from coal to natural gas as natural gas prices have dropped in the wake of its increased supply. While natural gas use in electricity generation gradually increased from 5.3 quadrillion Btu in 2000 to 6.38 in 2006 and 7.7 in 2011, coal experienced a small increase from 19.6 in 2000 to 20.5 in 2006 before dropping off quickly to 18.04 in 2011.

According to the Environmental Protection Agency, natural gas-fired electricity generates half the carbon dioxide of coal-fired production. An estimate of the indirect benefit of fracking should include an estimate of the potential social gains from this reduction. Historically, CO2 emissions grew alongside GDP, reaching a peak of just over 6 billion metric tons in 2007, according to data from the EIA. Since then, however, emissions have fallen off, and were expected to total less than 5.3 billion tons in 2012, a full 10 percent decrease over five years. Although some of this drop was related to a faltering economy in 2008, emissions have remained lowered even while GDP has recovered its previous size and then some. The EIA even projects that CO2 emissions will remain below their 2005 level (just under 6 billion metric tons) through 2040 – in some part because of increased reliance on renewables but in large part because of substitution of natural gas for coal.

The drop in natural gas prices worldwide would normally lead to a reduction in electricity prices in the United States. To the extent that geographic complementarities produce inframarginal benefits over and above the reductions in electricity prices that would normally follow from a reduction in price, these also should be included in net benefit calculations. If, for example, local electricity generation is a much higher value use than exporting the gas, then the inframarginal gains from that use would be included in any cost benefit calculus. The same would be true for other industries as well, such as the chemicals industry, fertiliser producers, and the steel and aluminum industries. To the extent that employment increases in these sectors, one would apply the same caution about interpreting this as a net benefit that applied to the direct employment effects.

Two additional indirect effects should also be mentioned, and considered by policymakers as they assess the benefits of regulatory interventions. First, a surge in production could well have Keynesian multiplier effects on a local economy. Second, land prices will surge throughout a state if fracking is suddenly allowed, and the higher prices will affect all relevant landowners' wealth and thus their consumption. This would have near-term economic effects on local economies (North Dakota luxury car dealers are presumably doing quite well) that may well be larger than the direct impact of production.

Several reports have attempted to quantify the impact of the expansion in fracking on the US economy but it is an extremely nascent literature. A 2010 study by Considine, Watson, and Blumsack of Pennsylvania State University used an input-output model to estimate that investment into natural gas extraction in the Marcellus shale region contributed 44,000 jobs to the economy. A 2012 study by IHS Global Insight made an attempt to model both the direct and indirect effects, employing a macroeconomic model. The study, which was funded by America's Natural Gas Alliance, is the most exhaustive study available to date. It concluded that the shale gas industry supported 600,000 jobs in 2010, a number which would increase to 870,000 by 2015. The study also found that three indirect jobs are created for each energy sector job, suggesting that the employment effects could be enormous. Looking at GDP growth, the IHS study found that, 'The shale gas contribution to GDP was $76.9 billion in 2010, will increase to $118 billion by 2015, and will nearly triple to $231 billion in 2035,' all in 2010 dollars. Alternatively, a study by economist J.G. Weber published in Energy Economics in 2012 estimates that 2.35 local jobs are created for every million dollars in gas production. If one assumes that total production increases by the approximately $68 billion from 2010 to 2035 assumed by the IHS study, then this would suggest a net increase of employment of only 159,859. Whether either of these jobs numbers reflects an increase in aggregate employment, of course, is another question, but the scale of the possible GDP gain is very large indeed, and sets a very high bar for opponents of fracking. If the debate over fracking is to be dominated by reason rather than emotion, researchers must refine our thinking of the economic benefits of rapid expansion of energy production, and improve our estimates of the potential environmental costs as well. ■

CLEAN ENERGY, ELECTRICITY AND CLIMATE CHANGE

The Case for a US Carbon Tax

JOSEPH E. ALDY

Every aspect of economic activity affects greenhouse gas emissions and, hence, the global climate. Since individuals and businesses bear virtually no cost for emitting greenhouse gases in the absence of public policy, and thus have no incentive to reduce these emissions, the government has a strong case for climate change policy. US policymakers may choose among three general approaches to drive more climate-friendly economic activity: (1) subsidise businesses and individuals to invest in and use lower-emitting goods and services; (2) mandate businesses and individuals to change their behaviour regarding technology choice and emissions; or (3) price the greenhouse gas externality, so that decisions take account of this external cost. Let's consider these options in turn.

