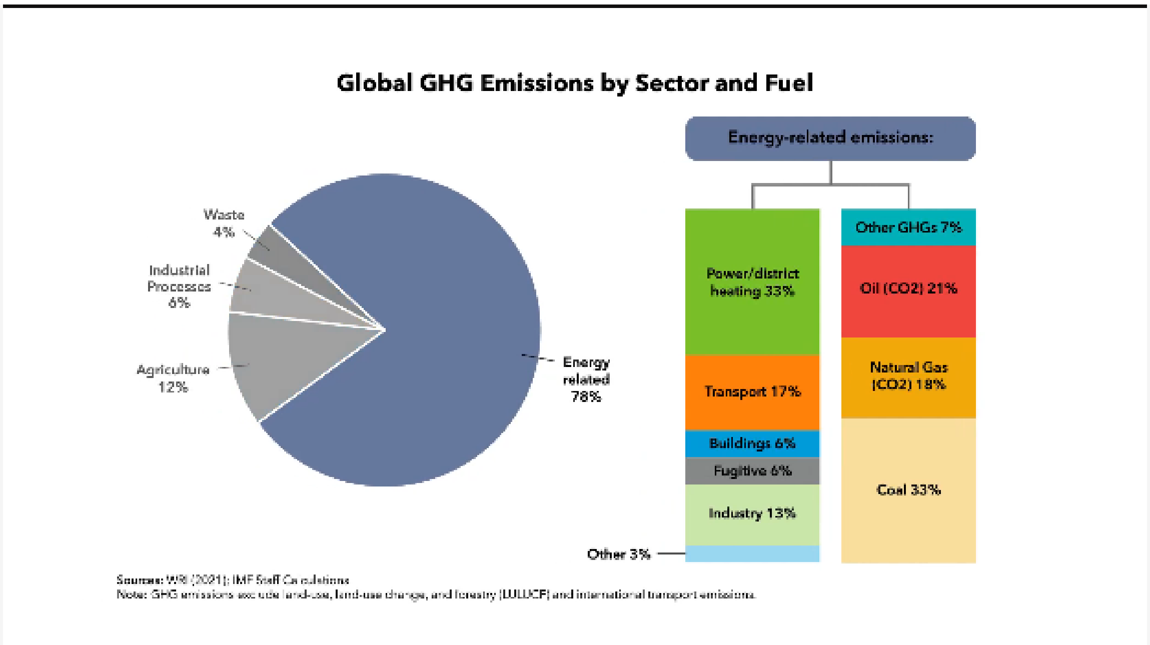


Figure 1

Countries will need comprehensive mitigation strategies which should include a package of mitigation instruments:

- carbon pricing,
- measures in the main energy sectors,
- pricing of broader emissions

Additional measures can enhance the political acceptability of the strategy such as

- incidence analysis,
- equitably distributed burdens, and
- measures to address competitiveness and free - riding at the international level.

Strategies should also include public investment in clean infrastructure networks and measures to address the technology - related market failures.

1.2 Carbon Pricing

Definition 2 *Carbon pricing is charges on the carbon content of fossil fuels or their emissions.*

The basic rationale for carbon pricing is that it *promotes all behavioural responses* for reducing emissions across the energy sector as the carbon price is reflected in higher prices for fossil fuels, electricity, and energy-intensive products. These responses include:

- reducing driving;
- shifting to electric vehicles
- shifting to cleaner gasoline/diesel vehicles;
- reducing building emissions,
- reducing industrial emissions,
- reducing electricity demand;
- shifting from coal/gas to renewable power generation; and
- other fuel switching to reduce the CO2 intensity of power generation, for example, from coal to gas and from these fuels to nuclear.

Carbon pricing also strikes the cost effective balance across these responses as the marginal cost of reducing emissions, which equals the carbon price, is equated across these responses (Fig 2). Other mitigation instruments, for example, subsidies for electric vehicles or for renewable generation, push on only one of these marginal cost curves rather than the envelope of the marginal costs.

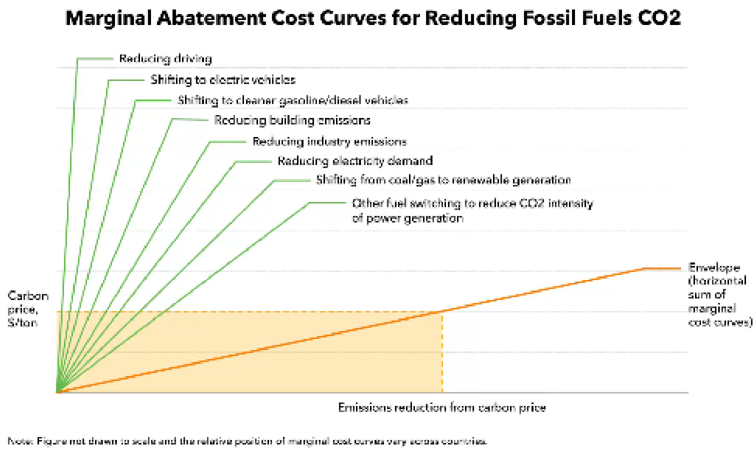


Figure 2

Other rationales for carbon pricing

- increases investment - Carbon pricing also provides the price signal that's critical for redirecting new investment to clean technologies;
- raises revenue - which is especially appealing to emerging market and developing economies with large informal sectors that might not be able to mobilize sufficient revenue for sustainable development goals from broader fiscal instruments.
- domestic environmental co-benefits generation like reductions in local air pollution mortality, which are potentially large in countries like China and India.
- can be straightforward administrate, for example, if it builds off existing fuel tax collection.

But it is important to get the **basic design details** right. This includes:

- emissions coverage - covering emissions from the power, industry, transport, and building sectors and with a uniform price;
- price certainty - providing a certainty over emissions prices to mobilise private investment.
- stringency - the stringency of the policy should be in line with mitigation commitments, with prices ramping up over time;
- revenue use - and revenues should be used equitably and productively, for example:
  - for targeted assistance for low income households,
  - lowering the burden of other taxes,
  - funding climate investments, or sustainable development goals.

The charges on carbon pricing are implemented through carbon taxes or emissions trading systems (ETSs).

Carbon Taxes vs. Emissions Trading Systems

Carbon taxes are the most natural carbon pricing instrument as they:

- can be imposed midstream on the carbon content of fossil fuel supply, which means integrating carbon charges into existing fuel taxes and applying charges to other oil products, natural gas, and coal.
- can provide price certainty by specifying a future trajectory of tax rates, and the revenues accrue directly to finance ministers for general purposes.
- are compatible with overlapping instruments like energy efficiency regulations, because these instruments will reduce emissions rather than the emissions price.

Emissions trading systems can provide similar benefits but only if they are designed to behave like taxes. These systems are applied downstream to smokestack emissions from power generators and industry, though there can be extended midstream to cover embodied carbon in transportation and building fuels. But emissions trading systems may not be practical for capacity constrained countries, and price floors implemented, for example through, minimum prices from allowance auctions can provide more certainty over emissions prices. And allowance auctions can generate revenue, they're often allowances are freely allocated or revenues from allowance auctions are often earmarked for environmental purposes.

Under pure Emissions Trading Systems overlapping instruments reduce emissions prices but not emissions, which are fixed by the cap. Their price floors can help to address this incompatibility.

Carbon pricing schemes are gaining momentum. There are now 64 carbon pricing mechanisms in place, including 30 schemes at the national level, and just this year, major pricing schemes have been implemented in China and Germany. The EU emissions price has risen to over 60 euros per ton, and Canada has announced it will increase its price to $135 US per ton by 2030. But only 15% of global emissions are currently priced. Only eight schemes have coverage rates exceeding 50% of greenhouse gas emissions, for example, Korea, New Zealand; and only eight schemes have prices above $40 per ton, for example, Sweden, Finland, Norway and the UK.

1.3 Sectoral Policies for Energy

There are limits on the acceptability of carbon pricing due to the burden of higher energy prices on households and firms. This creates an important role for reinforcing policy instruments at the energy sectoral level. These instruments avoid significant energy price in practice, because they avoid the pass through of carbon tax revenue or allowance rent in higher energy prices.

1.3.1 Feebates

Traditionally, sectoral measures have taken the form of regulations. For example, on vehicle emission rates, the energy efficiency of appliances or clean technology subsidies for renewable generation and electric vehicles. A more novel approach is feebates[1], which are the fiscal analogue of regulations and which provide a *sliding scale of fees* on products or activities with above average emission rates and a *sliding scale of rebates* for products or activities with below average emission rates.

Feebates promote all responses for reducing the emissions intensity of a sector. For example, shifting to electric vehicles and shifting from low to high fuel economy gasoline and diesel vehicles. In contrast, substitutes for electric vehicles only promote the former response.

Feebates can be revenue neutral. In contrast, a subsidy for clean technologies will lose revenue. **And feebates are automatically cost effective**, as they provide the same reward for reducing emissions by an extra ton across different responses. Regulations are only cost effective if there is extensive credit trading.

If applied to transportation, feebates would charge a fee on vehicle sales equal to a CO2 price times the difference between a vehicle's CO2 per mile and the fleet wide average CO2 per mile times the average amount vehicles are driven over their lifetime:

$$\begin{aligned} Fee = &[\text{CO2price}]* \\ &[\text{vehicle's CO2/mile} - \text{fleetwide avg CO2/mile}]* \\ &[\text{the avg lifetime mile driven per vehicle}] \end{aligned}$$

This would alter the relative price of vehicles without a new tax burden on the average motorist. For illustration, a feebate of $600 per ton of CO2 would provide a $6,000 subsidy for zero emission vehicles and impose taxes on emissions intensive vehicles that are broadly consistent with those in many European countries. The subsidies would decline over time, as the fleet wide average CO2 per mile declines, while taxes on high emission vehicles would increase.

Similarly, if applied to power generation, utilities would be subject to a fee equal to a CO2 price times the difference between their CO2 emissions per kilowatt hour average across their plants and the industry wide average CO2 per kilowatt hour multiplied by their output:

$$\begin{aligned} Fee = &[\text{CO2price}]* \\ &[\text{CO2/kWh - industry-wide avg CO2/kWh}]* \\ &[\text{output}] \end{aligned}$$

This would encourage reductions in the emissions intensity of generation without a significant increase in electricity prices. For illustration, a feebate with price of $50 per ton would impose a fee of $0.03 per kilowatt hour on coal generation and a subsidy of $0.02 per kilowatt hour for renewables based on the average emissions intensity of the US power generation fleet.

Feebates could also be applied to the industrial sector. For example, for the steel industry, firms could be subject to a fee equal to a CO2 price times the difference between their CO2 per ton of steel and an industry benchmark emission rate multiplied by their output. Similar schemes could apply to other industries with CO2 prices harmonized across the schemes to promote cost effectiveness. These feebates would encourage cleaner production

[1] A system of charges and rebates whereby energy-efficient or environmentally friendly practices are rewarded while failure to adhere to such practices is penalized, e.g. a feebate scheme rewards buyers of fuel-efficient cars and penalizes those who purchase gas-guzzlers

technologies without a cost increase for the average firm so they largely avoid the competitiveness concerns about carbon pricing, though unlike pricing, they do not encourage a reduction output.

In the building sector, feebates could be used to lower the relative price of energy efficient fridges, air conditioners, and other appliances. They could also be used to lower the relative price of low carbon heating systems, like electric pumps, and they could be integrated into property taxes to reward buildings that have high energy performance ratings and penalize buildings with low ratings.

