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Six Distributional Effects of Environmental Policy

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Perspective

Six Distributional Effects of Environmental Policy

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While prior literature has identified various effects of environmental policy, this note uses the example of a proposed carbon permit system to illustrate and discuss six different types of distributional effects: (1) higher prices of carbon-intensive products, (2) changes in relative returns to factors like labor, capital, and resources, (3) allocation of scarcity rents from a restricted number of permits, (4) distribution of the benefits from improvements in environmental quality, (5) temporary effects during the transition, and (6) capitalization of all those effects into prices of land, corporate stock, or house values. The note also discusses whether all six effects could be regressive, that is, whether carbon policy could place disproportionate burden on the poor.

KEY WORDS: Capitalization effects; climate policy; general equilibrium; tax incidence

1. INTRODUCTION

Existing literature in environmental economics emphasizes efficiency effects of pollution controls. It shows how to measure the costs of reducing pollution or energy use and how to measure the benefits. Overall benefits are balanced against overall costs to determine the optimal amount of abatement and to determine the most cost-effective way to achieve it. Fewer studies address the question of who bears those costs or receives those benefits, even though any individual's net gain or loss as a fraction of income may greatly exceed the economy-wide gain or loss as a fraction of income.

A large body of literature in public economics studies the distributional effects of taxes, but for several reasons, the study of the distributional effects of environmental policy can be much more difficult and interesting. First of all, most pollution policies are not taxes at all, but instead employ permits or command and control (CAC) regulations such as technology standards, quotas, and other quantity constraints. Second, the effects of environmental policy are much more varied, intricate, and indirect. Standard methods of tax incidence find effects on product prices and on returns to labor and capital, but energy or environmental policy can have six separately identifiable effects. These effects have been studied separately in different kinds of models because a single study to incorporate all effects simultaneously would be very difficult, complex, and likely infeasible.

These six effects are identified in the literature reviewed by Fullerton,(1) but that literature touches on many different policies and methods of estimation.[1] This short note cannot review all that literature. Instead, for coherency, it illustrates all six effects using a single comprehensive example, namely, a climate policy that imposes a price per unit of emissions. No other paper discusses all effects in the context of one policy, so the contribution of this note is to illustrate how one climate policy can have all six effects simultaneously. For any given person,

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[1] The tax incidence literature is reviewed by Fullerton and Metcalf.(2) Some of the distributional effects of environmental policy are discussed in a chapter of the classic text by Baumol and Oates.(3) Another recent review of the literature on these distributional effects is in Parry *et al.*(4)

the six effects may augment or offset each other. In this particular case, many or all effects may be regressive.[2] An implication is that a reform package can include features to offset losses to low-income families.

The policy problem here is climate change—including global warming, sea-level rise, and increased frequency and severity of extreme weather events such as droughts, floods, and hurricanes. Scientists believe that climate change is caused by emissions of various greenhouse gases (GHG), particularly carbon dioxide (CO_2). An actual policy to reduce such emissions might involve a combination of mandates and incentives such as low-carbon fuel standards, renewable energy credits, and other incentives for research and development. For simplicity, however, the generic "climate policy" discussed here merely imposes a price per ton of CO_2 emissions (or perhaps on all GHG emissions). Firms may then abate emissions using energy-efficiency investments, switching to low-carbon fuel, or selling less high-carbon products. For present purposes, this price could be a tax on each ton of emissions, or a cap-and-trade policy that requires emitters to buy a permit for each ton of emissions. These are equivalent, if the government collects the tax or sells the permits. Either the tax revenue or the permit value could then be used in particular ways, such as to help low-income families. For these reasons, the climate policy below is equivalently called a carbon tax, permit policy, or cap-and-trade.[3]

The rest of this section describes a simple model that can be used to analyze the six effects of climate policy. The following six sections discuss each effect in more detail.