In the United States, state and federal subsidies have supported the deployment of clean energy technologies for decades. The 2009 economic stimulus, the American Recovery and Reinvestment Act, represented the largest energy bill in US history by providing about $90 billion for investments in efficiency, renewable power, mass transit, smart meters, transmission lines, electric batteries, and other clean energy technologies. Among the energy sector impacts, US wind power generation doubled in about three years and lowered the electricity sector's greenhouse gas emissions by about 2 percent in 2010. Some clean energy subsidy programs were better designed and implemented more effectively than others. Nonetheless, the stark constraints in the current US fiscal outlook effectively preclude another major round of subsidies to promote the development and deployment of clean energy technologies.

Various regulatory agencies have the authority to require significant changes in the emission-intensity of cars and trucks, appliances, power plants, refineries, and other manufacturing facilities. For example, recent standards will effectively double the fuel economy of US passenger vehicles by 2025. Yet, pursuing a strategy of regulatory mandates one industry (and even one type of source within an industry) at a time can result in higher costs than necessary to drive emission reductions. Some industries may face a multitude of regulatory constraints and high emission reduction costs, while others face low costs, and all industries experience weaker incentives for clean energy innovation than they would under a more efficient policy approach. Moreover, a regulatory approach risks exposing businesses to uncertainty for a considerable time as a result of political challenges in Congress and legal challenges in the courts. The legal challenges will be potentially thorny since some of the likely regulatory proposals to address existing sources of greenhouse gases in the power sector and manufacturing would employ provisions of the Clean Air Act for the first time in its 40+ year history. In contrast to an economy-wide policy approach, an industry-specific regulatory approach would take many years to develop the dozens of rules necessary to cover most industrial sources of greenhouse gas emissions, which would then be subject to periodic regulatory revision. Moreover, eventually millions of small sources of greenhouse gas emissions – such as apartment buildings, corner grocery stores, and business offices – will need to apply for greenhouse gas emission permits absent new legislation, imposing significant administrative costs on small businesses and the government.

Given the fiscal constraints on subsidies and the prospect of inefficient, costly, and politically and legally uncertain regulatory options, the most effective policy approach to combat climate change is to price the greenhouse gas externality. In other words, it is time to tax carbon dioxide emissions in America.

Designing a Carbon Tax

A well-designed carbon tax should be cost-effective, efficient, and administratively simple. A cost-effective carbon dioxide tax would cover all emission sources. The government could set a tax in terms of dollars per ton of CO2 on the carbon content of the three fossil fuels (coal, petroleum, and natural gas) as they enter the economy. An efficient carbon tax would be set equal to the marginal benefits of reducing CO2 emissions, i.e., the social cost of carbon, and would increase over time to reflect the greater incremental damage from an additional ton of CO2 as atmospheric concentrations rise. Analysts – in academia and the government – have produced a wide array of estimates of the social cost of carbon. Nonetheless, the US government's current central estimate of the social cost of carbon of about $21 per ton CO2 is in the ballpark of what may be politically feasible given recent legislative proposals (see below).

Applying the carbon tax to the carbon content of fossil fuels targets the bottleneck in the product cycle of fossil fuels. Under such an upstream approach, refineries and importers of petroleum products would pay a tax based on the carbon content of their gasoline, diesel fuel, or heating oil. Coal-mine operators would pay a tax reflecting the carbon content of the tons extracted at the mine mouth. Natural-gas companies would pay a tax reflecting the carbon content of the gas they transport or import via pipelines or liquefied natural gas (LNG) terminals. This carbon content of fuels scheme would enable the policy to capture about 98 percent of US CO2 emissions by covering only a few thousand sources as opposed to the hundreds of millions of smokestacks, tailpipes, and so on that emit CO2 under a system targeting actual emissions.