1.4 Broader Emission Sources

For the forestry sector, IMF recommends a nationwide feebate approach, with landowners subject to a fee equal to an annualised CO2 price, times the difference between carbon storage on their land and a baseline period, and current carbon storage:

$$\begin{aligned} Fee = & [\text{CO2price (annualized)}] * \\ & [\text{baseline carbon storage - current storage}] \end{aligned}$$

This will cost-effectively promote afforestation, reduce deforestation, and changes in management practices to store more carbon.

This approach is more comprehensive than a project-by-project approach and avoids a fiscal cost to the government, though it does require property rights are well-established at the forest and agricultural border. Carbon storage is monitored by a combination of satellite aerial photography and on the ground tree sampling.

Agriculture is challenging because emissions are difficult to measure and the sector is trade-exposed. One possibility is to use a proxy pricing scheme based on farm-level data on outputs and inputs like fertilizer, and default emissions factors - and keep revenues within the sector, for example returning them in proportion to the value of output. This will promote a shifting from livestock to crop production and less emissions-intensive farming methods without a new tax burden on the average farmer.

And for the extractive sector, proxy pricing schemes might be based on fuel supply and default emission leakage rates. Rebates might be provided to firms that install metering technologies and can demonstrate their emissions are below the default rate.

2. Quantitative Analysis of Mitigation Policies

2.1 Achieving Paris Agreement

Under the Paris Agreement, countries agreed to contain warming well below 2 degrees, ideally to 1.5 degrees Celsius above pre-industrial levels. To achieve the Paris Agreement's

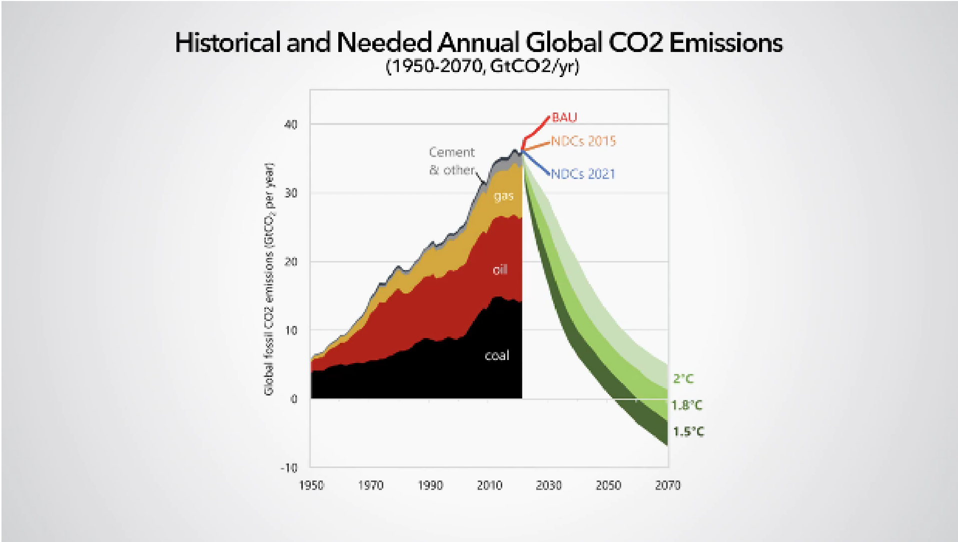


Figure 3

goals, emissions must be cut by one quarter to one half by 2030, followed by a rapid transition to net zero emissions by around 2050 (Fig 3).

To do this, the world needs to close two pervasive policy gaps:

1. First, there is a country ambition gap. All countries have committed to cutting emissions by 2030 and a growing number have committed to reaching net zero emissions by around 2050. Now although these targets are below business as usual, they're not aligned with what is required for well below 2 degrees, let alone 1.5 degrees.

2. Secondly, there is a mitigation policy gap. Current policies would not achieve the existing targets the countries have set out. So to achieve global climate mitigation, we must close both gaps quickly. The most important intervention we can make is to decarbonize energy consumption. Now this means two things.

   (a) First, we need to decarbonize electricity, shifting generation sources from coal and natural gas to low-carbon sources, like wind and solar.

   (b) Second, we need to electrify end uses of energy. This means shifting all energy-consuming capital goods in the world, including all the cars, all the buildings, and all the industrial equipment, away from fossil fuels towards low-carbon electricity.

There are other very important interventions we also need to make. This includes shifting to sustainable forms of agriculture, protecting carbon sinks, and shoring up biodiversity. But decarbonizing our use of energy is critical to cutting global emissions to zero.

Unfortunately, the world is not on track to achieve this (Fig 4). Following the temporary drop in global emissions in 2020 due to COVID-19, emissions are expected to rise well above a 1.5 or 2 degree pathway in the baseline. This could set up a disorderly transition after 2030 as the world would then need even more drastic emissions cuts, potentially undermining global prosperity and stability.

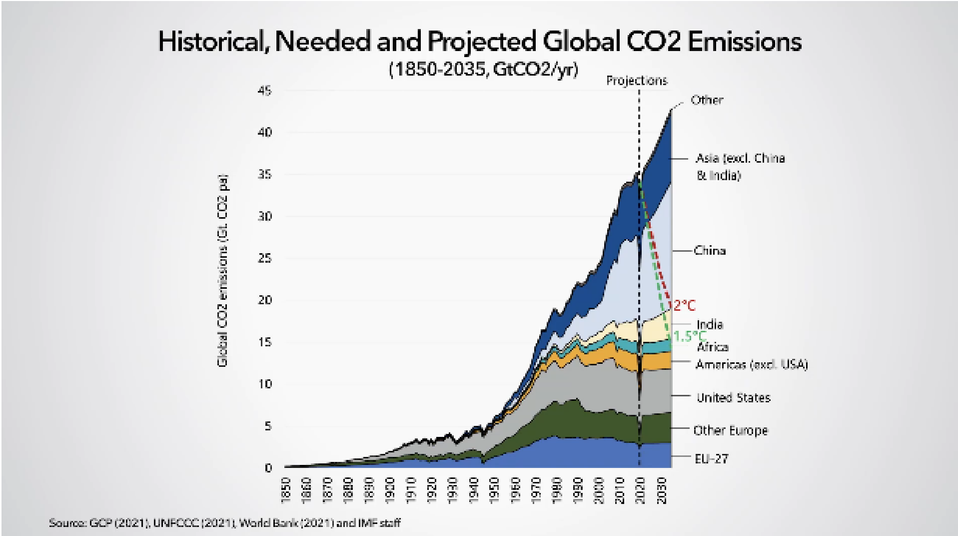


Figure 4

To achieve these rapid emissions reductions, all countries need to cut emissions. Accordingly, under the Paris Agreement, both developing and developed countries committed to cutting emissions. Developed countries are expected to cut faster while facilitating international climate finance to developing countries for equity reasons.

However, global incentives remain skewed towards overconsumption of fossil fuels. The global average explicit carbon price is only about \$3 per ton, but even when including all energy taxes, incentives remain weak. When we take all taxes on fuels and weigh by their carbon content, we get what's known as an effective carbon rate. This has not risen significantly for three decades, averaging around \$25 per ton of CO2 (Fig 5). To get below 2

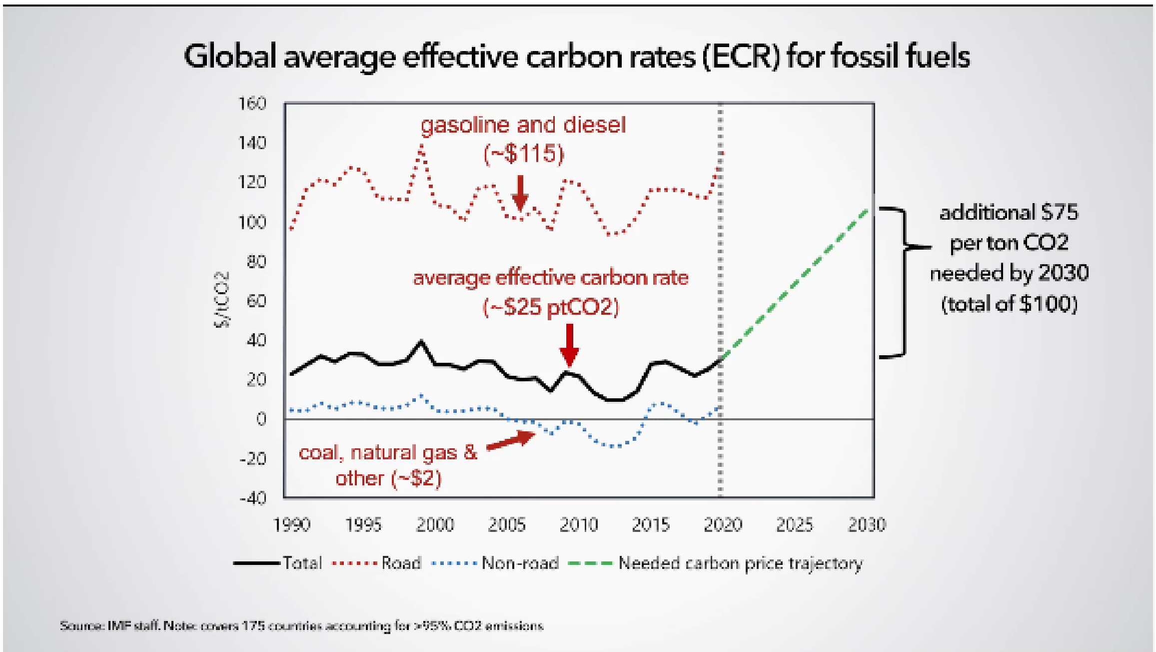


Figure 5

degrees C, we will need an additional \$75 by 2030, which means a total of around \$100 when including all energy taxes. As well as being too low, existing taxes on fossil fuels are heavily distorted. Just under 2/3 of fuel emissions are currently untaxed, and these are mostly coal and natural gas. About one third of emissions have some price, but this is mostly gasoline and diesel, which are both less responsive to pricing.

Lastly, there is the problem of negative pricing (Fig 6). Explicit fossil fuel subsidies cover a small portion of global emissions, but can be very large.

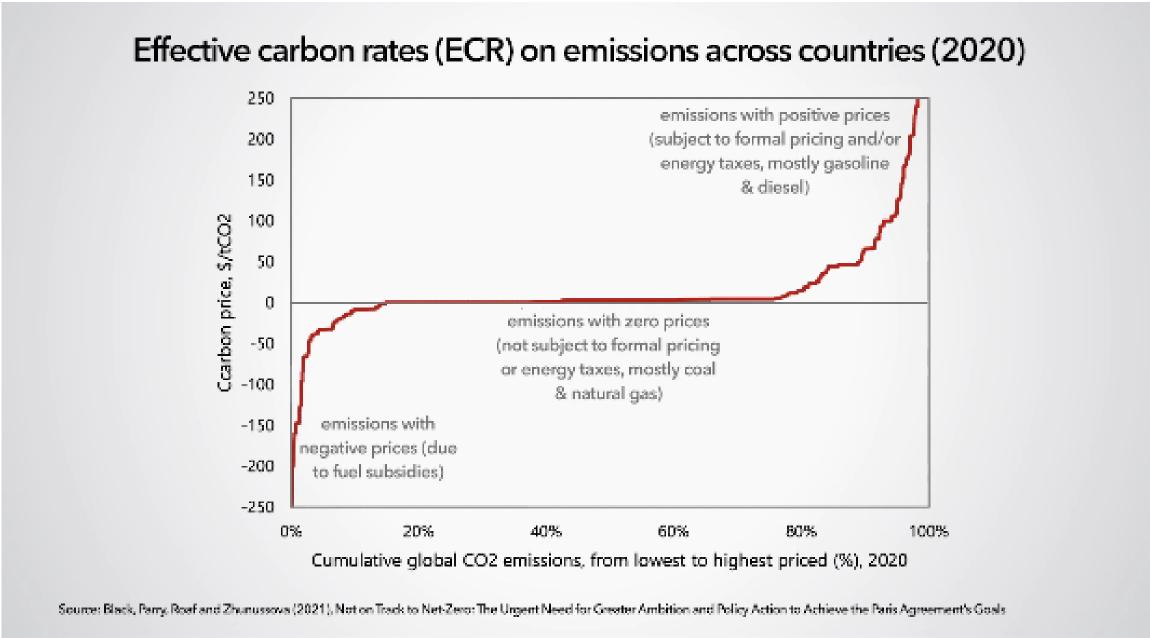


Figure 6

Though these are troublesome, undercharging for environmental costs or implicit subsidies are much worse. So globally, we need to significantly increase the price of fossil fuels.