These effects are best analyzed in a computable general equilibrium (CGE) model that accounts for all markets simultaneously, including changes in production that affect the relative price and quantity of each input, each output, and each asset.[4] An integrated assessment model (IAM) may also account for the effect of emissions on atmospheric GHG concentrations, ocean temperatures, and feedback effects.[5] For expositional purposes, however, all six effects can be explained in a partial equilibrium diagram of a single market.[(1)] In the case of climate policy, firms could reduce CO_2 emissions per unit of output (e.g., per kwh of electricity). The simplest way to show all effects in one diagram, however, is temporarily to assume fixed emissions per unit. Then the supply and demand for carbon is essentially the same as the supply and demand for the output.

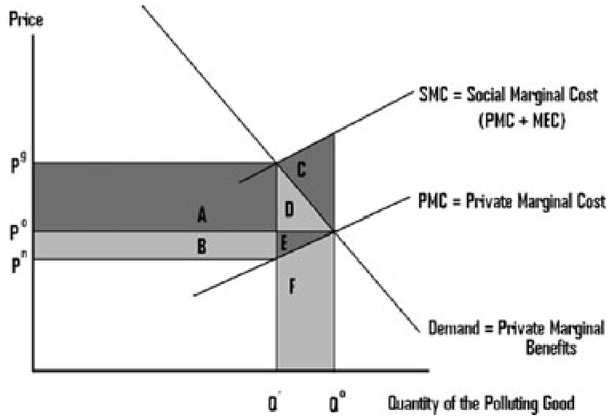

Fig. 1. Categories of gains and losses.

In Fig. 1, using this example, the demand curve reflects the private marginal benefit (PMB) of electricity. The supply curve reflects private marginal cost (PMC). Yet production causes an externality, because the cost of pollution is borne by others, not by the firm. Then the total cost of each unit is the social marginal cost (SMC), including both PMC and marginal external cost (MEC). In this diagram, the unfettered private market produces to the point where PMB = PMC, namely, output Q^o. The optimal output is where SMB = SMC, at reduced output Q'. An ideal policy would somehow restrict output to Q'. In the simple case with fixed emissions per unit output, a set number of CO_2 permits could restrict sales to Q'. In effect, supply is vertical at Q', so the new intersection of supply and demand is at equilibrium gross price P^g. After firms pay for permits, the new net price is P^n. The price of a permit is the difference $(P^g - P^n)$. If the industry is competitive, then pure profits are zero: net sales revenue is just enough to pay for all other inputs to production, such as labor, capital, fuel, and materials.

[2] A policy is regressive if the burden to income ratio is lower for those with more income. It is proportional if burden/income is the same for all groups, and it is progressive if that ratio is higher for those with more income. Even if the amount spent on electricity rises with income, the fraction of income spent on that good falls with income. Thus, any increase in the price of electricity is likely regressive.

[3] This short note cannot discuss all the details of specific legislation, but a U.S. example is HR2454, named after Representatives Waxman and Markey, titled the American Clean Energy and Security Act (ACES). It passed the House of Representatives in 2009, but then stalled in the Senate. For general information and further links, see: http://en.wikipedia.org/wiki/Waxman-Markey.

[4] Examples of CGE models range from Hazilla and Kopp[(5)] to more recent examples in Elliott *et al.*[(6)] and Rauch *et al.*[(7)]

[5] Kelly and Kolstad[(8)] define an IAM model as one that "combines scientific and socio-economic aspects of climate change" (p. 172). An example is in Nordhaus.[(9)]

2. COSTS TO CONSUMERS

Since the cap-and-trade policy raises the consumer's price of electricity to P^g, it reduces consumer surplus by the trapezoid area $A + D$. The amount of this price increase and the resulting burden depend on various considerations that need to be analyzed. It is relatively large, as drawn, because the negative elasticity of demand (η^D) has smaller absolute value than the elasticity of supply (η^S).[6] Thus economic analysis in each case needs both a demand and supply elasticity, and data on the fraction of each group's income spent on the good. For example, climate policy would raise the price of gasoline, for which West and Williams[(10)] estimate a set of demand parameters. They calculate four different measures of consumer surplus (area $A + D$) for each income group, and they find that the increase in gasoline price is regressive.[7] In some analyses it is not strictly regressive because the very poorest households cannot afford a car.[(11)]

