NBER WORKING PAPER SERIES

DISTRIBUTIONAL EFFECTS OF ENVIRONMENTAL AND ENERGY POLICY: AN INTRODUCTION

Don Fullerton

Working Paper 14241
http://www.nber.org/papers/w14241

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
August 2008

This chapter is the introduction for a book to be published by Ashgate that includes 21 previously published papers. I am grateful for comments from Tom Tietenberg, the series editor, and from authors of papers in the book, including Trudy Ann Cameron, Ian Parry, and Kerry Smith. This paper is part of the NBER's research programs in Public Economics (PE) and in Environmental and Energy Economics (EEE). Any opinions expressed are my own and not those of the National Bureau of Economic Research.

Distributional Effects of Environmental and Energy Policy: An Introduction
Don Fullerton
NBER Working Paper No. 14241
August 2008
JEL No. H22,Q48,Q52

ABSTRACT

This chapter reviews literature on the distributional effects of environmental and energy policy. In particular, many effects of such policy are likely regressive. First, it raises the price of fossil-fuel-intensive products, expenditures on which are a high fraction of low-income budgets. Second, if abatement technologies are capital-intensive, then any mandate to abate pollution may induce firms to use more capital. If demand for capital is raised relative to labor, then a lower relative wage may also hurt low-income households. Third, pollution permits handed out to firms bestow scarcity rents on well-off individuals who own those firms. Fourth, low-income individuals may place more value on food and shelter than on incremental improvements in environmental quality. If high-income individuals get the most benefit of pollution abatement, then this effect is regressive as well. Fifth, low-income renters miss out on house price capitalization of air quality benefits. Well-off landlords may reap those gains. Sixth, transition effects could well hurt the unemployed who are already at some disadvantage. These six effects might all hurt the poor more than the rich. This paper discusses whether these fears are valid, and whether anything can be done about them.

Don Fullerton
Department of Finance
University of Illinois
340 Wohlers Hall
1206 South Sixth Street
Champaign, IL 61820
and NBER
dfullert@illinois.edu

Public economics has well developed tools for analyzing the incidence and distributional effects of all personal taxes, payroll taxes, property taxes, and corporate income taxes. Some of that literature looks at distributional effects of environmental or energy taxes used to help control pollution or energy consumption. Yet most pollution policy does not involve taxation at all. Instead, it employs permits or command and control (CAC) regulations such as technology standards, quotas, and other quantity constraints. Existing studies are mostly about effects on economic efficiency. This literature addresses questions such as: how to measure the costs of reducing pollution or energy use, how to measure benefits of that pollution abatement, what is the optimal amount of protection, and what is the most cost-effective way to achieve it.

Yet CAC environmental restrictions do impose costs, and an important question is who bears those costs. Moreover, those restrictions provide benefits of environmental protection, and another important question is who gets those benefits. Thus, full analysis of environmental policy could address all the same questions as in the tax incidence literature. Perhaps such analysis could use the same tools to address distributional effects – not of taxes, but of these other policies that are used to protect the environment.

This introduction discusses some initial literature on distributional effects of environmental and energy policy. It uses the literature on tax incidence as a starting point, but then goes on to point out ways in which distributional effects of environmental policy are more interesting and difficult. For example, standard tax incidence literature would point out general equilibrium implications of an excise tax: not only does it affect the relative price of the taxed commodity, and thus consumers according to how they use income (uses side), but it also impacts factors intensively used in the production of that commodity, and thus individuals according to the sources of their income (sources side). This literature is reviewed in Fullerton and Metcalf (2002).

Yet an environmental mandate can have those effects and more! To identify the major effects around which this introduction is organized, consider a simple requirement that electric generating companies cut a particular pollutant to less than some maximum quota. This type of mandate is a common policy choice, and it has at least the following six distributional effects.

First, it raises the cost of production, so it may raise the equilibrium price of output and affect consumers according to spending on electricity (uses side).

Second, it may reduce production, reduce returns in that industry, and place burdens on workers or investors (sources side).

Third, a quota is likely to generate scarcity rents. Take the simple case with fixed pollution per unit output, so the only "abatement technology" is to reduce output. Then a restriction on the quantity of pollution is essentially a restriction on output. Normally firms *want* to restrict output but are thwarted by antitrust policy. Yet in this case, environmental policy *requires* firms to restrict output. It allows firms to raise price, and so they make profits, or rents, from the artificial scarcity of production. Just as tradable permit systems hand out valuable permits, the non-tradable quota also provides scarcity rents – to those given the restricted "rights" to pollute.

Fourth, if it cleans up the air, this policy provides benefits that may accrue to some individuals more than others. The "incidence" of these costs and benefits usually refer to their distribution across groups ranked from rich to poor, but analysts and policy-makers may also be interested in the distribution of costs or benefits across groups defined by age, ethnicity, region, or between urban, rural, and suburban households.

Fifth, regardless of a neighborhood's air quality improvement, many individuals could be greatly affected through capitalization effects, especially through land and house prices. Suppose this pollution restriction improves air quality everywhere, but in some locations more than others. If the policy is permanent, then anybody who owns land in the most-improved locations experience capital gains that could equal the present value of all future willingness to pay for cleaner air in that neighborhood. Similar capitalization effects provide windfall gains and losses to those who own corporate stock: capital losses on stockholdings in the company that must pay more for environmental technology, and capital gains on stockholdings in companies that sell a substitute product.

Capitalization effects are pernicious. A large capital gain may be experienced by absentee landlords, because they can charge higher rents in future years. Certain renters with cleaner air might be worse off, if their rent increases by more than their willingness to pay for that improvement. Moreover, the gains may not even accrue to those who breathe the cleaner air! If households move into the cleaner area after the policy change, then they must pay more for the privilege. The entire capital gain goes to those who happen to own property at the time of the change, even if they sell it at the higher price and move out before the air improves. Similarly, new stockholders in the burdened company may be "paying" for abatement technology in name only, with the entire present value of the burden felt by those who did own the stock at the time of enactment, even if they sell that stock before the policy is implemented.

Sixth, strong distributional effects are felt during the transition. If workers are laid off by the impacted firm, their burden is not just the lower wage they might have to accept at another firm. It includes the very sharp pain of disruption, retraining, and months or years of unemployment between jobs. These effects are analogous to capitalization effects, if the worker has large investment in particular skills – human capital that is specific to this industry. If the industry shrinks, those workers suffer a significant loss in the value of that human capital. They must also move their families, acquire new training, and start back at the bottom of the firm hierarchy, with significant psychological costs.

