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Cap and Trade Policies in the Presence of Monopoly and Distortionary Taxation

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Abstract

We extend a simple analytical general equilibrium model of environmental policy with pre-existing labor tax distortions to include pre-existing monopoly power as well. We solve for the endogenous net wage rate, labor supply, and monopoly profits as functions of exogenous parameters and the environmental policy shock. We use plausible parameter values to calculate the interactions of the three simultaneous market failures: pollution, taxes, and monopoly.

We confirm prior results that the extent of profits taxation affects whether environmental policy can improve welfare at all, even with uncorrected pollution. This result still holds with monopoly power. However, the existence of monopoly has two offsetting effects on welfare. First, the environmental policy reduces monopoly profits, and the negative effect on income increases labor supply in a way that partially offsets the pre-existing labor supply distortion. Second, environmental policy raises prices further, so interaction with the pre-existing monopoly distortion further exacerbates the labor supply distortion. Thus monopoly power means that the income effect of capturing the scarcity rents from the emissions restriction is less important, but the price effect of higher output prices on the real net wage is more important.

This second effect is larger, for reasonable parameter values, so the existence of monopoly reduces the welfare gain (or increases the loss) from environmental restrictions.

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The Clear Air Act of 1990 introduced cap and trade policies on a large scale for the electric utility industry in the United States. The goal of the tradable allowance program for sulfur dioxide (SO_2) emissions is to reduce emissions by 10 million tons below 1980 levels by 2008.[1] That goal is to be met through a two-step phased reduction in emissions. Phase I ran from 1995 through 1999 and phase II began in 2000. Allowances are given to electric utilities on the basis of historic emissions. Giving away allowances, rather than selling them, was a political expedient that helped generate sufficient support for the allowances program that it could get off the ground. Economists have long noted the distributional implications of giving away allowances; more recently, economists have noted the efficiency implications of giving them away in the presence of pre-existing tax distortions.[2] For example, Bovenberg and Goulder [7] calculate that if marginal environmental damages from carbon emissions are only $25 per ton, then the optimal carbon tax with revenues returned lump-sum is negative (their Table 2, p. 992). In other words, no carbon tax is better than a positive carbon tax. Allowances given to firms is conceptually equivalent to a tax with revenues returned lump-sum, so their results suggest that sufficiently low environmental damages mean that the allowance program is welfare reducing.

In this paper, we contribute to this literature in two ways. First, we extend a simple analytic general equilibrium model with environmental policy and pre-existing labor tax distortions to allow also for monopoly production of a polluting good. The electric generating industry has many characteristics of monopoly power. A recent report by the U.S. Department of Energy (Office of Policy [22]) notes that many electricity markets are highly concentrated and that the restructuring of electricity markets raises the possibility of increased market power. In an article describing this report, the *Wall Street Journal* stated: "Secretary of Energy Bill Richardson said he has 'strong evidence' that some utilities are using near-monopoly power to raise electric rates far beyond competitive levels" (Fialka [15], p. A4). Previous work in this area has assumed that firms operate in perfectly competitive markets. An important theoretical and empirical question is how the existence of market power affects the optimal design of environmental policy in the presence of distortionary taxation.

Second, we provide numerical calculations of the impact of pollution restrictions, both for a

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[1] See Schmalensee et al. [30] for a discussion of the characteristics of the emissions trading market. The program also put limits on nitrous oxide (NO_x) emissions.

[2] See for example, Bovenberg and Goulder [7], Parry [24], Goulder et al. [19], and Fullerton and

competitively-produced good and for a monopoly-produced good associated with pollution. An example of such a restriction on emissions is the introduction of permits under the Clean Air Act Amendments of 1990, but the model is general enough to represent different kinds of policies toward any pollutant in any country. Because all producers are identical in our model, a command and control (CAC) restriction on emissions is equivalent to a cap-and-trade permit policy. And because of perfect certainty, government capture of scarcity rents from either such quantity restriction is equivalent to a tax on pollution. Intermediate cases are also possible: handout of half the permits is equivalent to a pollution tax with half of the revenue returned lump sum.