The effects of climate policy on multiple output prices are calculated in detailed CGE models by Elliott *et al.* [(6)] and by Rausch *et al.*,[(7)] but a simpler analytical general equilibrium model with only two outputs is used by Fullerton and Heutel.[(12)] Their "dirty" good is an aggregation of carbon-intensive goods such as electricity, transportation, and petroleum refining, and their "clean" good includes everything else. Both sectors use labor and capital, but the dirty sector also uses carbon pollution as an input to production. They find that an increase in the CO_2 price from \$15/ton to \$30/ton would raise the price of the dirty good by 7.2%. They then use data on spending and incomes of thousands of households in the Consumer Expenditure Survey (CEX) to find that the ratio of burden to income falls monotonically from the lowest annual income decile to the highest. The first eight deciles bear more burden than the average fraction of income, while the highest two income deciles bear less than average.[8]

In analyzing distributional effects, a major issue is how to define who is rich or poor. A problem is that the lowest annual income group includes some whose income is temporarily low and others who are stuck at that level. An alternative is to classify households by their total annual consumption expenditures because it is a proxy for permanent income (assuming people smooth their consumption by spending less than their annual income in good years and more in bad years). When households in the CEX are classified by annual consumption, climate policy is less regressive.

Finally, of course, distributional effects could be measured not just across income groups, but across regions, age groups, or demographic characteristics. Climate policy would disproportionately burden southern states in the United States where people spend more than average on electricity to run their air conditioners, and it might burden those in the Northeast who rely on fuel oil for heat. The Midwest uses more natural gas, which has low carbon per unit of heat. And, of course, higher fuel and electricity costs would hurt current generations more than future generations who would benefit from technological progress that reduces the cost of renewable fuels and energy-efficient appliances.

Distributional effects also could be measured across countries. For the same carbon price, nations that rely disproportionately on coal would face higher electricity prices than those who use less-carbon-intensive fuel like natural gas. Denmark uses a lot of wind power, for example, while Sweden uses hydroelectric power.

3. COSTS TO PRODUCERS OR FACTORS

Energy or environmental policy may also impose burdens on producers or factors of production. In Fig. 1, the loss in producer surplus is area $B + E$. This area is small, as drawn, because the supply curve (PMC) is relatively elastic. These losses are larger if instead production involves industry-specific resources in relatively fixed supply, such as a specific type of energy, land with specific characteristics, or labor with particular skills. If so, then the cut-back in production burdens the owners of those limited resources.

Again, CGE models like those of Elliott *et al.*[(6)] or Rausch *et al.*[(7)] can be used to compute a new economy-wide wage, rate of return, or land rent. Sophisticated dynamic general equilibrium models could be used to solve for short-run effects, capital deepening, and the transition to a new balanced

[6] The permit price ($P^g - P^n$) is analogous to a tax wedge. Fullerton and Metcalf[(2)] show that the fraction of a tax borne by consumers is $\eta^S/(\eta^S - \eta^D)$. This fraction is higher with a larger η^S or smaller η^D.

[7] One measure assumes no price responses, one assumes all groups have the same price response, ones uses each group's own price response, and the fourth is the equivalent variation for each group. The higher gas price is most regressive with no return of revenue, less regressive when revenue is used to cut wage taxes, and becomes progressive when revenue is used to provide the same lump-sum rebate to each household.