Using these six categories in six sections below, this introduction covers research in economics that has begun to analyze distributional effects of environmental and energy policy.[1] Particular emphasis is given to the twenty-one papers published in economics journals that are reprinted in this book. To set the stage for that discussion, however, the rest of this preliminary section reviews some earlier papers.

The classic text in the economic analysis of environmental policy is the book by Baumol and Oates (1988), which devotes a whole chapter to distributional effects. Since they nicely review the literature prior to 1988, this book emphasizes later literature and the current state of the art. Yet that text effectively issues two challenges to subsequent researchers. First, because research on distributional effects was not very extensive or well developed, the allocation of an entire chapter to it effectively challenges the field of environmental economics to deal with this topic more seriously. This collection examines how well recent researchers have risen to the challenge.

A second challenge in that chapter of Baumol and Oates (1988) is related to the idea that many effects of environmental policy are likely regressive. Consider the six categories just listed. First, it likely raises the price of products that intensively use fossil fuels, such as electricity and transportation. Expenditures on these products make up a high fraction of low income budgets. Second, if abatement technologies are capital-intensive, then any mandate to abate pollution likely induces firms to use new capital as a substitute for polluting inputs. If so, then capital is in more demand relative to labor, depressing the relative wage (which may also impact low-income households). Third,

---

[1] Another good review of recent literature on distributional effects of environmental policy is provided by Parry, Sigman, Walls, and Williams (2006).

pollution permits handed out to firms bestow scarcity rents on well-off individuals who own those firms. Fourth, low-income individuals may place more value on food and shelter than on incremental improvements in environmental quality. If high-income individuals get the most benefit of pollution abatement, then this effect is regressive as well. Fifth, low-income renters miss out on house price capitalization of air quality benefits. Well-off landlords may reap those gains. Sixth, transition effects are hard to analyze, but could well impact the economy in ways that hurt the unemployed, those already at some disadvantage relative to the rest of us.

That is a potentially incredible list of effects that might *all* hurt the poor more than the rich. The second challenge for subsequent literature, then, is to determine whether these fears are valid, and whether anything can be done about them – other than to forego environmental improvements!

Following this introduction is a paper by Fullerton (2001, Chapter 2 of this volume) which does not make an original research contribution in the usual sense. Rather, it is a synthesis and exposition of economic analyses to compare eight pollution control policies: taxes, subsidies, permits handed out to firms, permits auctioned by government, CAC performance standards, CAC technology mandates, and even Coase (1960) solutions where the "property rights" to pollute might be owned by the polluter or by victims. It also shows which policies may equivalently affect each group. For example, the pollution tax and auction of permits both capture scarcity rents for the government, whereas the simple pollution quota and the handout of permits both give those rents to firms. The eight policy alternatives are compared on multiple grounds, including economic efficiency, administrative efficiency, political feasibility, enforceability, and distributional effects. The paper is included here because of the simple exposition of who gains and who loses from each environmental policy. A simple diagram shows the burden on consumers, the gains to the owners of the right to pollute, and the gains to those who value the environment.

I. Costs to Consumers

To categorize the six distributional effects, consider the market for a polluting good (such as electricity). In Figure 1, demand reflects private marginal benefits (PMB). Yet production has private marginal costs (PMC), and the pollution externality means that social marginal costs (SMC) include marginal environmental costs (MEC).[2]

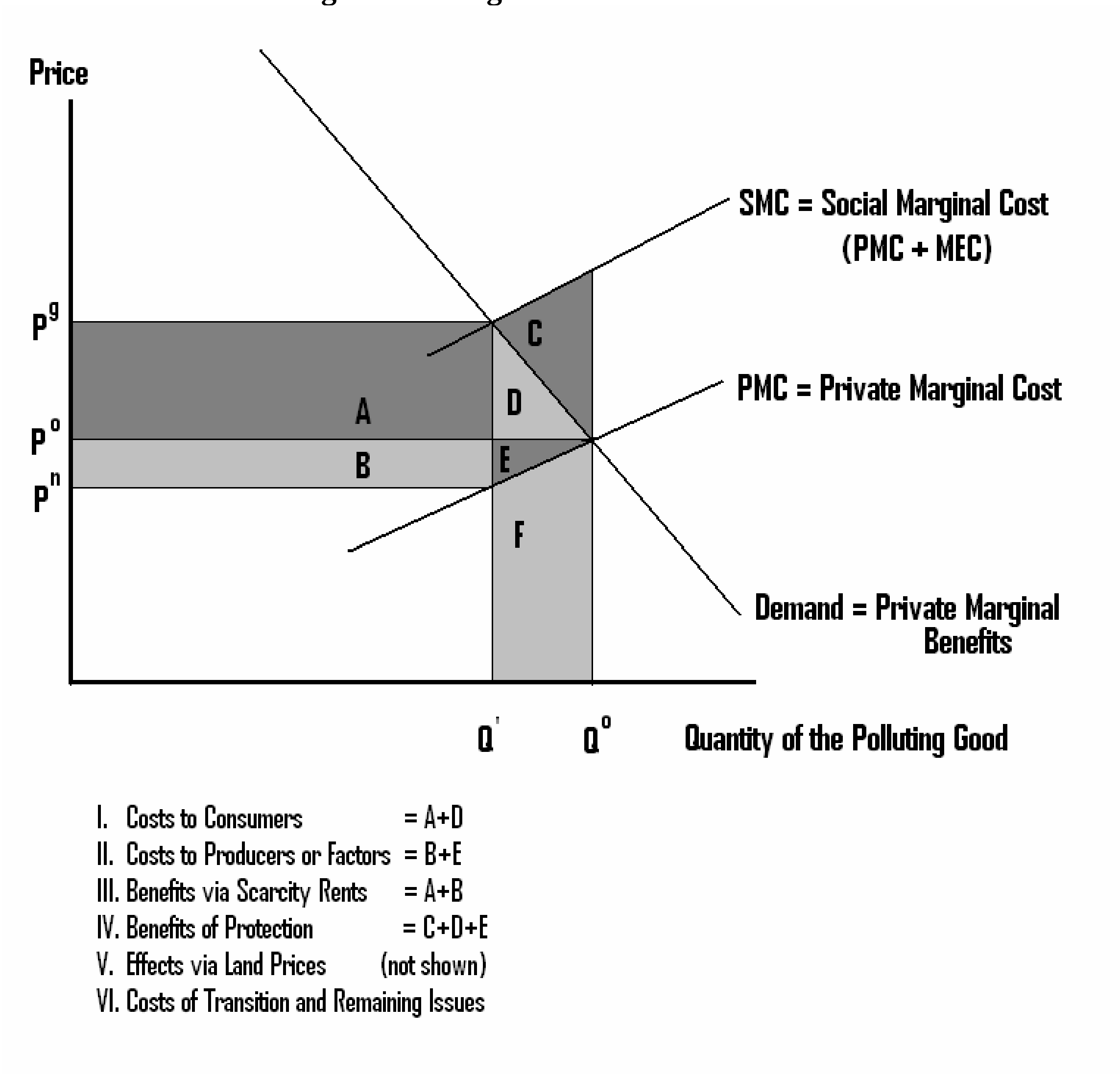
In this diagram, the private market with no policy restriction would produce to the point where PMB=PMC, namely output Q^o. The optimal output is where SMB=SMC, at reduced output Q'. A pollution quota would effectively restrict output to Q', and we can now categorize distributional effects. This section deals with costs to consumers.