There is significant heterogeneity among countries on both emissions targets and the needed prices to achieve those targets (Fig 7). Some countries can achieve their targets with very low carbon prices. This may be symptomatic of low climate ambition. For other countries, needed reductions can be as much as half of emissions by 2030 versus baseline. For these countries, carbon pricing can still make a significant contribution, but other policies may be needed, especially in hard-to-abate sectors like buildings, transport, and agriculture.

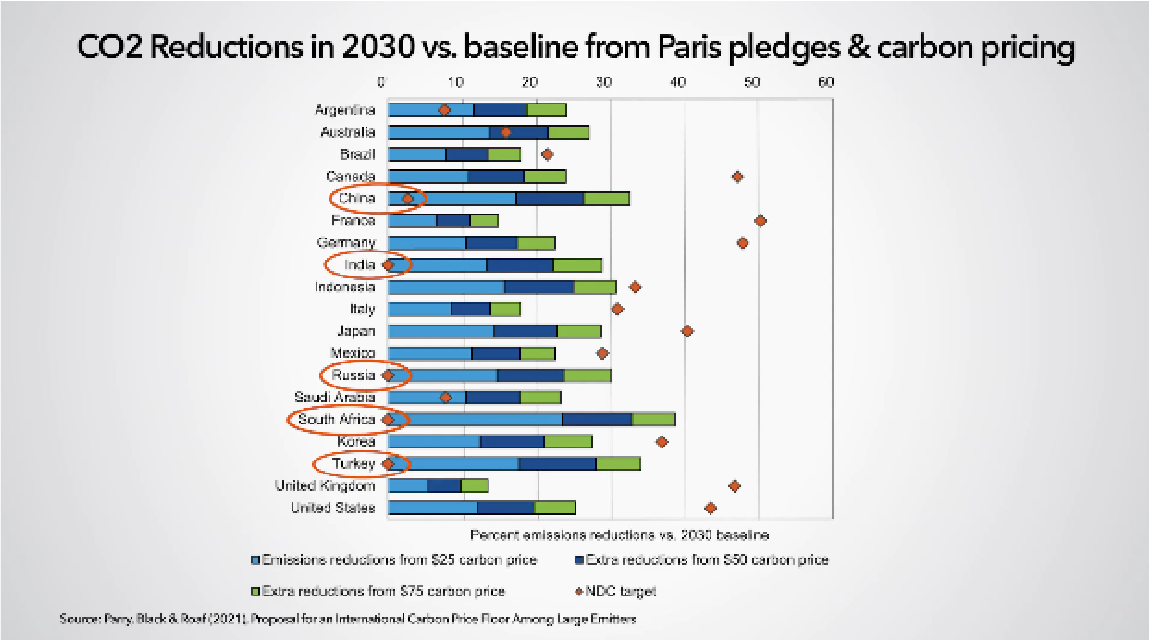


Figure 7

2.2 Environmental Externalities

Definition 3 *Environmental externalities are defined as the uncompensated environmental effects of production and consumption that affect consumer utility and enterprise cost outside the market mechanism.*

Beyond climate change, there are other environmental externalities from fossil fuel consumption. What are these externalities and how large are they?

Let's take an illustrative example to clarify concepts (Fig 8). Let's suppose you purchase a liter of gasoline at the pump which costs $0.28. Let's further suppose that the actual private costs are, in fact, $0.57. What explains the gap?

In this case, there is an explicit subsidy from the government of $0.19. This could, for example, be a direct financial transfer to fuel producers or consumers. Additionally, the government charges VAT on other consumer goods but not on gasoline. Hence, it forgoes $0.10 in revenue, which is an opportunity cost. But we know there are other costs from gasoline consumption beyond private costs.

Full social costs include externalities, not only the damages from global warming, but also from local air pollution, road accidents, and congestion. The full social costs equate to the socially optimum or efficient price of $1.00 per liter of gasoline. In sum, there is a subsidized price of $0.28; an explicit subsidy of $0.19 cents; and an implicit subsidy, which is equal to the forgone VAT plus externalities of $0.53.

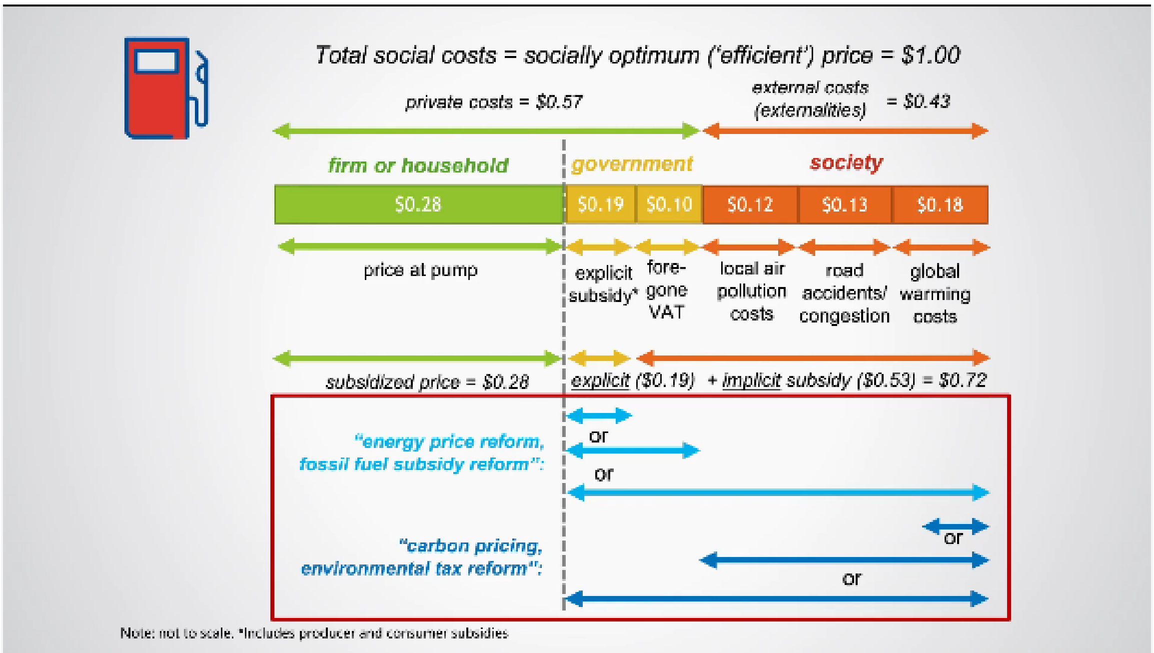


Figure 8

How can we close the gap between the subsidized price and the efficient price? Well, policy makers use various terms such as energy price reform, fossil fuel subsidy reform, or carbon pricing, and environmental tax reform. These sometimes seek to close part or all of the gap. But broadly, from a welfare maximization standpoint, the objective should be to narrow the full gap between current and efficient prices.

So overall, countries are still not getting energy prices right. Fossil fuel prices remain well below their socially optimal levels, especially on coal, despite its very negative impact on the climate, on air quality, and on human health. As a result, global fossil fuel subsidies remain persistently large (Fig 9).In 2020, total subsidies were around $5.9 trillion, worth about 6.8% of GDP. Explicit subsidies have declined slightly since 2015 but remain a small portion of total subsidies. Implicit subsidies, which are the externalities and forgone VAT, account for the vast majority of the gap. Without corrective policies they're expected to grow to 2025.

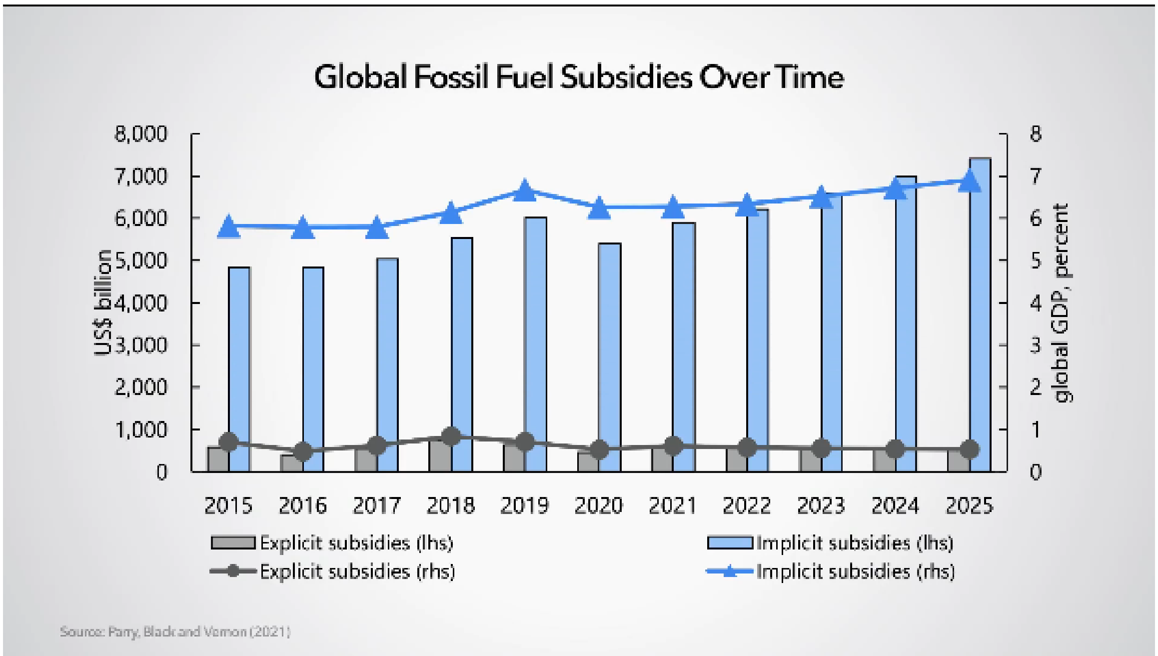


Figure 9

Closing the gap between existing and efficient fuel prices by 2025 would cut global CO2 emissions by 36% below baseline (Fig 10). This is in line with 1.5 degrees, though further measures would be needed to achieve net-zero emissions by mid-century.