A US carbon tax would be administratively simple and straightforward to implement, since it could incorporate existing methods for fuel-supply monitoring and reporting to the government. The US Energy Information Administration already tracks on a weekly, monthly, and annual basis the production, import, export, storage, and consumption of fossil fuel products. United States refineries and importers of petroleum products already pay a Federal per barrel tax (to finance the Oil Spill Liability Trust Fund) and coal mine operators already pay a Federal per ton tax (to finance the Black Lung Disability Trust Fund), so a national carbon tax could easily piggyback on these existing tax reporting systems. Monitoring the physical quantities of fuel combustion yields precise estimates of carbon dioxide emissions given the molecular properties of fossil fuels.

A crediting system for downstream carbon capture and storage technologies could complement the carbon tax system. A firm that captures and stores CO2 through geological sequestration, thereby preventing the gas from entering the atmosphere, could generate tradable CO2 tax credits, and sell these to firms that would otherwise have to pay the emission tax. Such a system of tax credits could provide a transparent means to finance such carbon capture and storage technologies.

While stimulating the investment in low-carbon, zero-carbon, and energy efficient technologies, the implementation of a carbon tax could adversely affect the competitiveness of energy-intensive industries. This competitiveness effect resulting from higher energy prices can lead to firms relocating facilities to countries without meaningful climate change policies, thereby increasing emissions in these new locations and offsetting some of the environmental benefits of the policy. Such 'emission leakage' may actually be relatively modest, because a majority of US emissions occurs in non-traded sectors, such as electricity, transportation, and residential buildings. Energy-intensive manufacturing industries that produce goods competing in international markets may face incentives to relocate and will advocate for a variety of policies to mitigate these impacts.

Additional emission leakage may occur through international energy markets – as countries with climate policies reduce their consumption of fossil fuels and drive down fuel prices, those countries without emission mitigation policies increase their fuel consumption in response to the lower prices. Since leakage undermines the environmental effectiveness of any unilateral effort to mitigate emissions, international cooperation and coordination becomes all the more important. Political concerns about competitiveness may call for a carbon border tax that effectively imposes a tax on the carbon content on goods imported into the United States. If the government implemented a carbon tax and threatened to impose a border tax on imports, then it could provide some negotiating leverage in multilateral fora to secure more stringent emission reduction policies among major trading partners, and thus minimise the competitiveness impacts. Also, it is important to keep in mind that these emission leakage effects exist with any meaningful climate policy, whether through carbon tax, cap-and-trade, or command-and-control.

The Impacts of a Carbon Tax on Energy Markets and the Economy

Energy suppliers will increase the price of the fuels they sell in response to the carbon tax. This will effectively pass the tax down through the energy system, creating incentives for fuel-switching and investments in more energy-efficient technologies that reduce CO2 emissions. The real-world experience of firms and individuals responding to changing energy prices demonstrates the potential power of a carbon tax to drive changes in the investment and use of emission-intensive technologies. The higher gasoline prices in 2008 resulted in larger market share of more fuel-efficient vehicles, while reducing vehicle miles traveled by drivers of existing cars and trucks. In recent years, electric utilities responded to the dramatic decline in natural gas prices (and the associated increase in the relative coal-gas price ratio) by switching dispatch from coal-fired power plants to gas-fired power plants that resulted in lower carbon dioxide emissions and the lowest share of US power generation by coal in some four decades. Historically, higher energy prices have induced more innovation – measured by frequency and importance of patents – and increased the commercial availability of more energy-efficient products, especially among energy-intensive goods such as air conditioners and water heaters. Imposing a carbon tax would provide certainty about the marginal cost of compliance, which reduces uncertainty about returns to investment decisions and eliminates the regulatory uncertainty that inhibits energy sector investment. Of course, certainty over costs results in uncertainty over emission reductions.