This environmental policy raises the equilibrium output price to a new "gross" price, P^g, and it reduces consumer surplus by the trapezoid area A+D. The amount of this price increase and resulting burden depend on various considerations that must be analyzed. It is relatively large, as drawn, because the elasticity of demand for this output is low compared to the elasticity of supply. If consumers can switch to good substitutes more easily, then demand is flatter, consumer burden is smaller, and the loss of producer surplus is larger. Thus the economic analysis in each case must measure both demand and supply elasticities, and the fraction of each group's income spent on this good.

---

[2] For simplicity, assume that pollution per unit of electricity is fixed. Then the demand for electricity is the "demand for pollution", and the only way to cut pollution is to cut output. The externality can be corrected by a tax on pollution, which is equivalent in this case to a tax on output. It also can be corrected by a permit system. The example in the text is a simple quota, or quantity constraint.

Figure 1: Categories of Gains and Losses



The Clean Air Act is likely to raise the cost of electricity, gasoline, and other products that rely on fossil fuel. Estimates suggest that such spending is a higher fraction of total spending for low-income than for high-income families, so early studies such as Gianessi *et al* (1979) find that costs of the Clean Air Act in the U.S. are regressive.[3] Then, in other research, Robison (1985) assumes that all industrial pollution control costs are passed forward into output prices, and he uses a disaggregate input-output model to calculate the ultimate effects on all goods purchased by twenty different income groups. He finds that burdens are very regressive, ranging from 0.76 percent of income for the poorest group to 0.16 percent of income for the richest group.

James Poterba (1991, Chapter 3 of this volume) looks at the gasoline tax, and he makes two points that both tend to offset that previous finding of regressivity. First, early studies rank families from the lowest annual income to the highest annual income. Yet annual income fluctuates, and it varies over the life-cycle. The very young and old spend

---

[3] Even if the amount spent on electricity is higher for a rich family than for a poor family, that electricity spending as a fraction of income is found to be lower for those with high income. Thus the policy is "regressive", meaning that the burden as a fraction of income is lower for those with more income. The burden is "proportional" if the ratio of burden to income is the same across all income groups, and it is "progressive" if that burden ratio is higher for those with more income.

more than their annual income, because they know that annual income is temporarily low. They are not "poor" in terms of permanent or lifetime income. Poterba points out that annual total consumption expenditure is a good proxy for permanent or lifetime income, and so he ranks families from the lowest to the highest annual consumption. Then, because those with low annual income tend to consume more of their income than those with high annual income, any commodity tax appears to be more regressive on the basis of annual income. Thus the change to annual consumption as a proxy for permanent income makes the gasoline tax less regressive.

The second point about the gas tax is that the very poorest households cannot afford to own a car at all. They take public transportation. Thus, Poterba finds that the burden of a gas tax is the highest percent of "permanent income" for those in the middle of that spectrum. It is not strictly regressive at all. This point would not necessarily reduce the regressivity of other taxes on energy, however, if the poorest households do use a high fraction of total expenditures on heating fuel and electricity.

Another two points are raised by Walls and Hanson (1999, Chapter 4 of this volume). They also compare annual and lifetime income, but not using consumption as a proxy for lifetime income. They start with 1,000 households from the 1990 National Personal Transportation Survey, which includes socioeconomic and demographic data as well as each household's vehicle make, model, and year. Then, to construct lifetime income for each household, they use coefficients on household characteristics from the lifetime wage-age profiles estimated by Fullerton and Rogers (1993) using longitudinal data from the Panel Survey of Income Dynamics. Second, instead of just looking at a gas tax, Walls and Hanson look at emission policies. For each vehicle in the NPTS cross-section, they assign an emissions rate (using remote-sensing emissions data on 90,000 vehicles). They then calculate the effect on each household of (1) the current system of annual registration fees based on car value, (2) basing annual fees on vehicle miles traveled (VMT) of that vehicle, (3) a fee based on the emission rate of the vehicle, or (4) on the estimated emissions of the vehicle (emissions per mile times miles).

Interestingly, the current fees based on car value are only somewhat regressive: low income families spend a high fraction of income on cars, but higher income groups buy higher-valued cars. Yet those fees perversely charge *less* for the more-polluting cars (which have lower value). The attempt to fix those incentives by placing more tax on the low-valued polluting cars undeniably makes the fee more regressive. The VMT fee looks a lot like the gas tax discussed above. The emissions fee is more regressive, because it is VMT times the emission rate, but the fee based on emissions rate is the most regressive. All such fees are less regressive when viewed in a lifetime perspective.

Contributions come in pairs in this section, including those of Metcalf (1999, Chapter 5 of this volume). First, instead of looking only at gas or vehicle taxes, he considers a comprehensive environmental tax reform that includes a carbon tax, gas tax, air pollution taxes, and a virgin materials tax. Together these would raise prices of various energy-related goods (and revenue equal to 10% of current federal receipts in the U.S.). He then uses an input-output model to calculate the increase in price of every industry's output, and he calculates the effect of those price increases on a large sample of households from the Consumer Expenditure Survey (CEX). He shows that all of those environmental taxes are regressive when measured against annual income, to varying degrees, but each is less regressive when measured against lifetime income.

Second, however, he points out the importance of what is done with the revenue. If the package were revenue-neutral, the new environmental taxes could be used for a combination of: an exemption from payroll tax for the first $5,000 of wages, a $150 tax credit for each exemption in the personal income tax, plus an across-the-board income tax cut of 4%. This tax shift is still somewhat regressive when measured by annual income, but the overall package has no effect (or is slightly progressive) when measured by lifetime income. The key point is that environmental tax reform does not need to be regressive; the revenue could be used in ways that are even more progressive than the payroll and income tax cuts assumed by Metcalf.