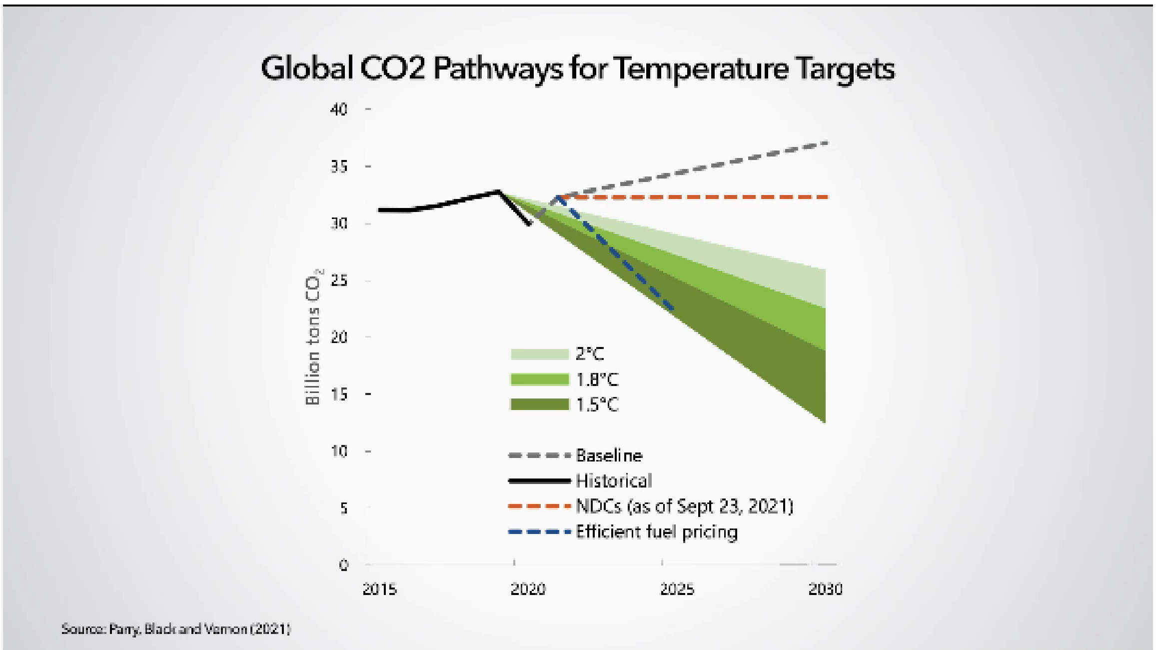


Figure 10

2.3 Energy Prices, Emissions, and Revenues

What are the impacts of reforms like carbon pricing? So we'll first talk about the impacts on energy prices, emissions and revenues. And for that, let's take an example, in this case, a \$75 carbon tax in Mexico by 2030 (Fig 11). We know that carbon pricing raises fossil fuel prices, especially on coal, followed by natural gas, liquid fuels like gasoline, diesel, LPG, and kerosene, and finally, electricity, depending on the carbon intensity of generation. This reduces demand for fossil fuels.

Energy price changes for \$75/tCO2 in 2030 in Mexico
(weighted by consumption)

Fuel	Unit	Baseline price in 2030, \$/unit	Price with \$75 carbon tax in 2030, \$/unit	% change	Share in energy-related CO2 emissions, 2018	Share of household consumption, 2018
Gasoline	liter	1.13	1.34	19%	25%	90.8%
Diesel	liter	1.18	1.45	22%	13%	0.1%
LPG	liter	0.68	0.84	25%	7%	73%
Kerosene	liter	0.71	0.92	29%	0%	0%
Oil	barrel	59.80	97.81	64%	9%	0%
Coal	GJ	2.57	10.29	300%	11%	0%
Natural gas	GJ	5.25	9.81	87%	36%	3%
Electricity	kWh	0.08	0.10	29%	—	21%

Source: IEA (2021), IMF staff
Notes: Household consumption is calculated as a share in total industrial, transport, and residential consumption.
We assume that households consume 91% of gasoline in transport consumption and all LPG

Figure 11

Initially, firms and households may opt to reduce their immediate demand or engage in fuel switching (Fig 12). Then they gradually invest in renewable energy and low carbon assets. For instance, households may switch from gasoline or diesel to electric vehicles. And firms may adopt or innovate in new low carbon technologies. So overall, demand for energy decreases, and the composition of energy demand gradually becomes greener.

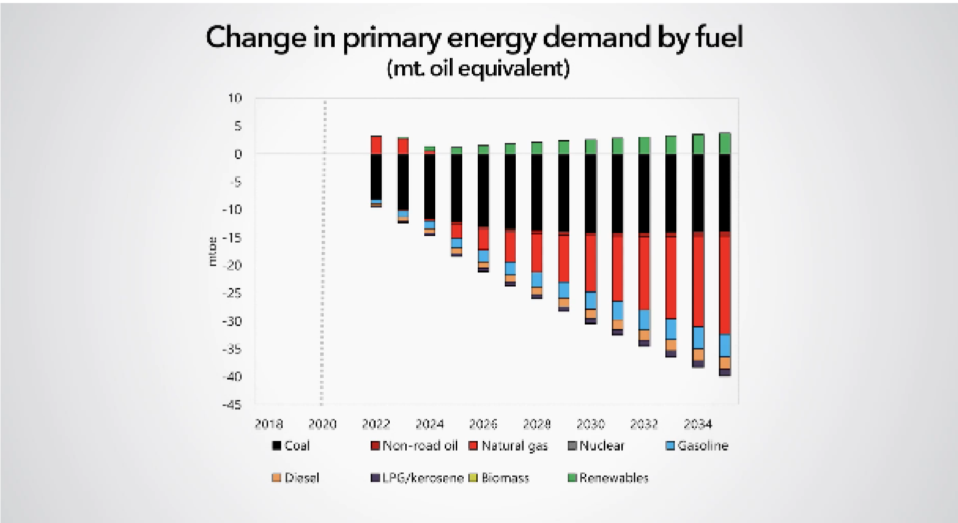


Figure 12

Critically, there's a shift in the power sector, which, as we saw, is essential to decarbonization for all countries. Pricing initially results in fuel switching from coal to gas as a source of generation and then increases investment in renewable sources like solar and wind (Fig 13).

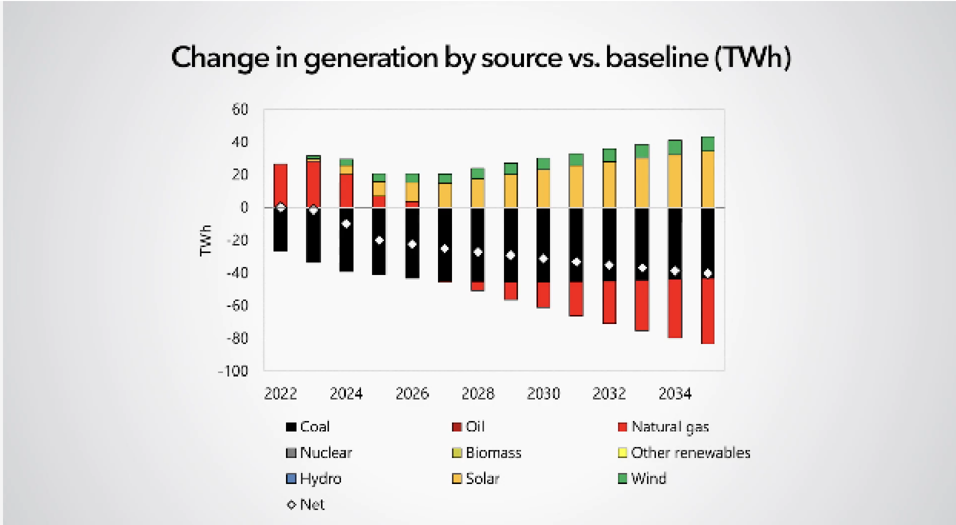


Figure 13

So there is a gradual shift towards lower and zero carbon sources of generation, with solar and wind increasingly diffusing within the grid, subject to the availability of batteries to ensure system stability and reliability.

Other major energy consuming sectors also increase energy efficiency and shift the composition of energy consumption, notably in transport, industry, and to a lesser extent, residential (Fig 14). These sectors have very marginal abatement costs and price responsiveness.

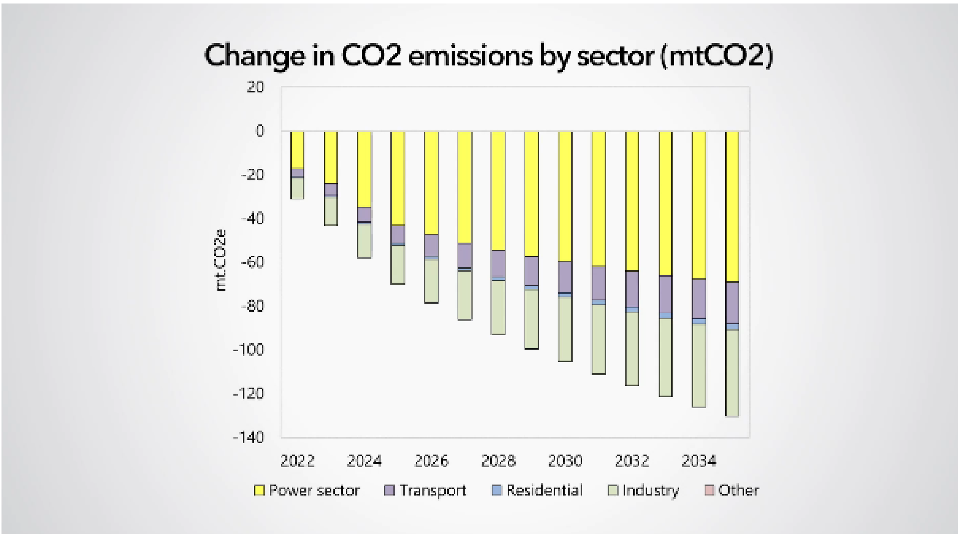


Figure 14

So as a result of this policy reform, Mexico could achieve its Paris Agreement target. Additionally it would help get Mexico on a pathway to net zero emissions by 2050.

The taxation policy could also raise substantial revenues, worth about 1.8% of GDP by 2030. How to use these revenues is critical for GDP impacts. For instance, using the revenues for a mix of transfers, public investment, and labor tax reductions would partly or more than fully offset the negative impacts of the tax on GDP. You can see from this chart (Fig 15), the reform is slightly negative initially, reducing GDP by around 0.2%. But in subsequent years the policy raises GDP growth rates by about 0.3%.