Consider a hypothetical, economy-wide carbon tax that starts at $15 per ton CO2 and increases annually by 5 percent plus inflation. Such a scenario is very similar to the Republican proposed carbon tax in the US House of Representatives in 2009 (H.R. 2380, “Raise Wages, Cut Carbon Act of 2009” would set a carbon tax of $15 per ton CO2 and increase it 6.5 percent annually for thirty years) and is generally consistent with US Environmental Protection Agency estimates of the allowance prices expected under the 2009 Waxman-Markey cap-and-trade bill (H.R. 2450). Over the first decade, such a carbon tax program would impose an average price on carbon of nearly $20 per ton CO2 and generate revenue of about $100 billion per year according to the 2012 Annual Energy Outlook published by the Energy Information Administration (EIA).

In doing so, energy prices would increase on average about 10 percent over this first decade, with coal bearing a greater price impact while natural gas, renewables, and nuclear would bear smaller impacts. In light of the more than two-thirds increase in real energy prices over the decade ending in 2008, this change of about 10 percent would not deliver significant economic costs, and productive uses of the tax revenues through tax reform could eliminate most if not all of the costs of mitigating greenhouse gas emissions. Even in energy-intensive, trade-exposed industries such as steel, aluminum, chemicals, and cement, the declines in output would be much less than the annual swings they have experienced over the past two decades. Based on the impacts of historic energy price changes on industry output, Billy Pizer and I have estimated that a tax of $15 per ton CO2 would reduce production on the order of about 2 to 3 percent in these industries. The changes in relative energy prices and the certainty about the carbon price are important, since they will drive investment in new, clean energy technologies. As a result, the EIA estimated that US carbon dioxide emissions would decline to 18 percent below 2005 levels in 2020 under such a carbon tax scenario.

> ***“Applying the carbon tax to the carbon content of fossil fuels targets the bottleneck in the product cycle of fossil fuels.”***

Carbon Tax and Tax Reform

Some observers of the US body politic may note that carbon pricing through a cap-and-trade program suffered political defeat in 2010 in part because opponents labeled it ‘cap-and-tax’. If cap-and-trade appeared more politically appealing than a carbon tax a few years ago and any proposal to raise taxes suffers the inherent problem of being called a tax, how could a carbon tax represent a viable option today? The relevant legislative policy debate in America today is not about the path forward on climate policy but instead the path forward on fiscal and tax reform. The choice is not between a carbon tax and cap-and-trade, but rather between a carbon tax and other means of raising revenues or cutting spending.

The approximately $100 billion in annual revenues from the hypothetical carbon tax above could play an important role in making a fiscal and tax reform add up. It is roughly equal to the so-called budget sequestration that calls for blunt, politically unpopular cuts to US domestic and defence spending. It is slightly less than the revenues generating by eliminating the politically popular if economically inefficient home mortgage interest deduction in the US tax code. It is on par with the 2 percent payroll tax reduction enjoyed by all workers over the past two years, but that expired on 31 December 2012. These revenues could also help reduce significantly the deficit, which effectively translates into lower future taxes.

The effects of a carbon tax on emission mitigation and the economy will depend in part on the amount and use of the tax revenue. Using carbon tax revenues to finance tax reforms that improve the efficiency of the tax code could stimulate economic activity and offset some or all of the costs of cutting emissions. In addition, a relatively small percentage of the annual carbon tax revenues could also support the research and development of climate-friendly technologies, which suffer underinvestment by the private sector.

Raising energy prices could disproportionately impact low-income households, since a larger fraction of their budgets is dedicated to energy expenditures. The regressive nature of a carbon tax can be mitigated through the recycling of revenues back to the economy. For example, British Columbia's economy-wide carbon tax program returns all revenues to the economy by cutting corporate and individual income tax rates and through a means-tested Low Income Climate Action Tax Credit. If a carbon tax is part of a broader fiscal and tax reform, the overall progressivity of the package will depend in part on the use of carbon tax revenues, but more substantially on decisions regarding entitlement spending (especially means-tested Medicaid) and changes to the tax code for businesses and individuals.