Sarah West (2004, Chapter 6 in this volume) studies gasoline taxes and car policies related to emissions, as do those reviewed above, but she makes two additional points. First, consumers have preferences over VMT, rather than gasoline *per se*, and so utility-based welfare measures are best calculated from VMT demand. Yet the price of driving a mile is endogenous. It depends on miles per gallon, which depends on the choice of vehicle, which depends on the price of gasoline and on all of the household's unobserved characteristics. Since the price of a mile is endogenous, a regression of VMT demand on VMT-price would yield biased coefficients. She corrects for this bias by first estimating discrete demand for vehicle type and then using those results in the estimation of continuous demand for VMT. This correction is important, and most good subsequent studies of car and gas demand have undertaken similar corrections.

Her second major point is that groups have different price responsiveness. She uses total consumption to classify households from poor to rich (as a proxy for permanent income), and she estimates VMT demand for each decile separately. She finds that poorer groups are more price-responsive, which reduces their gas tax burden. In Figure 1 above, their demand would be flatter, and so the same increase in price (from P^o to P^g) would reduce quantity more (from Q^o to Q'). It would thus shrink their loss in consumer surplus (area A+D). This effect reduces the regressivity of the gas tax.[4]

The last paper included in this section is by West and Williams (2004, Chapter 7 in this volume). In their words, their "study makes two main contributions" (p. 536).[5] First, they use an estimated demand system to calculate four different measures of "burden" for each group. The simplest procedure used in early literature assumes no price responses, but they also calculate a consumer surplus measure assuming all groups have the same price response, a consumer surplus measure using each group's own price response, and an additional measure based on the equivalent variation for each group. The first of those makes the gas tax look most regressive. As in West (2004), the use of each group's own response makes the gas tax look least regressive. The second point of West and Williams is to calculate incidence for three different assumptions about use of the revenue. The gas tax is most regressive with no return of revenue, it is less regressive when revenue is used to reduce wage taxes, and the whole reform becomes progressive when revenue is used to provide the same lump-sum rebate to each household. This last result highlights the tradeoff between equity and efficiency, since the uniform lump-sum rebate cannot reduce income tax distortions by cutting taxes on work effort.

II. Costs to Producers or Factors

Energy or environmental policy may also impose burdens on producers or on factors of production. Figure 1 shows a simple partial equilibrium model, where the loss

---

[4] Many of the poorest households don't own cars or buy gas, so the gas tax is somewhat progressive over the first few deciles and then regressive over remaining deciles. The fact that the price elasticity falls with income means that the gas tax is even more progressive over the first few deciles and less regressive beyond that. West also calculates the incidence of a subsidy to newer cars; it may encourage the purchase of newer cars with lower emission rates, but it is a decidedly regressive policy.

[5] Like other papers discussed above, it really makes more than two contributions. Unfortunately, however, space constraints here preclude more than about two points from each paper included in this volume.

in producer surplus (area B+E) is relatively small because the supply curve (PMC) is relatively elastic. These losses could be 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 industry-specific skills. If so, then the cut-back in production burdens the owners of those limited resources.

A general equilibrium model could be used to solve for the new economy-wide wage, rate of return, or land rents, and a more sophisticated dynamic general equilibrium model could be used to solve for short run effects, capital deepening, and the transition to a new balanced growth path with a new labor/capital ratio.

The early development of this literature is exemplified by the dynamic growth model of John and Pecchenio (1994, Chapter 8 in this volume). In this model, production uses labor, physical capital, and natural environmental capital. Each agent's earnings when young are allocated between savings for consumption when old, or for maintenance of the environment. That choice takes into account that environmental maintenance can increase welfare when old, but it does not take into account the welfare of unborn generations. Thus the framework is useful for studying a particular kind of distributional effect – between generations. As in other natural resource models, this economy can have multiple equilibria: one with low environmental maintenance that leads to low production and low investment, and the other with high physical capital and good environmental quality. This insight also helps explain some observed distributional differences between rich and poor countries, even poor countries that start with abundant resources. The paper also describes alternative transition paths: one with growing capital and degrading environment, one with both capital stocks shrinking, and one with both growing. It also points to the importance of environmental accounting, since rising income does not necessarily mean rising welfare for future generations.

A different kind of general equilibrium model is in Fullerton and Heutel (2007a, Chapter 9 in this volume). It is not a growth model, since labor and capital are both in fixed supply, but it can be used to solve analytically for the effect of an energy 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. First, the "substitution effect" places less burden on whichever factor is a better substitute for pollution (and more burden on the other one). Second, because the pollution tax 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.[6]

They then look at special cases. Even if both factors are equal substitutes for pollution, the intensively-used one does not always bear more burden. If the dirty sector is capital intensive, for example, then the output effect would tend to place more burden on capital, depending on consumers' ability to substitute between the two outputs. But if that effect is relatively small, it can be more than offset by the fact that the dirty sector is trying to substitute out of pollution and into *both* capital and labor at its current capital/labor ratio, which means *less* burden on capital. Finally, these authors employ stylized facts and plausible parameter values to conclude that "the impact of factor intensities over the plausible range is less important than the impact of the elasticities of substitution between pollution and capital or labor" (p.587). In other words, to know who bears the burden of energy policy, it is important to estimate cross-price elasticities.

---

[6] 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.

In a working paper, Fullerton and Heutel (2007b) note that most environmental policies do not use taxes. Instead, regulators have employed CAC restrictions on the quantity of pollution (a "quota"), on pollution per unit output (a "performance standard"), or on pollution per unit of some input (a "technology mandate"). They find the same effects as before but identify other new effects as well. The restriction on the ratio of pollution to output can be achieved both by reducing pollution in the numerator *and* increasing output in the denominator. Thus, it involves an implicit "output subsidy". Under plausible conditions, this effect can *help* any factor that is intensively used in the polluting sector.

In other words, actual policies can be tricky. With multiple offsetting effects on the wage rate and return to capital, we cannot just assume that a restriction on the polluting sector will injure whatever factor is intensively employed there.

III. Benefits via Scarcity Rents

When the quantity of the polluting good is restricted in Figure 1, the restriction makes the good scarce and gives rise to scarcity rents (area A+B). If the policy is a tax on pollution or the auction of permits, then the government captures those scarcity rents as revenue. If the policy is a handout of permits or a quantity restriction (quota), then area A+B becomes profits to the firms that are allowed to produce and sell that newly-restricted quantity. That simple theory may be obvious in the case of Figure 1, where pollution is a fixed ratio to output, because then a restriction on pollution also restricts the quantity of output. But what if firms can abate pollution per unit of output? What if the policy requires a particular technology, and entry is permitted?

Maloney and McCormick (1982, Chapter 10 in this volume) show how scarcity rents can still be generated in these circumstances, and they provide empirical evidence for two different regulations, using data on stock market returns around the time the new regulation is imposed. First, in 1974, the Occupational Safety and Health Administration imposed new cotton-dust technology standards uniformly on all textile firms.[7] Looking at a portfolio of 14 textile stocks, they find a significantly positive abnormal return around the time this rule is imposed. This result is not sensitive to various alterations of the model and time period, and it is not explained by other events at the time.