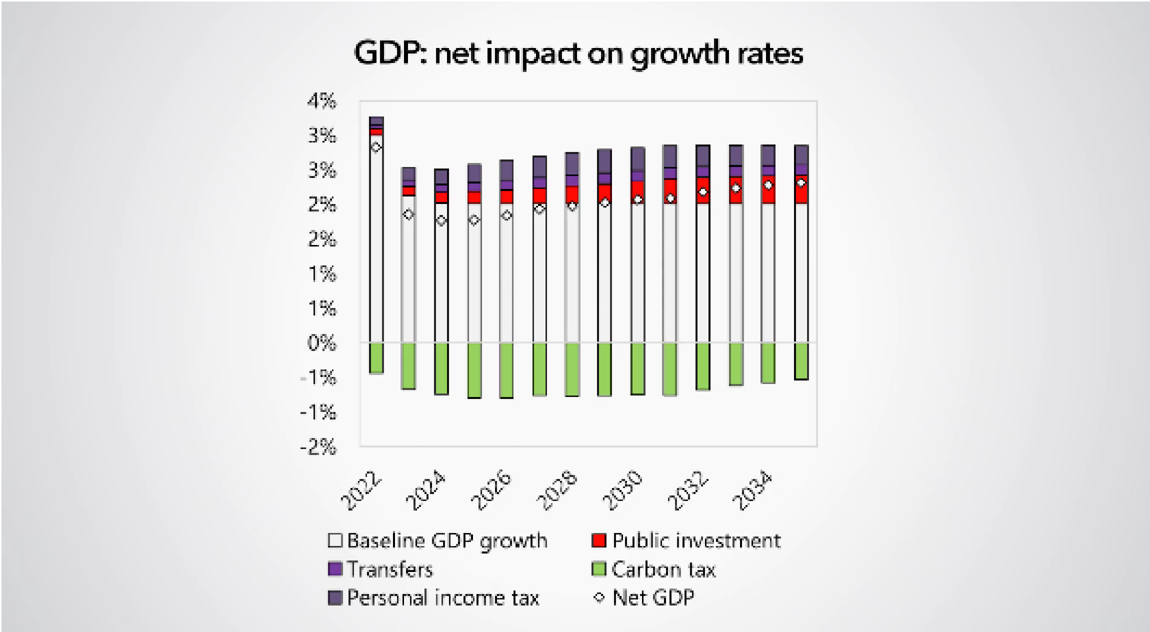


Figure 15

2.4 Employment and Output

Carbon pricing and fossil fuel subsidy reforms can have economic impacts:

1. First, it is important to note that, for many countries, much of the economy is already low carbon. In the EU, about 80% of employment and gross value added are in the sectors which account for less than 20% of emissions (Fig 16).

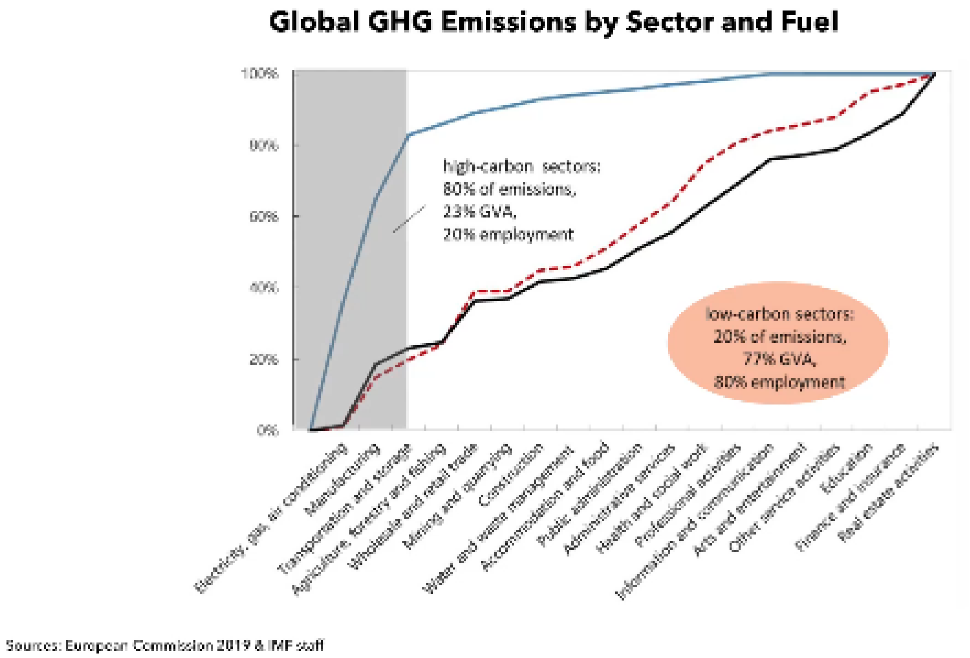


Figure 16

2. Second, there are a lot of studies in environmental economics, examining the potential effects of environmental fiscal reforms on emissions, output, and employment.

   Fig 17 summarises about 100 of the early simulation-based studies looking at these potential impacts. Almost all found a reduction in CO2 emissions. Most found an increase in net employment. And there was about an even split between those finding an increase or a decrease in economic output.

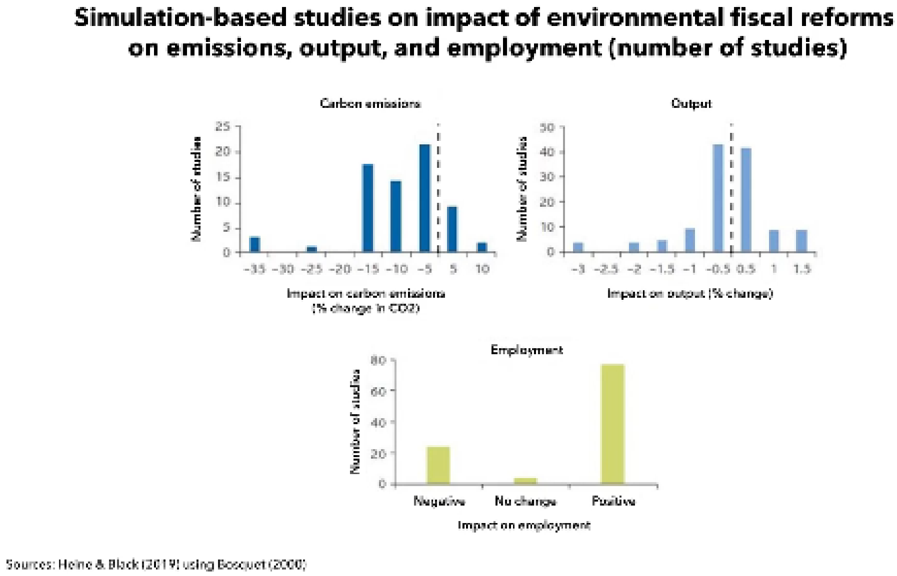


Figure 17

More recently, econometric studies have examined these reforms, with some support for earlier findings. For example, this study across 75 developing and developed countries finds that labor taxes broadly reduce GDP more than energy taxes (Fig 18). For a 1% worth of GDP increase in revenues from personal income taxes, multiplier effects range from about 1.4% to 2.3%, after three years. By contrast, energy taxes lower GDP by less, or about 0.9% at impact and 1.9% after three years. Though, it should be noted, the range is wider. And also, in the long run, the effect is not statistically significant.

Similarly, for employment, labuor taxes reduce employment by about 0.7% in the long run, which is statistically significant (Fig 19). Energy taxes, by contrast, are not found to have a statistically significant impact on employment.

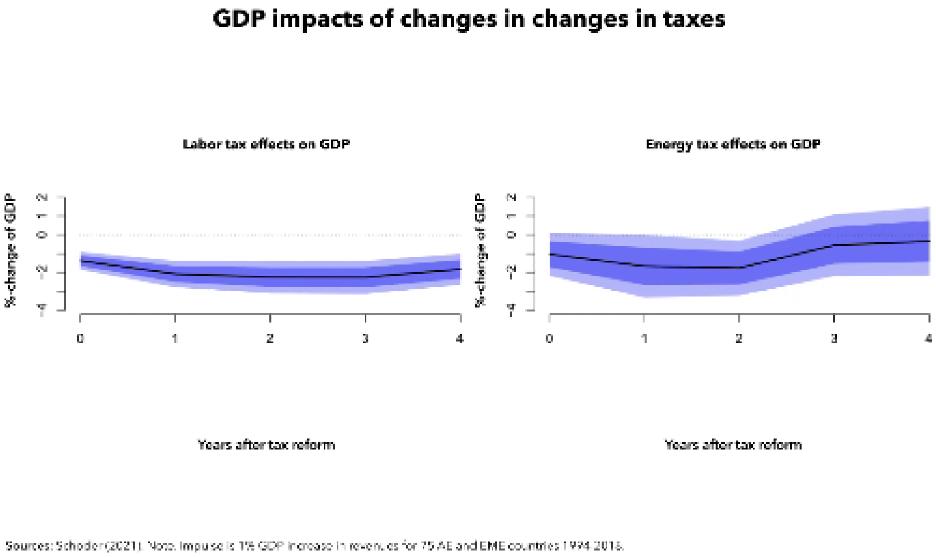


Figure 18

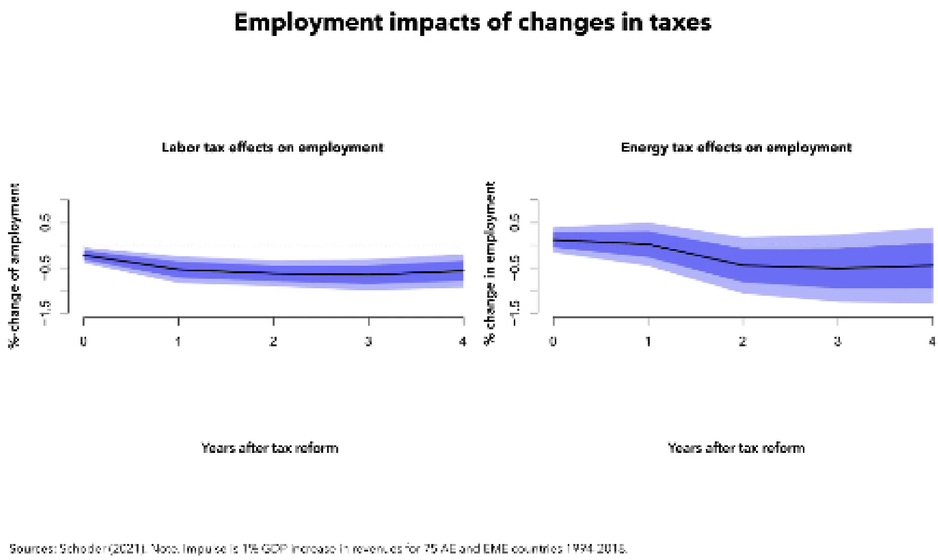


Figure 19

Put together, these findings suggest that shifting the tax burden from labor to carbon emissions may have positive effects on GDP and employment in the long run. Though, there could be some transitional costs. So that's energy taxes, but what about actual carbon tax reforms that include revenue recycling?

This analysis of carbon pricing reforms in 31 European countries finds no evidence of a reduction in either GDP or a reduction in employment (Fig 20).

Similarly other studies have found either slightly negative, zero, or slightly positive impacts of carbon pricing reforms on GDP.

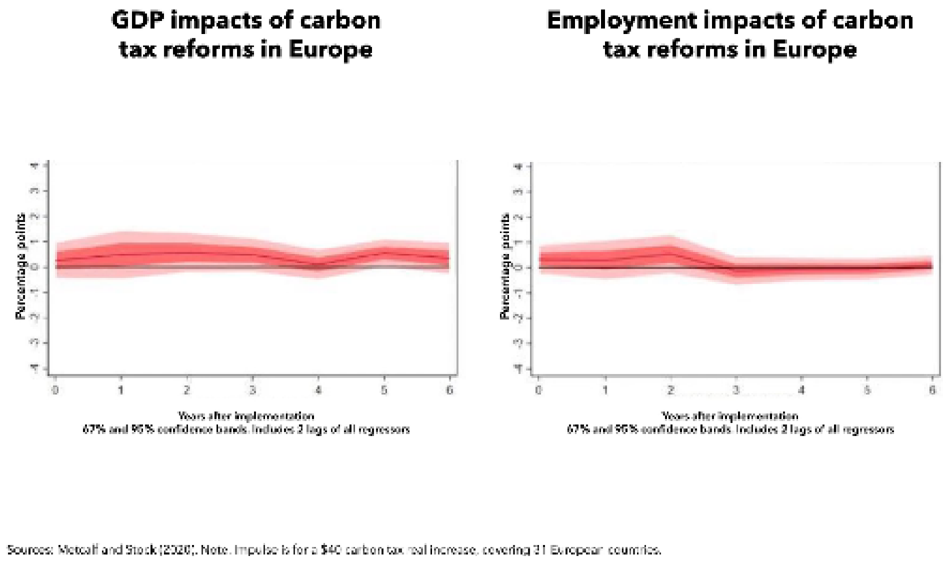


Figure 20

Additionally, some have looked at the relative impact of investments in green versus non-green energy (Fig 21). Broadly, these find that green investments have tended to increase GDP more than non-green investments. As a result, using some of the revenues from environmental fiscal reform for green investment may support GDP.