[8] These results are consistent with those of many larger CGE models such as Hazilla and Kopp.[(5)]

growth path with a new labor/capital ratio. The analytical general equilibrium model of Fullerton and Heutel[12] is not a growth model, since labor and capital are both in fixed supply, but it can show intuitively the effect of a carbon tax on multiple output prices and factor prices—including the wage for labor and the return to capital. The "clean" sector uses only labor and capital, but the "dirty" sector uses labor, capital, and pollution. With three inputs, any two can be complements or substitutes. The "substitution effect" places less burden on whichever factor is a better substitute for pollution (and more burden on the other one). Because the carbon policy raises output price and reduces production, the "output effect" is likely to place more burden on whichever factor is intensively used in the dirty sector.[9] Rausch *et al.*[7] also consider other sources of income such as from natural resources and from existing U.S. transfer programs. Government transfers are often indexed to inflation, so an increase in energy prices leads to automatic cost-of-living adjustments. This aspect of existing policy makes carbon pricing less regressive or even progressive.

4. BENEFITS OF SCARCITY RENTS

Any restriction on the quantity of the polluting good in Fig. 1 makes the good scarce and gives rise to scarcity rents (area $A + B$). If the policy is a carbon tax or auction of permits, then government captures the scarcity rents as revenue. If it is a handout of permits or a simple quota, then area $A + B$ becomes profits to the firms that are allowed to produce and sell the restricted quantity.[13] Normally, firms *want* to restrict output but are prevented by antitrust policy. Yet here, climate policy *requires* firms to restrict output. It allows firms to raise price, and so they make profits.

That simple theory may be obvious in the case of Fig. 1, where pollution is a fixed ratio to output, because a restriction on pollution also restricts output. But what if firms can abate pollution per unit? Policy can still generate profits when firms can vary pollution itself, as shown by Maloney and McCormick.[14] They provide evidence for two different regulations, using data on stock market returns around the imposition of each regulation. First, the Occupational Safety and Health Administration imposed new cotton-dust technology standards uniformly on all textile firms in 1974. They look at a portfolio of 14 textile stocks, and they find a significantly positive abnormal return when this rule is imposed. Also, in 1973, the U.S. Supreme Court ruled in favor of groups that sued the EPA to "prevent significant deterioration" of air quality in areas already complying with national standards. The new stricter standard only affected new entrants such as nonferrous ore smelting plants that emit sulfur oxides and particulates, so the authors consider stock prices of existing copper, lead, and zinc smelters. Significant positive abnormal returns were found for existing firms in those industries.

One might normally think that firms would oppose costly new environmental regulations, but Maloney and McCormick show that "the interests of environmentalists and producers may coincide against the welfare of consumers" (pp. 99–100). This point is key both for the politics of environmental legislation and for distributional effects.

In the case of climate policy, Parry[15] shows how grandfathered permits generate profits that accrue to shareholders. His analytical model has explicit formulas that show the impacts of underlying parameters, but profits in his model are essentially area $A + B$. Thus, the policy may effectively transfer money from low-income consumers (area A) and from factors of production (area B) to higher income households who own corporations that make profits from scarcity rents (area $A + B$). This transfer can be avoided if the policy does not hand out permits to firms but instead sells permits at auction and uses the proceeds to help low-income consumers. For this reason, the House Bill would dedicate some permit value to reducing consumers' electric bills.

5. BENEFITS OF PROTECTION

The gain from environmental protection in Fig. 1 is area $C + D + E$, the sum of "MECs" over the range that emissions are reduced (from Q^o to Q'). What groups receive these benefits from reduced global warming? Any ton of CO_2 is a global pollutant, in that it affects ambient air concentration all around the world, but the same increase in that CO_2 concentration may have different effects in different places. Low-lying countries may feel more brunt of sea-level rise and increased storm severity. Some countries may experience more temperature increase than others, and some may experience more loss in

[9] In this model, environmental quality is separable in utility. In a more complicated model, the increase in environmental quality itself could affect the relative demands for goods and thus returns to factors.

biodiversity. In terms of agricultural productivity, some may gain while others lose. Even within the United States, some states may gain or lose agricultural productivity from climate change, while only low-lying states suffer from sea-level rise.

Moreover, even if two people experience the same effect such as lost biodiversity, they may value it differently. One person may care more about wildlife and thus be "willing to pay" more to protect biodiversity. If so, that person benefits more from a climate policy to reduce the effect of climate change on lost biodiversity. Because of this long list of different effects on different kinds of people in different places, it is virtually impossible to say whether the overall "benefits of protection" are progressive or regressive. To explain some of the potential effects, however, consider a few examples.