In addition, many rules do effectively restrict entry by imposing stricter regulation on new firms only, while "grandfathering" existing firms. Maloney and McCormick also look at the 1973 decision of the U.S. Supreme Court in favor of environmental groups that sued the EPA to "prevent significant deterioration" of air quality in areas already in compliance with National Ambient Air Quality Standards. Because this decision could not be fully anticipated, it represents a good "event" to study. Only new entrants are forced to meet stricter standards, especially those who emit sulfur oxides and particulates. These emissions are concentrated in nonferrous ore smelting, so they look at stock prices of existing copper, lead, and zinc smelters. Again they find significant positive abnormal returns to existing firms in those industries.

One might think that producers would abhor costly new regulations, in a political battle between polluters and environmentalists, but this evidence suggests that "the interests of environmentalists and producers may coincide against the welfare of

[7] If marginal and average costs were perfectly flat and identical for all firms, and if this regulation shifted costs up by the same amount for all firms, then none would make profits. But if a fixed number of competitive firms have U-shaped average cost curves, then a new technology standard may increase marginal costs more than average costs. If so, the new intersection of demand and marginal cost determines a price that is above average cost, generating profits.

consumers" (pp. 99-100). The implications are important not only for the political economy of enacting environmental legislation, but for the distributional impact as well: environmental policies impose abatement costs that must be borne by producers and consumers, but also can provide significant benefits to others by generating profits.

The U.S. is now contemplating a policy to limit carbon emissions that contribute to global warming, and such a policy might have huge effects both because fossil fuel is such a large input to production *and* because the policy might require large reductions. Dinan and Rogers (2002, Chapter 11 of this volume) find that restricting emissions by just 15%, relative to business as usual, would raise prices by 2.8%. If this policy were a carbon tax, it might raise $128 billion (in 1998 levels and dollars). More likely, however, U.S. policy would hand out tradable permits and $128 billion of private profits for firms. Thus they find that "the magnitude of the wealth that would be redistributed … could substantially exceed the actual cost to the economy" (p.200).[8]

Dinan and Rogers use results from the input-output model of Metcalf (1999) on the carbon content and price increase for each commodity, and they use a large sample of 57,247 households from the Current Population Survey matched with tax return data from the Statistics of Income and consumption data from the CEX. They also account for a few intricacies: first, the permit policy would exacerbate deadweight losses from taxes that have their own distributional effect; second, the corporate tax would capture for government some of the profits; third, the policy decision about use of that revenue would have its own distributional effects; fourth, the higher output prices would trigger increases in indexed transfer programs like Social Security, with further distributional effects. With all of these intricacies, the predominant effects are still (1) low-income households spend more of their income on carbon-intensive products, and (2) high-income households own the corporations that receive profits. Thus, the policy is overall highly regressive unless government captures a higher fraction of the scarcity rents *and* uses that money to provide an equal lump sum amount to every individual.

Parry (2004, Chapter 12 of this volume) addresses some of the same questions, but uses a more stylized analytical model with less detailed calculations but with explicit formulas that show impacts of underlying parameters. He also looks at other pollutants (SO_2 and NO_X) and other policies (performance standards, technology mandates, and taxes on dirty inputs). He finds that grandfathered permits benefit stockholders and thus can provide gains to high-income groups while imposing large costs on the poor. This effect is diminished with more substantial requirements for abatement. The burden on low-income groups can be reduced by the other policies that do not provide windfall profits to stockholders. When abatement costs differ between sources, then a permit system can minimize the overall costs of abatement, but that gain in economic efficiency can be offset by the social costs of adverse redistribution if the social welfare function exhibits aversion to income inequality. In other words, social welfare might be raised more by inefficient CAC mandates than by grandfathered permits. And the auction of permits achieves efficiency without that handout of profits to wealthy stockholders.

A rather contrary view is expressed in the next paper by Louis Kaplow (2004, Chapter 13 of this volume), who suggests that evaluation of the economic efficiency of such a reform need not account for adverse distributional effects at all! If a gas tax or other pollution policy imposes costs on low-income groups and benefits to high income groups, those redistributive effects could be offset by adjustments to the income tax.

[8] Theory suggests that U.S. firms could profit from the distribution of these carbon permits, but this theory is confirmed by evidence for the European Union's Emissions Trading System. Sijm *et al* (2006) find that 60 to 100% of the cost of CO_2 permits are passed through to consumers in Germany and the Netherlands, even though power companies receive permits for free. Firms thus realize substantial windfall profits.

Moreover, any policy's adverse distributional effects should not be attributed to the policy, but rather, to the failure to make those income tax adjustments. The point is that we need not choose the less efficient environmental policy in order to avoid adverse distributional effects, since we could instead offset those effects through income tax adjustments. His argument is more complicated and subtle than can be stated in this short introduction, which is a good reason to include the whole paper in this volume.[9] The interesting conceptual point is not that environmental policy can proceed regardless of measured effects on distribution. Indeed, measures of distributional effects provided by the various papers in this book are important, in order to know *how* to adjust the income tax in a way that would neutralize these distributional effects.

Because quotas or grandfathering of permits provides benefits to firms as well as to environmentalists, it can create a powerful coalition that greatly increases the political feasibility of environmental protection. Bovenberg, Goulder and Gurney (2005, chapter 14 if this volume) investigate exactly what fraction of permits or rents must be allocated to firms to cover their losses, while other permits are sold at auction to achieve greater efficiency by cutting distortionary taxes. They build analytical and numerical models with perfect competition, constant returns to scale, a clean good, an intermediate good, and a final good produced in a polluting process. All three goods use labor and capital. If those inputs were perfectly mobile, then each industry would earn zero profits both before and after a pollution tax or auction of permits, so the simplest case implies that no permits need to be grandfathered to firms. Yet Bovenberg *et al* recognize adjustment costs in the re-allocation of capital, so firms would indeed make losses upon imposition of a sector-specific policy. For little abatement, they find that only about a quarter of permits must be handed out, but higher levels of required abatement increase that fraction – and the loss in efficiency from not cutting other taxes.

IV. Benefits of Protection

A policy to abate pollution also provides benefits to those who breathe the air, those who drink the water, and those who enjoy recreation. In Figure 1, these gains are represented by area C+D+E, the sum of "marginal environmental damages" over the range that pollution is reduced (from Q^o to Q'). Who are these individuals, and what socioeconomic groups receive most of these benefits? These questions are related to who bears the cost of pollution (except that a proposal may not abate pollution proportionately everywhere). A key question is whether polluters choose to locate disproportionately in poor or minority areas. This is the question of "environmental justice."