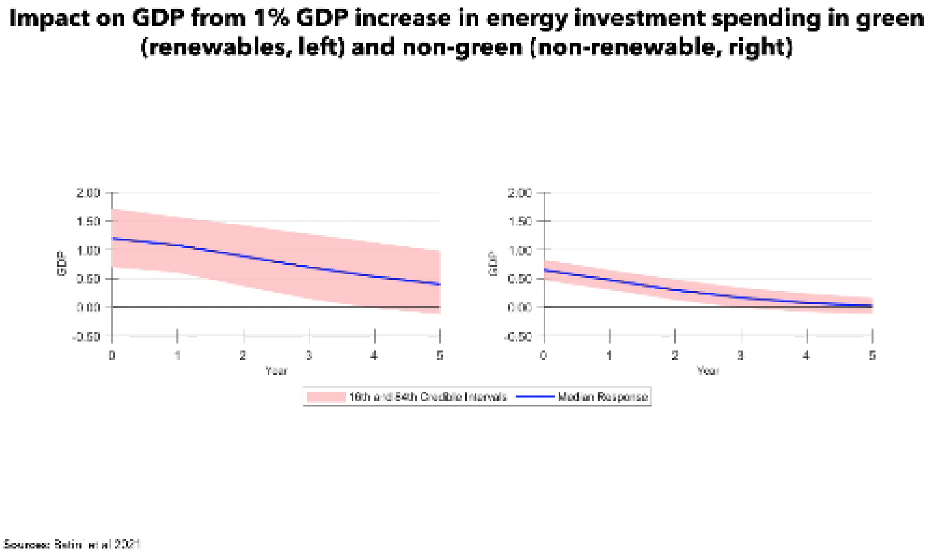


Figure 21

2.5 Development Co - benefits

Definition 4 *Development co-benefits refer to local benefits of climate change policies, such as improvement of environmental quality, increased access to energy sources, and rural development.*

Carbon pricing also has other benefits beyond climate known as co-benefits. Now, there is a long history of fossil fuels having a negative impact on local air quality. Take, for example, the great smog of London of 1952. Coal was being widely burned, and in just five days, an estimated 12,000 people died from the smog. The reason for this is fossil fuel combustion emits tiny particulates smaller than a human hair or a grain of sand. These get into the lungs, the bloodstream, and the brain. This increases the risk of major diseases, like heart and lung disease, stroke, lower respiratory infections, pneumonia, cancer, and now, even COVID-19.

This air pollution kills about seven million people per year, making it the fourth highest mortality risk factor above alcohol use, drug addiction, and obesity. Worse, it mostly affects the most vulnerable in society, such as the elderly and children. Cutting fossil fuel use by carbon pricing and environmental taxation can help cut these air pollution costs.

For example, if all countries price fuels efficiently, it would save about 1 million lives every year by 2025. As an example, in Mexico, the policy we referred to earlier can help reduce particulate matter emissions in both rural and urban areas, while helping to avoid around 12,000 premature deaths by 2030 (Fig 22).

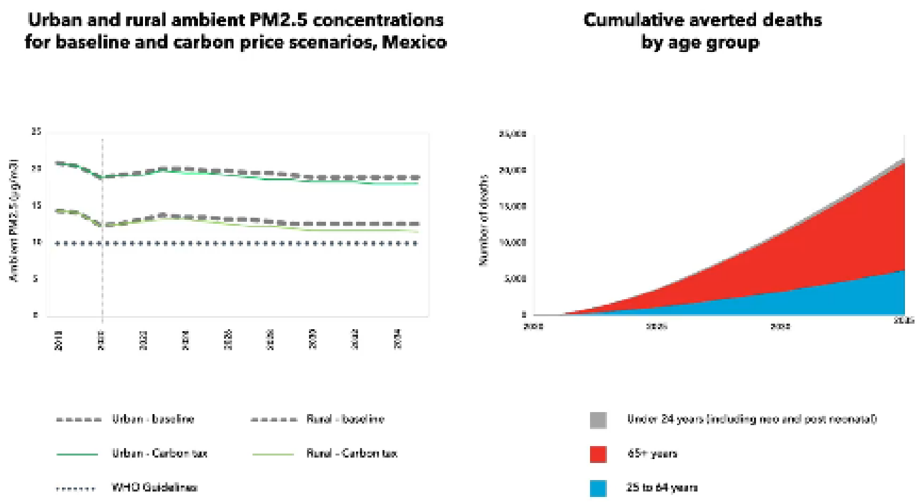


Figure 22

Carbon pricing also has other benefits for development. Here are the 17 sustainable development goals countries have committed (Fig 23). Carbon pricing can contribute to all of these goals, firstly, by cutting environmental externalities, and secondly, by being a critical source of revenues.

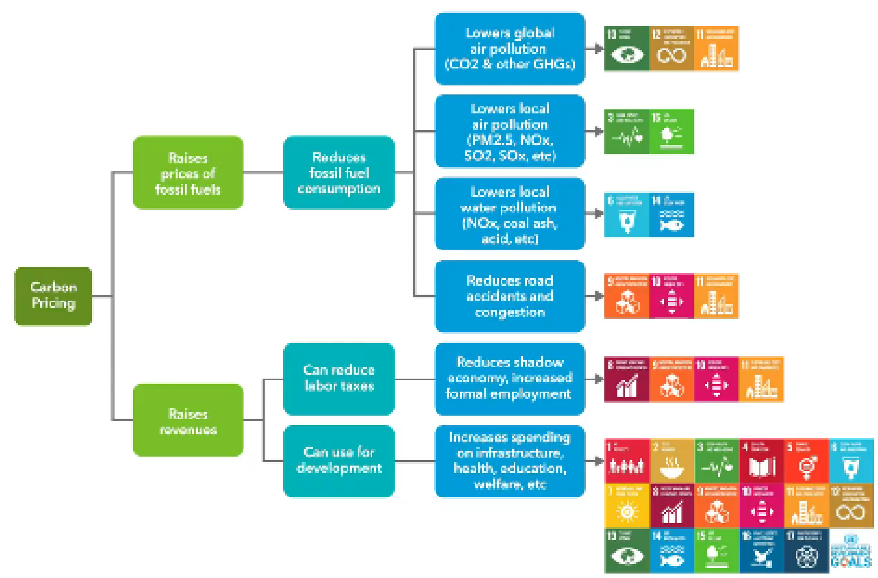


Figure 23

Now, when we come to monetize the local benefits of improved air quality and others, it means, in aggregate, carbon pricing tends to be in countries own interests, even if they don't care about climate (Fig 24).

Though there can be economic costs in the near term either in terms of deadweight losses or transitional costs, the welfare gains from improvements in local air quality, reduced congestion, and improved road safety and others usually dwarf these costs.

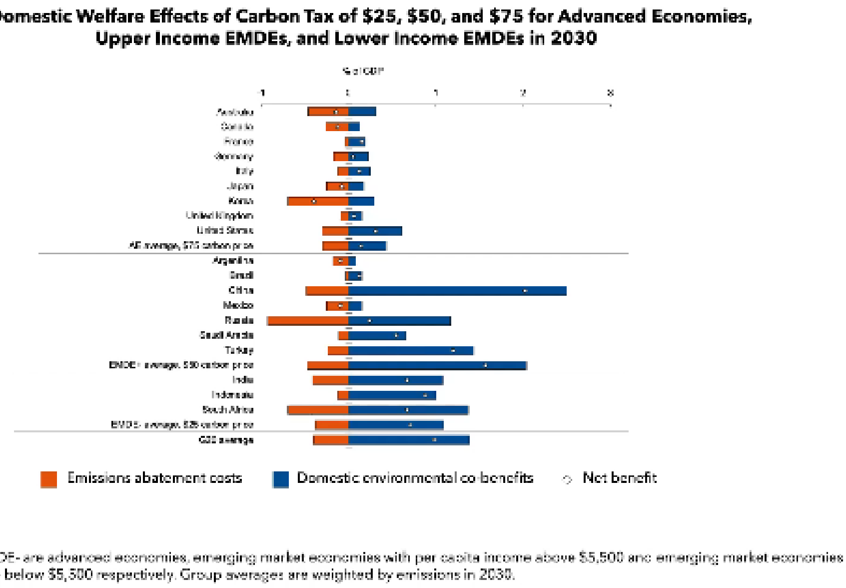
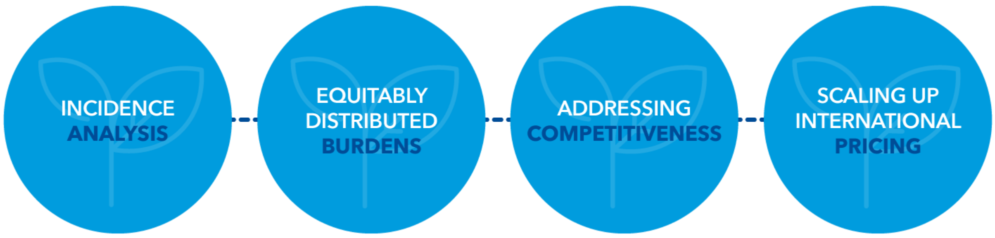


Figure 24

3. Political Economy for Scaling Up Carbon Prices



3.1 Incidence Analysis

Incidence analysis is important because policymakers need to know the burden of carbon pricing on different household and industry groups and how these burdens can be reduced through recycling carbon pricing revenues and other measures.

Definition 5 *Incidence analysis is a method for computing the distribution of public expenditure across different demographic groups.*

The immediate burden of carbon pricing on households and firms depends on its impacts on energy prices. For example, averaged across the G20 countries, a $50 per ton carbon price in 2030 would increase coal, gas, electricity, and gasoline prices by about 170%, 50%, 40%, and 15% respectively. The absolute price increases are similar across countries for coal, gas, and gasoline, though the absolute price increase for electricity will vary with a country's generation mix.

Coal and some electricity, natural gas, and petroleum products are intermediate inputs, so it is important to trace through cost increases for these fuels into higher prices for consumer goods in general. We do this using input-output tables. These are then mapped to household budget surveys showing the budget shares of different goods for different household groups. IMF has incidence analysis available for 50 countries. Their analyses project incidence impacts forward and account for behavioural responses to pricing.

One caveat is that IMF's standard assumption is full pass through of carbon pricing into higher consumer prices. In practice, some of the burden may be passed backwards in lower producer prices, for example, in industries that are price takers in world markets.

Ultimately, this burden is reflected in lower labor and capital income for households, which gets complicated to measure.

Figure 25 shows estimates of the burdens by household income quintiles, for a $50 per ton carbon price in 2030.