For effects within the United States, first consider how climate policy protects biodiversity. Those who are "willing to pay" more to protect wildlife are probably those in relatively high income brackets (while low-income families worry instead about necessities like food and shelter). If so, then this one benefit from climate protection may be regressive by helping predominantly high-income individuals. Biodiversity protection may also help drug companies develop new medications. If those companies are owned by high-income individuals, then this effect may also be regressive. Second, climate policy would benefit those who own coastal property, that is, those rich enough to own coastal property. While those effects might be regressive, other effects may be unknown or progressive. Third, for example, Schlenker and Roberts(16) find that climate change increases the number of very hot days and thus reduces agricultural productivity even in places like the United States with moderate climates. If climate change thus increases food prices, and the poor spend a higher than average fraction of income on food, then climate policy to prevent those effects may be progressive. Fourth, carbon policy might also reduce emissions of local pollutants, and thus reduce morbidity and mortality.[10] If the rich have better access to private health care to protect themselves, then a climate policy that reduces morbidity and mortality may provide more benefits to the poor. With all of these offsetting effects on different income groups, the overall effect is an open question.

Aside from effects across income groups, climate policy may have distributional effects across age groups or across regions. Within the United States, global warming might help those in cold areas while imposing more costs on those in warm climates and on low-lying areas subject to floods. For example, Daniel *et al.*(18) summarize 117 estimates from 19 U.S. hedonic house price studies of the effect of flood risk on house values, controlling for differences in house and neighborhood characteristics.[11] They conduct a "meta-analysis" to summarize those studies, finding that a 0.01 decrease in probability of flood each year raises house value by 0.6%, all else equal. Owners in low-lying areas benefit if climate policy prevents increases in flood probabilities.[12]

Climate policy would reduce burning of fossil fuel and thus affect local pollutants and health, but it may also affect deaths from extreme hot or cold. Deschênes and Greenstone(19) use annual temperature variation in two climate models to find that climate change will increase U.S. mortality by a small amount that is not statistically significant, but it would raise infant mortality more significantly. To offset some of those effects, people will increase residential air conditioning and thus energy use by 15–30%, and they may move location to avoid hotter temperatures. Thus, climate policy may reduce all these costs on those who now live in hotter climates.

These studies are mere examples of possible effects on different U.S. groups from climate change. A GHG policy would mitigate these effects within the United States as well as other distributional effects between countries. Mendelsohn *et al.*(20) use predicted climate changes across the globe to calculate each country's gain or loss. Currently, agricultural productivity is highest in cool or temperate regions, and so countries in hot climates tend to be poor already. Even for the same increase in temperature worldwide, cool regions become more productive while warm regions become less productive. If

[10] The U.S. EPA(17) finds that most benefits of the Clean Air Act are mortality reductions. Older or less healthy individuals have higher baseline mortality risk, and thus might benefit more from a reduction in the risk of dying this year. If so, climate policy benefits the elderly and infirm. On the other hand, they may have fewer years to live and be willing to pay less for a reduction in the risk of dying this year.

[11] With data on many house sales, the price can be estimated as a hedonic function of house characteristics and neighborhood characteristics such as air quality, water quality, or distance from a toxic waste site. The coefficient on such a variable indicates the market's willingness to pay for environmental improvement.

[12] Homeowners and landlords are usually in higher income brackets than renters (who gain nothing if their rent rises to reflect the lower flood probability).

so, policy to reduce global warming may provide the most benefit to the poorest countries.

6. COSTS OF TRANSITION

Other distributional effects of climate policy include the costs of adjustment and transition. These costs may be large, even if temporary. In Fig. 1, area $E + F$ is the value of capital and labor leaving the industry. With perfect mobility, they immediately earn the same return elsewhere. With imperfect mobility, however, a policy shift can make existing plants obsolete and impose capital adjustment costs. It can disrupt labor markets as well, and impose costs of retraining, relocation, and possibly long spells of unemployment between jobs.