As a representative of early attempts to address these questions, Brooks and Sethi (1997, Chapter 15 of this volume) employ much data from the 1988-1992 Toxic Release Inventory (TRI) in the United States, plus 1990 census data on race, ethnicity, poverty status, and educational attainment at the zip code level. They improve upon prior papers by weighting different air emissions according to toxicity, and calculating for each zip code an exposure based on the distance to various pollution sources around it. They regress this exposure on census variables and other controls to find that exposure is significantly and positively related to: the proportion of blacks in the community, the proportion who are renters, the percent poor, lower voter turnout, and lower educational attainment. Most of the paper is careful to discuss the "relationship" between exposure and these socioeconomic variables, but some of it lapses into causal interpretations. The

[9] In particular, he assumes that leisure is separable in utility, whereas many other papers assume instead that the environment is separable in utility.

main problem is the endogeneity of all these variables: if high pollution reduces local land values and housing rents, and if low-income households have more need for basic necessities than for the "purchase" of clean air, then low rents may bring them into the area – reverse causality. If so, then estimated coefficients are biased, and pollution does *not* impose disproportionate burdens on poor and minority households.

The possibility of simultaneous location decisions by households and firms was raised as early as Vicki Been (1994). This problem is pernicious, however, and pervades the literature. Few have tried to model both decisions simultaneously. For example, Hite (2000, Chapter 16 of this volume) looks at endogenous location choices of households, given fixed locations for environmental harms. She estimates a "random utility model" of location choices using 2,889 house sales with data on house characteristics, neighborhood characteristics, and distance to any of the four landfill sites around Columbus Ohio. With full information and no location constraints such as discrimination, then no household would envy another in the sense of preferring the other's consumption bundle. Using the model, she can calculate the probability that a household in one area with estimated preferences would really prefer to live in a different area. If so, it could indicate discrimination. She finds some evidence for environmental discrimination against African American households, but not against poor households. Note that this potential discrimination would be discrimination in housing markets. Since polluter locations are fixed, she does not look at discrimination in location decisions of firms.[10]

A further step towards dealing with the simultaneous location decisions by both firms and households is taken by Gray and Shadbegian (2004, Chapter 17). They look at many determinants of air and water pollution and of enforcement actions at 409 pulp and paper mills from 1985 to 1997, including local demographic variables. They recognize potential for reverse causation, however, since poor households could move into dirty neighborhoods for cheaper housing, and those with small children or elderly who are sensitive to pollution could move out. Thus, demographics near the plant are endogenous, and OLS regressions are biased. They do not model household location decisions directly along with polluter location decisions, because the sample of plants is quite old. Instead, they run a regression of those endogenous local characteristics on a set of instruments, namely, the demographic characteristics of people living 50-100 miles away from the polluting plant. The idea is that these "spatially lagged" variables are highly correlated with local characteristics, but not influenced by effects of pollution from that plant, since pollution effects decline with distance. Using predicted local characteristics in place of actual local characteristics, they find that plants in poor neighborhoods emit more pollution, and those near kids or elderly emit less, but surprisingly, they find that plants in nonwhite neighborhoods also emit less pollution.

Most of this introduction is concerned with distributional effects across income groups, although this section has touched on effects across ethnic groups. However, effects of environmental policy could be measured across groups defined by age, health status, region, or other breakdown. Also, most of these studies employ various "revealed preference" data on willingness to pay (WTP) for a cleaner environment, such as through house prices. In contrast, Alberini, Cropper, Krupnick, and Simon (2004, Chapter 18 of this volume) use surveys of "stated preferences" to look at WTP by different groups defined by age and health status.

When the U.S. EPA (1999) looks at all costs and benefits of the Clean Air Act, they find the huge majority of benefits in the form of mortality reductions. Who benefits

[10] In a 2002 working paper, Ann Wolverton looks directly at plant location decisions and the community characteristics at the time the plant was originally sited. She finds that the polluting plants in her sample did not locate disproportionately in minority neighborhoods.

from these mortality reductions? Theoretical predictions are ambiguous. Older or less healthy individuals have higher baseline mortality risk, and thus might be willing to pay more for a reduction in the risk of dying this year. If so, environmental policy benefits the elderly and infirm. On the other hand, they may have fewer years to live, and for that reason be willing to pay less for a reduction in the risk of dying this year. Following established contingent valuation techniques, Alberini *et al* survey 930 Canadians and 1200 Americans.[11] They find an overall Value of a Statistical Life (VSL) between $1.5 and $4.8 million, somewhat less than the $6 million figure used by the EPA. Although no statistically significant age effect is found in the U.S., the WTP falls significantly after age 70 in Canada. The WTP rises with income in both samples, but significantly only in the U.S. The value of risk reductions is significantly higher in both samples for those with family history of chronic heart or lung disease and for those recently admitted to a hospital for a heart or lung condition.

Cameron and McConnaha (2006, Chapter 19) do not provide direct evidence on distributional effects of environmental policy, but they shed light on whether polluters locate in certain types of neighborhoods, whether people "come to the nuisance", or both. They look simply at migrations between the four census measurements over three decades (1970-2000), in response to environmental hazards and subsequent cleanups. The units of observation are census tracts within a 12-mile radius around each of four contaminated Superfund sites. For the vicinity around each site, they estimate changes in the distance profile over time for the concentration of each of 22 household characteristics (using 88 different regressions). For ten of the 22 characteristics, they find statistically significant changes in its relative concentration near the site over time (as these sites are identified and then cleaned up). In the first decade after the contamination is announced, they find declines in the prevalence of "children under six" and "married couples with children", and they find increases in seniors, married couples without children, female-headed households without children, and non-family households. In many cases, those migrations are reversed in the decade after a clean up is complete. Results on nonwhites differ across their four sites.

The implication here is not just that families with children might well be burdened by pollution, but that they move away! Other less-sensitive groups take their place. This evidence makes it very difficult, in the next generation of literature, for researchers to take neighborhood characteristics as exogenous – as done by some earlier researchers. Other evidence reviewed above makes it equally difficult to take pollution levels as exogenous. The simultaneity of household and polluter location choices continues to be one of the greatest challenges to economic research in this area.