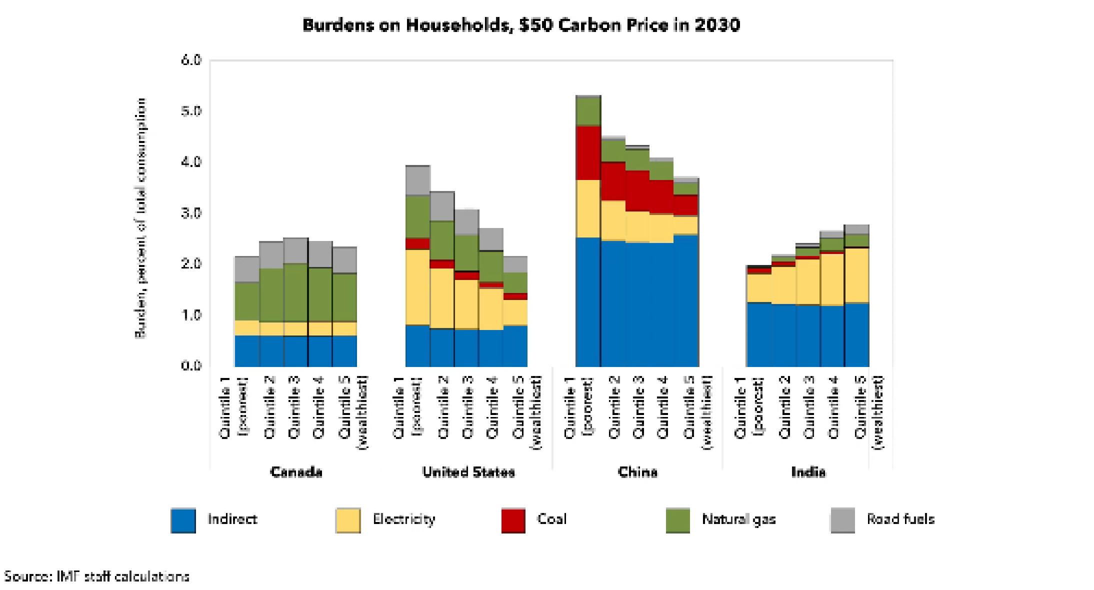


Figure 25

The average household burden varies from about 2.5% of consumption in Canada and India to 3% in the United States and 4% in China. Carbon pricing is regressive in the United States and China, about distribution-neutral in Canada, and moderately progressive in India, reflecting lower rates of grid access among low-income households. Indirect effects from the pass through of higher energy costs for industry are a significant component of the burden, anything from about 25% in the United States to about 60% in China. These estimates overstate the actual household burden, because they ignore the domestic environmental co-benefits of carbon pricing like fewer air pollution deaths, and revenue recycling, which I'll come back to.

On the industry side, carbon pricing significantly increases costs for energy-intensive trade-exposed industries like iron and steel, cement, other metals, for example, by between 5% and 15% for a $50 per ton carbon price in China.

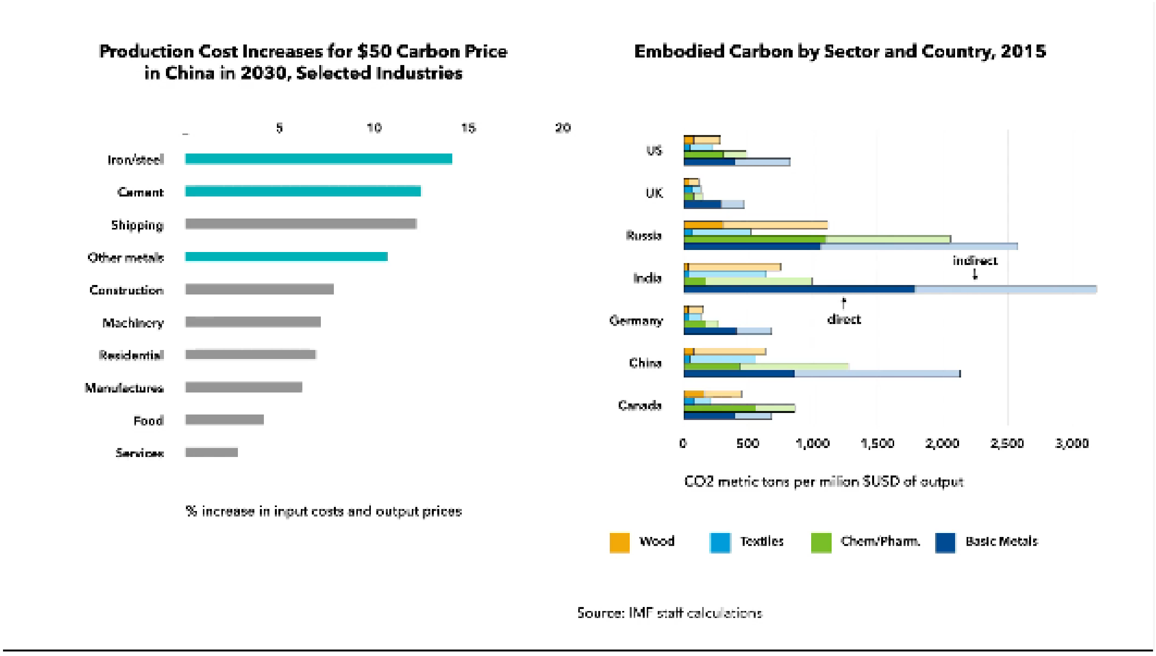


Figure 26

And the absolute cost increases would be broadly comparable in other emerging market economies like India and Russia, as they have relatively high embodied carbon in industrial products, both from their direct fuel combustion and from embodied carbon in their electricity inputs. Cost increases would be significantly smaller for advanced economies given the lower embodied carbon in their industries.

3.2 Equitably Distributed Burdens

Definition 6 *Equitably distributed burdens refer to ensuring that the general burden from the climate mitigation strategy is equitably distributed across households, and that targeted assistance is provided for the most vulnerable households, workers, and regions.*

Recycling carbon price revenues, which are typically around 0.5% to 2% of GDP for a $50 per ton carbon price in 2030 offsets most of the burden on the average household from higher energy prices.

And measures for vulnerable groups need only use a minor fraction of the carbon pricing revenues.

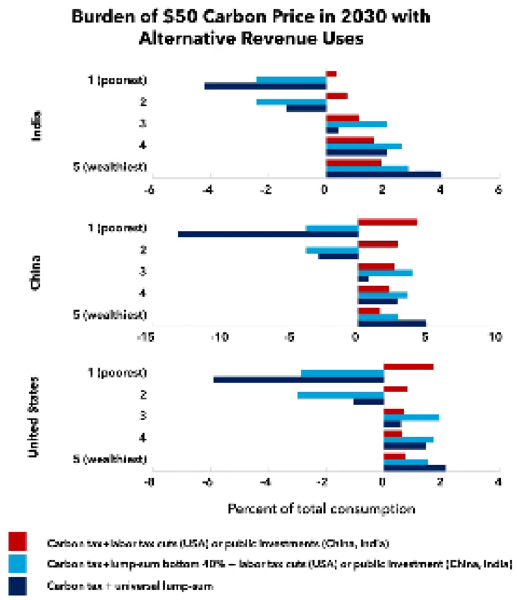


Figure 27

The figure illustrates different scenarios for revenue recycling.

If all revenues were returned an equal lump sum payments for all, the bottom two quintiles are substantially better off on net.

If instead all revenues are used to cut labor taxes or fund public investments, then the overall policy is moderately regressive in China and the US and progressive in India.

Alternatively, if 40% of the revenues go to the bottom two quintiles and the rest is used for labor tax cuts or investment, the bottom two quintiles are substantially better off on net.

But there's a lot at stake in terms of economic efficiency and how carbon pricing revenues are used.

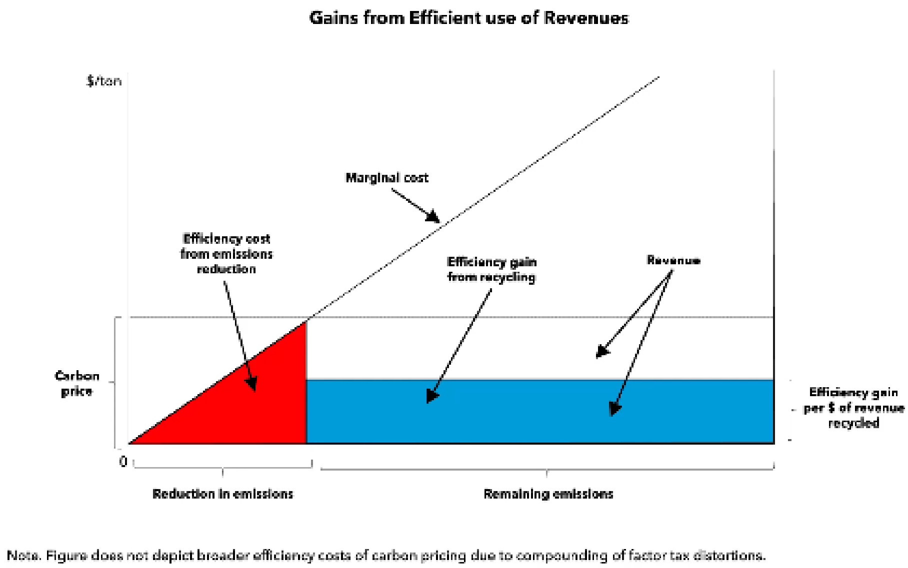


Figure 28

If they are used to cut distortionary taxes on labor and capital or fund productive investments for sustainable development goals, there is a gain in economic efficiency. This is the blue rectangle, the revenue raised, times the efficiency gain per dollar of revenue recycled. This efficiency gain can be large relative to the efficiency cost of cutting emissions, the red triangle under the marginal abatement cost schedule. If instead revenues are given away in lump sum transfers, this efficiency gain is foregone. I should note that there are broader efficiency costs to carbon pricing not shown in this figure due to their impact on contracting overall economic activity, which in turn compounds the efficiency costs a pre-existing factor tax distortions. There is a large analytical literature exploring when these broader costs are larger or smaller than the efficiency benefits from revenue recycling. We can also conduct incidents analysis for other mitigation instruments like feebates and regulations, which have a much smaller impact on energy prices than carbon pricing, but there is no counteracting benefit from revenue recycling.

Here's another example of instance analysis, which we just did for Mexico for $75 per ton carbon tax in 2030.

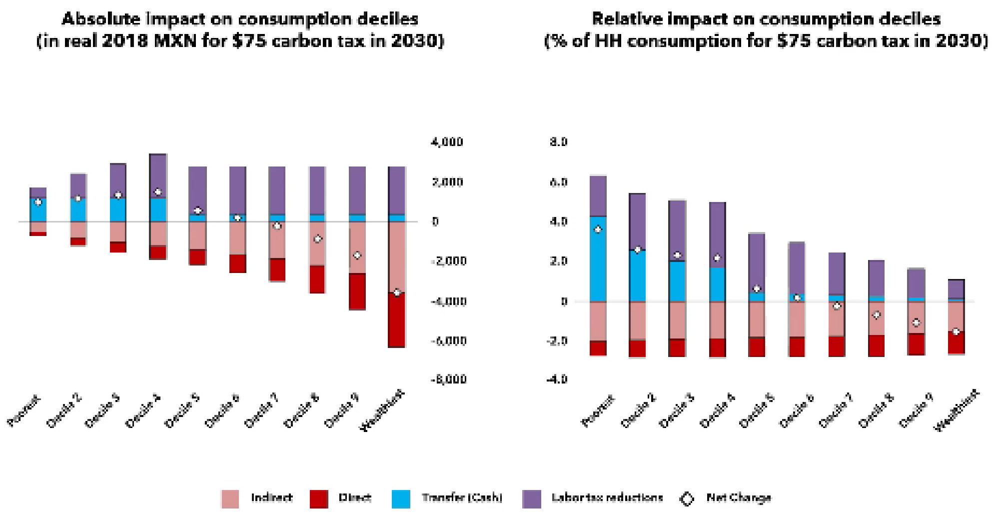


Figure 29

The red bars indicate burdens from carbon pricing in terms of direct impacts on energy prices and the indirect impacts on non-energy goods. These are broadly distribution neutral, an average about 3% of household consumption. The blue bars indicate benefits when 25% of carbon pricing revenues fund targeted assistance for the bottom four deciles, and the purple bars indicate benefits when the remaining 75% funds a general reduction in labor income taxes.