Few have studied labor adjustment costs, especially from climate policy. In one exception, Deschênes[(21)] looks at the effect of energy costs on labor demand. He finds a negative cross-price elasticity. Since the cap-and-trade bill that passed the U.S. House of Representatives in 2009 would raise electricity prices by about 4%, his preferred estimate suggests that U.S. employment would fall by 460,000 (about 0.6%).

That estimate captures the effects on industries that react to their own higher electricity costs by reducing employment. It does not capture other effects. Climate policy does not operate through electricity prices, for example, if it reduces employment in mining or logging. These occupations constitute major sources of income for entire towns in some areas. Those workers may have acquired industry-specific human capital, and they lose that investment when the industry shrinks. At the same time, the new policy may increase employment in abatement technology, renewable fuel production, and reforestation. In other words, some lose from climate policy and others gain.

7. EFFECTS ON ASSET PRICES

These five types of gains or losses are measured annually, in Fig. 1, but they also can be capitalized into asset prices. For example, a corporate stock price might rise immediately from the expected future annual flow of scarcity rents (area $A + B$). Also, the current price of agricultural land can rise to reflect future benefits from reduced global warming, and the price of oceanfront property can reflect benefits of reduced sea-level rise (areas $C + D + E$). If a policy to reduce CO_2 also reduces other emissions, then it likely provides different air quality improvements to different neighborhoods. If so, then the present value of those gains can be captured by certain homeowners at the time of the change.[13] The homeowner may then sell the house at a premium to someone else. If so, then the person who breathes the cleaner air is not the person who benefits from the environmental improvement. When assets change hands, capitalization effects make it particularly difficult to measure the distributional effects of climate policy.

Sieg *et al.*[(22)] use data from 1989 to 1991 in southern California to estimate parameters of a structural model, and they use those estimates to calculate the welfare effects of air quality improvements from 1990 to 1995 (when ozone levels in different neighborhoods fell from 3% to 33%). Areas with the most improvement might see upward pressure on house prices, but then some households sell at a gain and move to other cheaper neighborhoods. These shifts induce further house price changes, until all prices achieve a new general equilibrium. In one location where ozone fell by 24% in their study, they found that house prices rise nearly 11%. Moreover, landlords reap gains while renters may lose. Areas with the most environmental improvement may see the most increase in rents, which forces out low-income renters.

Climate policy may cause major cutbacks in particular industries such as logging, mining, and coal-fired electricity generation. Corporate stock prices may fall by a large amount, but those losses in certain industries are not necessarily a major problem to any one person if investors diversify their portfolios. But workers may devote years of training and learning on the job in such an industry, and then become unable to find any work in that industry after cut-backs. If so, the burden is not just the lost wage in a given year, but the entire present discounted value of lost wages in all future years. This human capital investment is not diversifiable, and so it can impose a much larger percentage loss for certain individuals than other asset price capitalization effects of climate policy.

[13] The asset price increase exactly equals the present value of future benefits only if markets clear with perfect information and no transaction costs. With major moving costs, however, the allocation of houses to owners may not perfectly reflect their willingness to pay. Also, the capitalization is moderated by any elasticity in the supply of land. The price may rise less if fringe land can be converted to residential use.

8. CONCLUSION

Prior literature emphasizes the economic efficiency effects of environmental policy, but economists are now beginning to study distributional effects that can be much more difficult and challenging. This article illustrates the many types of distributional effects that can arise from just one new climate policy, and it shows why any full analysis of all such effects might be too complex to incorporate within one study. It may require multiple analyses to characterize all the distributional effects of one policy. Initial studies have looked at output price and factor price changes, and generally find the impact to be regressive. If the permits are sold at auction, then revenue is available to rebate to low-income households and offset those regressive effects. But only careful analysis of all six effects can ensure improvements in environmental protection without adverse distributional consequences.

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