V. Effects via Land Prices

The gains and losses each period that are depicted in Figure 1 can be capitalized into asset prices. Section III above discussed how the annual flow of "scarcity rents" (area A+B) is capitalized into corporate stock prices, and this section discusses how the "benefits from environmental protection" (area C+D+E) are capitalized into land prices. If a policy provides cleaner air to a particular neighborhood, then the entire present value

---

[11] The protocol includes much information on changes to risk, and yes-or-no dichotomous choice questions about whether the respondent would be willing to purchase that reduction in risk for a particular price (chosen randomly from one of four predetermined values). Additional questions relate to income and health status, followed by debriefing questions to check the respondent's comprehension.

of those gains can be captured by whoever owns a house site at the time of the change.[12] These individuals who gain may not be the same as those who breathe the cleaner air. Similarly, if certain households migrate into an area near a contaminated Superfund site to take advantage of cheaper housing, then the clean up of that site does not compensate those who suffered the losses from the environmental hazard.

Since at least Ridker and Henning (1967), economists have estimated house price as a hedonic function of house 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 improvement in that environmental measure.[13] This method will not easily reveal the distributional effects of all pollution, or all abatement policies, but it can be used to calculate the distribution of gains from a marginal policy to abate. Ted Gayer (2000, Chapter 20 of this volume) uses 6,562 house sales and GIS data to calculate distance to each Superfund site around Grand Rapids Michigan. However, the environmental risk itself may be determined in part by house prices, if polluters are more likely to locate near inexpensive homes. If so, then the usual OLS regression of house price on house and neighborhood characteristics and this environmental risk yields biased coefficients. Gayer finds that this variable is indeed endogenous, and he corrects for it using a first stage regression of that risk on exogenous instrumental variables. Results indicate that welfare gains of risk reduction would be greater for neighborhoods with high income and education, and lower for with more nonwhites.

This correction for endogeneity is an improvement. Still, however, Gayer's exogenous instruments include the neighborhood's socioeconomic variables as well as measures of potential for collective action. Firm location or pollution decisions can help affect environmental risks and house prices simultaneously in his model, but household characteristics are exogenous. Thus this research does not yet solve the chicken and egg problem regarding whether polluting firms locate in low-income and minority neighborhoods, or poor families arrive later to take advantage of low house prices.

Using data from 1989-91 in Southern California, Sieg, Smith, Banzhaf and Walsh (2004, Chapter 21 of this volume) estimate the parameters of a structural model that can be used to calculate the welfare effects of *large* air quality improvements, such as those from 1990 to 1995 that reduced ozone from 3% to 33% across different neighborhoods. They incorporate how preference heterogeneity leads some households to respond to changes in local amenities by moving, which induces changes in house prices, which might induce further moves until a new equilibrium is attained. The paper shows that the general equilibrium calculation of value accounting for these house price changes is quite different from the partial equilibrium value based on fixed house prices. In the results for particular locations, the two measures differ much more than on average and may have different signs. Even when a poor location experiences some improvement, house price increases can offset that benefit. In one location where ozone fell by 24%, house prices rise nearly 11%. Poor families may lose, while landlords gain.

While local or regional pollutants may be capitalized into residential land prices, global effects can be capitalized into other land prices. Mendelsohn, Nordhaus and Shaw (1994) regress agricultural land prices on soil attributes and other local characteristics including temperature, precipitation, and other climate variables. The use of a cross section implies that all farmers have already adapted to their climate. This Ricardian

---

[12] That statement is strictly true only with inelastic supply of land. The price change is moderated if supply is elastic, such as by the conversion of more fringe land into residential use.

[13] An excellent recent example of hedonic house price estimation is Chay and Greenstone (2005). Their estimates could be used to study distributional effects, but they focus mostly on aggregate estimates correcting for omitted variable bias and self selection issues.

method can be used to calculate the long run gain or loss to each location from climate change. A few such studies have been undertaken for developing countries.

Mendelsohn, Dinar, and Williams (2006, Chapter 22 of this volume) use such results to calibrate response functions for each sector of each country. They then employ three different climate models to predict temperature and precipitation for a grid of points on the globe in the year 2100, and they calculate the gain or loss to each country. They find that poor countries suffer most of the damages from global warming. The reason is not that those countries will experience more dramatic climate change than other countries; indeed, results are similar when merely assuming that all experience the same changes. Rather, poor countries suffer the most damage because they are already in warmer locations. Poor countries near the equator become even warmer and less productive, while richer countries in cool climates become warmer and more productive.

This paper is also a good example of the multiple ways to define distributional effects of environmental policy: across different countries as well as within a country between groups defined by income, age, or ethnicity.

VI. Conclusion: Costs of Transition and Remaining Issues

This introduction has reviewed studies of the effects of environmental policy on consumers and on producers, through scarcity rents, and benefits of protection. Other effects of environmental policy are not as well studied in available literature, however, such adjustment costs and other transition costs. In Figure 1, area F represents the value of inputs no longer employed in this industry. They are often assumed to be re-employed elsewhere, with no loss. Yet a change in environmental policy can be very disruptive, especially for a local economy highly dependent on the resource just protected. Logging or mining is often a predominant occupation in a town that can be virtually annihilated by environmental protection. Those individuals may acquire a great deal of industry-specific human capital, the value of which is lost by the shrinking of that industry. This human capitalization effect can imply a much larger percentage loss for individuals than other asset price capitalization effects of environmental policy discussed above.

The first section above describes two challenges of Baumol and Oates (1988), so we now turn to judge progress in subsequent literature. First, they challenge economists to deal more seriously with distributional effects of environmental policy. While the prior literature does indeed emphasize effects on economic efficiency, the collection of papers in this volume is ample evidence that economists are beginning to study distributional effects. Yet much remains to be done.

The second challenge of Baumol and Oates (1988) is to determine whether energy or environmental policy is really as regressive as it appears, and if so, what can be done about it. Papers in this volume show that environmental protection does likely raise the price of goods such as electricity and transportation that constitute high fractions of low-income budgets. In addition, pollution permits handed out to firms bestow scarcity rents on the well-off individuals who own those firms. Yet some of the papers in this volume show how rebates to low-income households can offset those regressive effects and allow for environmental protection without adverse distributional consequences. This point makes it important to use emissions taxes or the auction of permits, to raise revenue enough to cover the cost of those rebates.

Other papers in this volume estimate whether high income individuals get more benefits from environmental protection, because of higher willingness to pay. Results are mixed. Certainly high income families have more ability to pay, and thus may have higher demand for recreation and other environmental amenities, but the actual valuation by different groups depends on what amenity is being valued. Thus, environmental policies can be designed to provide sufficient protection to low-income neighborhoods. Some of the most pernicious effects of environmental policy, however, are the capitalization effects that provide windfall gains and losses. Those who own land or corporate stock at the time of environmental damage suffer a capital loss, and they may sell that asset before the abatement policy is implemented. It then provides gains to others who did not suffer the loss. Capitalization effects also apply to human capital, with even greater proportional gains and losses to individuals. These effects also are a challenge to the economics profession.