On net, as indicated by the white diamonds, the bottom four deciles are better off from the carbon tax reform. The next three deciles are approximately no better or worse off, while wealthier households are worse off on net, but by a fairly modest 1% of consumption.

Impacts on specific regions and groups of workers from mitigation policy generally occur, regardless of the type of mitigation instrument. For example, the map shows that coal mining is a substantial fraction of local employment, 5% to 15%, in a handful of regions in the US, Germany, China, and India.

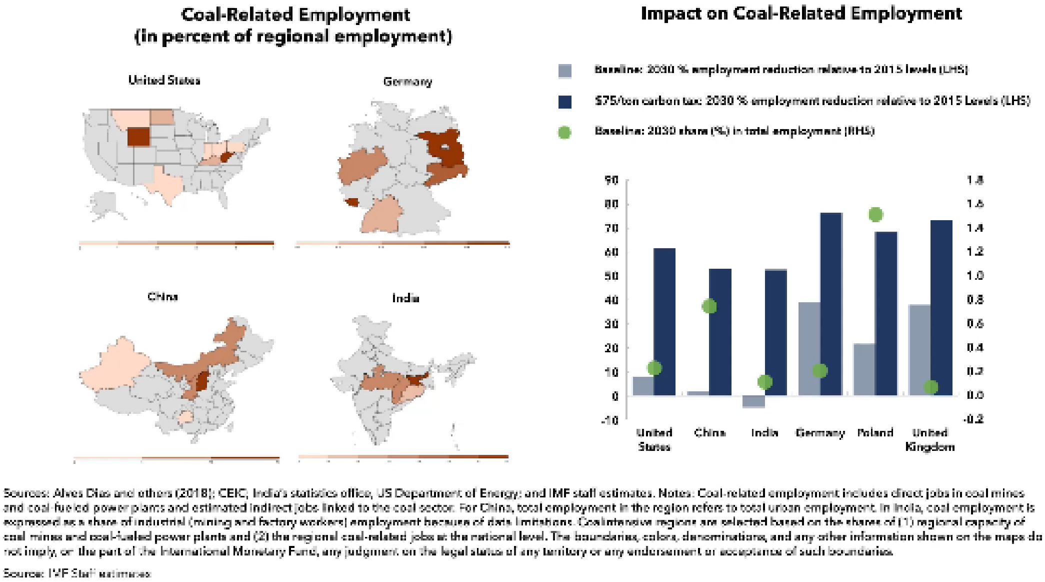


Figure 30

And the right figure indicates that under a $75 per ton carbon price in 2030, coal mining employment would be between 50% and 70% lower than 2015 levels in the US, China, India, Germany, Poland, and the UK, although in some of these cases, there would be a large reduction in coal mining employment in the baseline even without carbon pricing.

Assistance measures for vulnerable groups might include, for low income households, cash and in-kind transfers like food stamps, discounted prices for energy, earned income tax credits, and payroll tax rebates. Measures for displaced workers could include extended unemployment benefits, training and re-employment services, financial assistance for job search and relocation, and early retirement support. Regional assistance might include support for reclaiming abandoned mining and drilling sites, assistance for local enterprises, and temporary budget support for local governments.

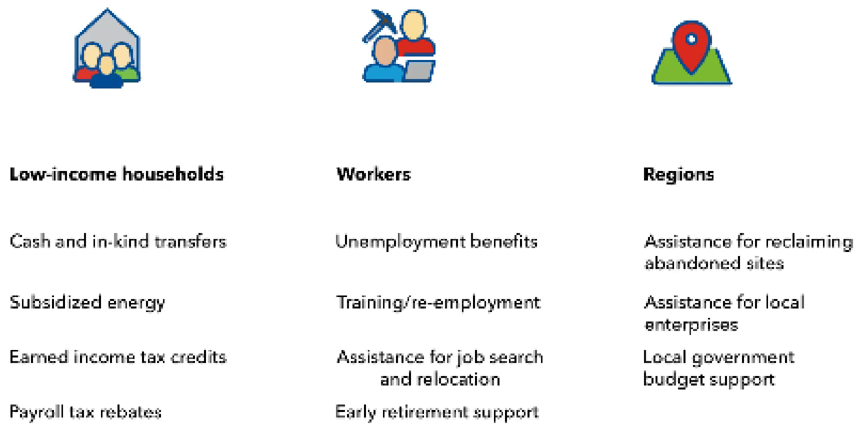


Figure 31

3.3 Addressing Competitiveness

Moving on to the competitiveness concerns which are a major obstacle to carbon pricing. There's much discussion about border carbon adjustments, BCAs.

Definition 7 *These are charges on the embodied carbon of imported products, perhaps matched by rebates for domestic exporters. Charges can take the form of taxes or allowance purchase requirements.*

The EU intends to phase in a BCA from 2023 and others are considering it, including Canada, the UK, and the US. There are three rationales for BCAs:

1. First, they can preserve the competitiveness of domestic energy intensive trade exposed or EITE industries like steel, aluminum, cement, chemicals, plastics, petroleum refining that are subject to carbon pricing.

2. Second, that can help to address concerns about emissions leakage that domestic production will move abroad in response to carbon pricing, leading to offsetting emissions elsewhere.

3. Third, we might encourage other countries to price carbon to gain an exemption from the BCA. But the incentives are modest. For example, as indicated by the figure, embodied carbon in China's exports to the EU and in total exports is 1% and 10% of China's domestic carbon emissions, respectively.

Other measures, like free allowances as in the EU and Korea, that are currently used become less effective at addressing competitiveness and leakage with deeper decarbonization. One giant drawback of BCAs, however, is that they may incur legal challenges. Currently, there is much uncertainty about whether BCAs are WTO compatible. Another drawback is they may violate the principle of differentiated responsibilities if they impose the same carbon price on developing countries as advanced countries.

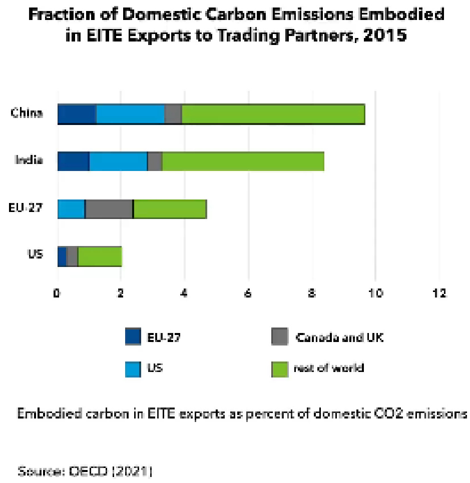


Figure 32

There are several issues to consider in designing a BCA. As regards sectoral coverage, IMF recommends focusing on EITE industries, rather than other sectors like services, agriculture, mining, and electricity. This limits administrative burdens and embodied carbon for the EITE industries is reliably measured. As regards to measuring embodied carbon, ideally, this will be done at the firm level, given large heterogeneity in emission rates among firms in some industries. But this is not presently practical due to data constraints. At the industry level, country-specific benchmarks would be more efficient given variation in emission rates across countries.

But there may be a pragmatic case for using domestic industry benchmarks, at least initially, to avoid disproportionate burdens on emerging market economies given their high embodied carbon. Rebates for carbon charges for domestic exporters are warranted on competitiveness grounds but should be based on exogenous industry benchmarks. If instead they are based on firm level emissions, rebates will undermine mitigation incentives for exporters. Adjusting BCAs for carbon pricing abroad is appropriate on competitiveness grounds but not for regulations, as regulations do not charge firms for their remaining emissions. Revenues from a BCA are modest, about 0.1% to 0.2% of GDP for a $50 per ton carbon price. And in cases like China, revenues from a BCA would be negative if export rebates were included as embodied carbon and exports for China is greater than embodied carbon in imports.

An EU BCA of $50 per ton would collect $4 billion a year in revenue from China with country-specific emission rate benchmarks but only $1 billion a year with domestic benchmarks.

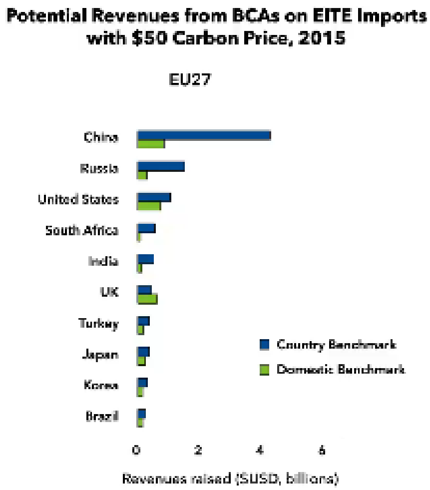


Figure 33

3.4 Scaling Up International Pricing

As explained earlier, one way to address the competitiveness concerns of carbon pricing is via border carbon adjustments (BCAs). However, BCAs are not effective at scaling up global mitigation as they only price emissions embodied in traded products. Therefore, international cooperation over mitigation policy is needed. But how can we more efficiently facilitate global mitigation negotiations, while also addressing the competitiveness concerns of carbon pricing?

There are two key obstacles to scaling up mitigation under the Paris Agreement:

1. First, it is very difficult to negotiate greater mitigation ambition because there are too many parties to the agreement, 195, negotiating over too many parameters, one per party.

2. Second, when countries act unilaterally, it is very difficult to aggressively scale up mitigation policy due to concerns about competitiveness and that other countries may free ride and not meet their mitigation pledges.

The IMF staff proposal for an international **carbon price floor** therefore has two key elements:

1. First is a focus on a small number of large emitting countries to facilitate negotiation while covering the bulk of global emissions. For example, China, the EU, India, and the US alone account for nearly 2/3 of projected baseline emissions by 2030. Including the rest of the G20 brings this up to 85%.

2. Second is a focus on a minimum carbon price because this is an efficient and easily understood parameter.

Simultaneously scaling up carbon pricing among large emitters would be the best way to address competitiveness and free rider concerns. A price floor allows countries to set higher prices if this is needed to meet their mitigation pledges. But, most likely, the arrangement needs pragmatic design to address equity concerns or differentiated responsibilities through differentiated price floors, according to level of development and/or simple mechanisms to transfer financial and technological assistance to low income emerging market economies.

Moreover, it is important to allow flexibility for countries that are not doing carbon pricing so long as they achieve equivalent emissions outcomes through other instruments.

Other design issues would need to be agreed, such as the scope of emissions sources to be included, and monitoring pricing when countries are changing pre-existing energy taxes. An example, how effective an international carbon price floor could be -

if advanced countries were subject to a price floor of $75 per ton in 2030, high income emerging market economies like China, a price floor of $50, and low income emerging market economies like India, a price floor of $25 per ton, then this would be sufficient to align 2030 G20 emissions with keeping warming below 2 degrees with just six participants in the floor price– Canada, China, EU, India, the UK, and the US.

This assumes G20 countries meet their mitigation pledges, and if they are in the price floor, the minimum price, whichever is the more stringent.

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