Businesses that face the possibility of a carbon tax would likely oppose it, especially if they also must comply with greenhouse gas regulations under the US Clean Air Act. Lowering the tax rate on corporate income may address some business reservations. Moreover, a meaningful, economy-wide, long-term carbon tax would obviate the need for many if not all greenhouse gas regulatory options. A carbon tax would deliver more cost-effective and efficient emission reductions and promote innovation more effectively than the Clean Air Act regulatory authority, as well as avoid some of the potential legal and political pitfalls and administrative costs of regulations. Exchanging regulatory authority for a carbon tax could also improve the political viability of taxing carbon dioxide emissions.

Price Carbon Now

This case for pricing carbon through a tax regime rests on the understanding of the best scientific scholarship that shows that increasing atmospheric concentrations of greenhouse gases are posing and will continue to pose substantial risks to the planet. Uncertainties about climate science certainly still exist, but such uncertainties are no reason for inaction. Indeed, the prospect, albeit uncertain, of sea-level rise, more frequent extreme storms like Hurricane Sandy in the US East Coast in 2012, reduced agricultural productivity, and so on, justify action now. Prudent first steps are cost-effective, no-regrets approaches. A carbon tax that can send signals for long-term innovation, deliver efficient emission mitigation, and finance tax reform that promotes economic growth fits this bill. ■

CLEAN ENERGY, ELECTRICITY AND CLIMATE CHANGE

California Starts Trading Carbon

DAVID BUCHAN

California has again proved itself to be a pioneer in climate and energy policy. On 1 January it launched the first serious state cap-and-trade system in the USA designed to reduce greenhouse gases. A similar scheme already exists at the other end of the country – under their Regional Greenhouse Gas Initiative (RGGI or Reggie as the acronym is pronounced) nine New England states have been capping and trading CO2 emissions from their power plants since 2008. But the RGGI cap only covers electricity generation, and is so loose – in its first phase of 2009–2014 it is only aimed at stabilising the level of emissions – that permits trade for less than $2 a tonne of carbon. By contrast, the California scheme's cap will eventually cover almost the entire economy of the state; it tightens in its first year with a 2 percent reduction; and its minimum auction price is $10 a tonne. The cap-and-trade system is one of several measures in California's Global Warming Solutions Act of 2006 which is aimed at returning the volume of the state's greenhouse gas emissions to that of 1990 by 2020, a cut of around 15 percent from 2012 levels.

However, the immediate importance of the California system's launch will be more political than environmental. RGGI was launched in the period of relative benevolence towards climate action of the mid-2000s. But after the largely abortive Copenhagen climate summit in December 2009, climate politics turned poisonous in the USA, as Republicans denounced emission trading as 'cap-and-tax', cowed Democrats and the Obama administration into acquiescence, and killed the plan for a federal cap-and-trade system in Congress. Once re-elected, Barack Obama has dared to mention climate policy again, but he is a cautious man and will proceed slowly.

In these political circumstances, it is a minor miracle that the Californian initiative has come to fruition. It survived a referendum vote in 2010 and numerous court challenges that led to the postponement of emissions permit trading by a year until 2013, but it still faces new legal appeals that have been launched by business groups in the past few weeks quite deliberately to destabilise the trading system.

> ***"California has again proved itself to be a pioneer in climate and energy policy."***

Yet California's cap-and-trade system is expected to have much less impact on emissions than the political sound and fury over its introduction would seem to indicate. The California Air Resource Board (Carb) has estimated cap-and-trade will contribute less than a quarter of the total emission reduction from the state's various climate measures. This is a far smaller contribution to emission reduction than the European Union had initially hoped to get from its Emission Trading System over the decade up to 2020 (though, as we now know, this hope