The Economics of Carbon Capture

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The coming months will see intense political wrangling over the terms of future carbon dioxide (CO_2) regulations. One of the most vexing issues in connection with a cap-and-trade system is the difficulty in predicting the resulting market price for CO_2 emission permits. This price would be the effective carbon tax imposed on the world's economies. Critics of cap-and-trade regulation argue that, barring technological breakthroughs, the effective carbon tax could reach levels that would severely injure all energy intensive sectors of the economy. Such predictions are too dire. In fact, we estimate substantial reductions in CO_2 emissions could be achieved at a marginal cost in the range of \$25 – \$30 per metric ton ('tonne').

The imposition of a cap-and-trade system is likely to spawn a range of alternative CO_2 abatement strategies. Among these, Carbon Capture and Storage (CCS) at fossil fuel power plants is not only within technological reach, but current engineering estimates also suggest that it will be a cost-effective approach for eliminating most of the emissions from coal and natural gas power plants.

Since power generation currently accounts for a sizeable share of the overall 'emissions pie,' CCS is bound to have a major role in limiting the effective carbon tax under a cap-and-trade system. At the same time, the availability of CCS technology puts a sharp upper bound on the expected increase in electricity prices. In turn, this will make CCS beneficial for other sectors of the economy which, once carbon emissions are priced, will have incentives to switch to electric power for their energy needs.

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THE STATE OF CCS TECHNOLOGIES

The possibility of capturing CO_2 at fossil fuel (coal and natural gas) plants by means of Carbon Capture and Storage technologies has gained currency in recent years. The technical feasibility of several CCS technologies has been shown in pilot projects. As described in an interdisciplinary MIT study led by chemist John Deutch and physicist Ernest J. Moniz, a variety of processes are known for capturing CO_2 gas either before or after burning the fossil fuel. Thereafter the CO_2 is transported via pipelines to underground formations, such as depleted oil and gas fields, where it is then stored permanently.

Several energy companies are currently seeking to 'certify' these technologies not only in demonstration projects but for power plants on a commercial scale (at least 500 Megawatt). While large scale demonstration of CCS in the electric power sector is still pending, the CO_2 abatement potential of these technologies is indisputable. For both coal-fired and natural gas plants, the adoption of CCS technology is expected to cut CO_2 emissions by 85 – 90 percent per kWh of electricity. This amounts to a significant slice of the emissions pie since fossil fuel power plants are a major contributor to greenhouse gas emissions. In particular, the U.S. share of global emissions was about 25 percent in 2007. Out of the 6 Gt (Gigatonnes or billions of tonnes) emitted by the U.S., more than 40 percent originated from fossil fuel power plants, with roughly 2 Gt originating from coal-fired power plants and the remainder from natural gas plants.

A number of recent engineering studies have projected the cost structure of fossil fuel power plants with CCS capabilities. CCS will result in higher variable operating costs, in part because CO_2 capture requires additional electricity consumption and because of the expenditures associated with CO_2 transportation and storage. In addition, the investment in new power plants with CCS capabilities entails a substantial increase in upfront construction costs. Our own recent analysis uses these engineering estimates to predict when the adoption of CCS technology becomes economically viable.

EMISSION CHARGES AND CCS ADOPTION

How far would the price of CO_2 emission permits have to rise, before the operators of power plants would find it advantageous to install CCS technology rather than buy emission permits? In recent years, a sizeable minority of states in the U.S. have deregulated the supply of power generation. One plausible market structure, therefore, is that utilities procure electric power in a competitive wholesale market and then distribute it to consumers. For this competitive scenario, we project a break-even price of approximately \$25 per tonne of CO_2 for the adoption of CCS. Thus operators of coal-fired power plants will reduce their long-run production cost by investing in new coal-fired plants with CCS capabilities, provided CO_2 emission permits trade for at least \$25 per tonne. In this context, we note that our forecast here is at the lower end of various estimates regarding the unit cost of reducing CO_2 emissions by means of CCS. Governmental agencies and analysts have issued estimates that point to higher cost figures in the \$30 – 45. These varying estimates are difficult to reconcile not only because of different assumptions about technology, but more so because of the lack of a common economic framework.

The break-even value for the adoption of CCS capabilities provides a significant data point in forecasting the effective carbon tax, that is, the market price for CO_2 emission permits under a cap-and-trade system. The overall marginal cost of reducing emissions will ultimately reflect the effectiveness of different CO_2 abatement strategies, including CCS, energy saving measures, biofuels and afforestation. As part of this portfolio, CCS for coal-fired power plants contributes an abatement potential of approximately 8 Gt on a worldwide scale (out of a total of 28 Gt in 2008). In the course of the next 30 years, this abatement potential could be realized at a marginal cost of $25 per tonne.

Power plants running on natural gas can also capture CCS. In contrast to coal-fired plants, however, we project that natural gas plants would find an investment in CCS economical only if emissions trade for at least $60 per tonne of CO_2. This substantially higher break-even price emerges because (i) traditional natural gas plants emit only about half as much CO_2 as traditional coal-fired plants per kWh and (ii) the increase in plant construction costs associated with CCS technology is comparatively high for a natural gas plant.

One recurring suggestion in connection with a cap-and-trade system is to introduce so-called safety valves which would commit the government to issuing additional emission allowances once the market price for permits reaches a certain threshold. If this threshold were to be set above $60 per tonne of CO_2, the availability of CCS at fossil fuel plants will substantially reduce the likelihood that safety valves would ever be activated. Chances of the effective carbon tax reaching this level ultimately depend on the timetable for setting more stringent emission caps. The legislative proposals currently in front of Congress envision a sharp acceleration in CO_2 reductions for the period post 2020. Such 'backloading' of the overall reduction levels significantly enhances the prospects of CCS as an effective abatement strategy.