References

Alberini, Anna, Maureen Cropper, Alan Krupnick, and Nathalie Simon, "Does the Value of a Statistical Life Vary with Age and Health Status? Evidence from the US and Canada," Journal of Environmental Economics and Management 48(1), July 2004, 769-92.

Baumol, William J. and Wallace E. Oates, The Theory of Environmental Policy, New York: Cambridge University Press, Second Edition, 1988.

Been, Vicki, "Locally Undesirable Land Uses in Minority Neighborhoods: Disproportionate Siting or Market Dynamics?" Yale Law Journal 103, 1994, 1383-1422.

Bovenberg**,** A. Lans, Lawrence H. Goulder, and Derek J. Gurney, "Efficiency Costs of Meeting Industry-Distributional Constraints under Environmental Permits and Taxes," RAND Journal of Economics 36(4), Winter 2005, 951-71.

Brooks, Nancy, and Rajiv Sethi, "The Distribution of Pollution: Community Characteristics and Exposure to Air Toxics," Journal of Environmental Economics and Management 32(2), February 1997, 233-50.

Cameron, Trudy Ann, and Ian T. McConnaha, "Evidence of Environmental Migration," Land Economics 82(2), May 2006, 273-90.

Chay, Kenneth, and Michael Greenstone, "Does Air Quality Matter? Evidence from the Housing Market," Journal of Political Economy 113(2), April 2005, 376-424.

Coase, Ronald, "The Problem of Social Cost", Journal of Law and Economics 3, 1960, 1-44.

Dinan, Terry, and Diane Lim Rogers, "Distributional Effects of Carbon Allowance Trading: How Government Decisions Determine Winners and Losers," National Tax Journal 55(2), June 2002, 199-221.

Fullerton, Don, "A Framework to Compare Environmental Policies," Southern Economic Journal 68(2), 2001, 224-48.

Fullerton, Don, and Garth Heutel, "The General Equilibrium Incidence of Environmental Taxes," Journal of Public Economics 91, April 2007a, 571-91.

Fullerton, Don, and Garth Heutel, "The General Equilibrium Incidence of Environmental Mandates," NBER Working Paper No. 13645, Cambridge, MA, 2007b.

Fullerton, Don, and Gilbert E. Metcalf. "Tax Incidence", in Alan Auerbach and Martin Feldstein, eds. Handbook of Public Economics, Volume 4, Amsterdam: North Holland, 2002.

Fullerton, Don, and Diane Lim Rogers, Who Bears the Lifetime Tax Burden?, Washington DC: The Brookings Institution, 1993.

Gayer, Ted, "Neighborhood Demographics and the Distribution of Hazardous Waste Risks: An Instrumental Variables Estimation", Journal of Regulatory Economics 17(2), March 2000, 131-55.

Gianessi, Leonard P., Henry M. Peskin, and Edward Wolff, "The Distributional Effects of Uniform Air Pollution Policy in the United States," Quarterly Journal of Economics 93, May 1979, 281-301.

Gray**,** Wayne B., and Ronald J. Shadbegian, " 'Optimal' Pollution Abatement--Whose Benefits Matter, and How Much?," Journal of Environmental Economics and Management 47(3), May 2004, 510-34.

Hite, Diane, "A Random Utility Model of Environmental Equity", Growth and Change 31, Winter 2000, 40-58.

John, Andrew and R. Pecchenino, "An Overlapping Generations Model of Growth and the Environment," The Economic Journal 104, November 1994, 1393-1410.

Kaplow, Louis, "On the (Ir)Relevance of Distribution and Labor Supply Distortion to Government Policy," Journal of Economic Perspectives 18(4), Fall 2004, 159-75.

Maloney, Michael T. and Robert E. McCormick, "A Positive Theory of Environmental Quality Regulation", Journal of Law & Economics 25(1), April 1982, 99-123.

Mendelsohn, Robert, Ariel Dinar, and Larry Williams, "The Distributional Impact of Climate Change on Rich and Poor Countries," Environmental and Development Economics 11, 2006, 159-78.

Mendelsohn, Robert, William D. Nordhaus, and Daigee Shaw, "Measuring the Impact of Global Warming on Agriculture," American Economic Review 84(4), 1994, 753-71.

Metcalf**,** Gilbert E., "A Distributional Analysis of Green Tax Reforms," National Tax Journal 52(4), December 1999, 655-81.

Parry, Ian, "Are Emissions Permits Regressive?", Journal of Environmental Economics and Management 47(2), March 2004, 364-87.

Parry, Ian, Hilary Sigman, Margaret Walls, and Roberton Williams, "The Incidence of Pollution Control Policies," in H. Folmer and T. Tietenberg, eds., International Yearbook of Environmental and Resource Economics 2006/2007 , Cheltenham, UK: Edward Elgar Publishers, 2006.

Poterba, James, "Is the Gasoline Tax Regressive?", in D. Bradford, ed., Tax Policy and the Economy 5, Cambridge, MA: MIT Press, 1991, 145-64.

Ridker, Ronald G. and John A. Henning, "The Determinants of Residential Property Values with Special Reference to Air Pollution," Review of Economics and Statistics 49, May 1967, 246-57.

Robison, H. David, "Who Pays for Industrial Pollution Abatement?", Review of Economics and Statistics 67, November 1985, 702-6.

Sieg, Holger, V. Kerry Smith, Spencer Banzhaf, and Randall Walsh, "Estimating the General Equilibrium Benefits of Large Changes in Spatially Delineated Public Goods," International Economic Review 45(4), November 2004, 1047-77.

Sijm, Jos, Karsten Neuhoff, and Yihsu Chen, "CO2 Cost Pass-Through and Windfall Profits in the Power Sector," Climate Policy 6(1), 2006, 49-72.

Walls**,** Margaret and Jean Hanson, "Distributional Aspects of an Environmental Tax Shift: The Case of Motor Vehicle Emissions Taxes", National Tax Journal 52(1), March 1999, 53-65.

West, Sarah, "Distributional Effects of Alternative Vehicle Pollution Control Policies," Journal of Public Economics 88(3-4), March 2004, 735-57.

West, Sarah, and Roberton Williams, "Estimates from a Consumer Demand System: Implications for the Incidence of Environmental Taxes," Journal of Environmental Economics and Management 47(3), May 2004, 535-58.

Wolverton, Ann, "Race Does Not Matter: An Examination of a Polluting Plant's Location Decision", mimeo, US Environmental Protection Agency, National Center for Environmental Economics, Washington, DC, 2002.

U.S. Environmental Protection Agency, "The Benefits and Costs of the Clean Air Act, 1990-2010," Report to the U.S. Congress, Washington, DC, 1999.