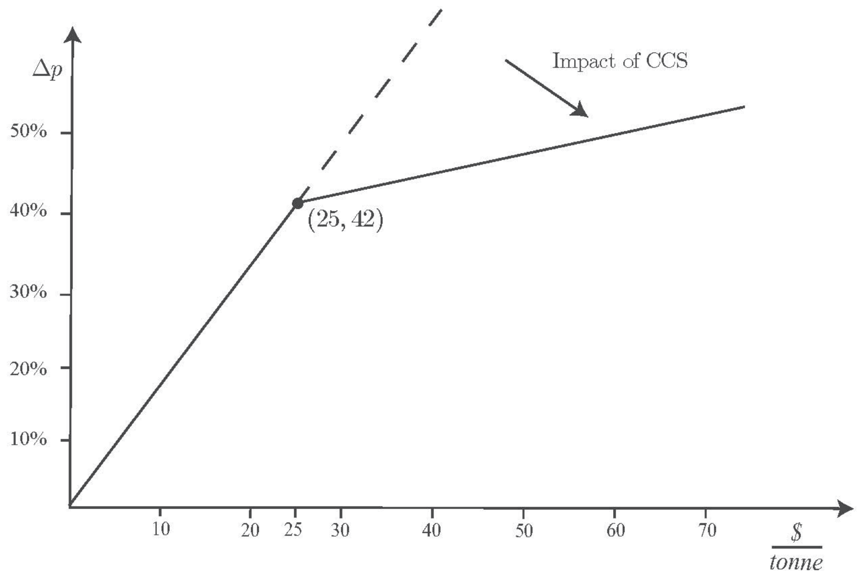
CCS ADOPTION AND ELECTRICITY PRICES

By how much will electricity prices increase if coal-fired power plants adopt CCS technology? The competitive market price of electricity will reflect the increase in the long-run unit cost of power generation due to the adoption of CCS technology. Our calculations indicate a corresponding increase in electricity prices at the retail level by about 25 – 30 percent. This forecast takes into account that electricity generation contributes roughly 60 percent to the retail price of electricity, the remainder coming from the cost of transmission and distribution. Thus, we come to a more optimistic conclusion than the more dire projections that have envisioned a doubling of electricity prices in connection with CCS adoption.

Moreover, CCS capabilities entail an important 'option value' as electricity prices are essentially shielded from any further increases in the effective carbon tax (the market price for CO_2 emission permits). Since newly constructed power plants with CCS capability will reduce their CO_2 emission by 85 – 90 percent, power generators will have to pay emission charges only on the remaining 10 – 15 percent of their emissions. Figure 1 illustrates this point by plotting the percentage increase in the wholesale price of electricity, Δp, as a function of the effective carbon tax. Consistent with the above forecast for coal-fired plants, the kink in the price curve occurs at $25 per tonne of CO_2 emitted. Without CCS, the wholesale price of electricity increases at a rate of 17 percent for every additional $10 in the carbon tax, yet with CCS capabilities further price increases are limited to a rate of 2 percent for every $10 increase in the emissions charge.

Predictions regarding the impact of CCS adoption on electricity prices must take into consideration that in most U.S. states electricity is delivered by a vertically integrated utility that bundles power generation and

Figure 1



distribution services. Product prices are then frequently set according to a rate-of-return regulation scheme, that is, the regulated firm is reimbursed for its full production cost including an adequate return on invested capital. For this regulation scenario, we find that an effective carbon tax of about $25 per tonne of CO_2 would again be the critical value that would make CCS adoption advantageous for coal-fired power plants.

In contrast to the competitive power generation scenario, though, the corresponding increase in electricity price would be phased in gradually over time. The reason is that rate-of-return regulation is based on historical accounting cost. If utilities receive emission allowances for CO_2 emitted from older power plants constructed prior to the adoption of the cap-and-trade system (100 percent 'grandfathering'), we project that electricity prices will rise almost linearly over a 30-year time window to their new equilibrium level which would be about 25 – 30 percent above the current level. For partial grandfathering policies, electricity prices could increase more dramatically in the short-term in response to high emission charges.

FURTHER CONSIDERATIONS FOR PUBLIC POLICY

CCS has considerable potential to reduce CO_2 emissions not only by a significant amount but also at a social cost that most economists would not consider prohibitive, particularly in comparison to the social costs predicted for a business-as-usual scenario with unregulated carbon emissions. The certification of known CCS technologies for power plants on a commercial scale should therefore become a priority. In the U.S., one of the most prominent such efforts is the FutureGen project in Illinois which was shelved in 2008 but now seems destined for continuation, with partial funding provided by the Department of Energy. While commercial scale certification is still pending, corporate and public decision makers will have to weigh the costs and benefits of investing in new power plants that lend themselves to being retrofitted with CCS capabilities.

The ability to capture CO_2 at fossil fuel power plants should also have positive spillover effects on other parts of the emissions pie. For instance, the transition to electric cars could become more attractive once the effective carbon tax passes the mark of $25 per tonne, because CCS effectively shields electricity prices from higher CO_2 charges. Similar substitution effects will emerge for the use of coal itself. In other parts of the world coal is still widely used in industrial processes to power machinery and equipment. The emergence of a carbon tax, coupled with the availability of CCS, will provide incentives for these industrial processes to rely increasingly on electric power.

In the upcoming negotiations over a global climate agreement, the participation of non-OECD countries, including China and India, is considered crucial. Both of these countries rely heavily on coal-fired power plants and many developing nations envision reliance on fossil fuels for their growing electricity needs. The availability of CCS technology for these countries should be a major factor in their willingness to join an international climate agreement that embraces aggressive CO_2 caps.

Letters commenting on this piece or others may be submitted at submit.cgi?context=ev.

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