Whereas Pigou [26] suggests a tax on pollution equal to social marginal damages, Buchanan [11] first notes that this prescription must be modified when the producer is a monopolist. Buchanan shows that the desired policy response in the case of a monopoly is to increase output, while the desired policy in the case of pollution is to decrease output. Thus, with a pollution-generating monopolist, one cannot tell *a priori* if a tax is desirable at all. Asch and Seneca [1] identify conditions under which the imposition of a pollution tax equal to social marginal damages would increase or decrease welfare, again in the special case of linear demand and cost. In addition, they provide some data from the 1970s to show that a substantial number of industries have marked monopoly power and are significant sources of pollution. Misiolek [21] extended Asch and Seneca's analysis by deriving the formula for the optimal tax rate on pollution for the special case of linear demand and cost. When the socially-efficient output is below the monopoly output, the optimal tax equals social marginal damage less a term equal to the ratio of social marginal damage to the price elasticity of demand. Barnett [3] derives an optimal tax rule that does not impose linearity and also allows for pollution abatement activities.

All of these models are partial equilibrium and ignore the impact of pollution taxes on factor markets. They also ignore the possibility of pre-existing distortionary taxes in other markets. Browning [9] shows that because monopoly power raises prices, it reduces the real net wage and exacerbates labor tax distortions. Then Browning [10] shows that because taxes raise prices relative to the wage, they enlarge the welfare cost of monopoly. While Browning considers the interaction of monopoly power and taxes, other papers consider the interaction of environmental policy and taxes (see Bovenberg and de Mooij [6], Parry [23], and other papers mentioned in footnote 2 above). Thus, a

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Metcalf [18].

contribution of our paper is that we consider all three distortions simultaneously in a general equilibrium model that can be solved analytically.

In prior competitive models where environmental policy generates scarcity rents (Fullerton and Metcalf [18]), the extent of government capture of those rents affects whether environmental policy can improve welfare at all. However, that prior paper does not consider monopoly power, and it does not include any parameter values or numerical magnitudes. Here, we find that the rate of profits taxation is equally important with monopoly power. However, the existence of monopoly has two offsetting effects on welfare. First, the environmental policy reduces monopoly profits. The resulting negative effect on income increases labor supply, which partially offsets the pre-existing labor supply distortion. Second, both monopoly and environmental policy raise prices and thus reduces the real net wage, so interaction between them exacerbates the labor supply distortion. Thus, monopoly power means that the income effect of capturing the scarcity rents is less important, but the price effect of higher output prices on the real net wage is more important. The relative magnitudes of these two offsetting effects can only be determined numerically. When we add parameter values and calculate the size of each effect, we find that this second effect is larger. For reasonable parameter values, the existence of monopoly reduces the welfare gain (or increases the loss) from environmental restrictions.

Next, in Section I, we sketch out the general equilibrium model used in our analysis. Our initial model assumes perfectly competitive firms. In Section II, we provide some numerical results from a special case of our model in which the pollution to output ratio for the dirty good is fixed. Section III then relaxes that assumption and allows for substitution between a clean and dirty input in production. In section IV, we extend the model to allow for monopoly production of the dirty good. Section V concludes.

I. The Model

We develop a simple general equilibrium model with N identical individuals who own a single resource and sell it in the market to earn income that can be used to buy two different goods. One of the goods is a "clean" good and the other is a "dirty" good (that is, one for which pollution is a by-product of the production process).

This static model considers only one time period, with no saving decision. For simplicity we refer to the resource as time available for labor supply, but under some conditions it can be interpreted more generally as a fixed total amount of labor, capital, land, and any other resource that can be sold in the market (in amount L) or used at home (in amount L_H). The resource kept at home could be interpreted either as leisure or as a resource used in home production. We assume perfect certainty, no transactions costs, and constant returns to scale production.[3]

Each individual receives utility from per-capita amounts of a nonpolluting good (X), a polluting good (Y), and leisure (L_H), and from the total amounts of a government-provided nonrival public good (G), and another nonrival public good called environmental quality (E). The per-capita amount Y is produced using per-capita amounts of labor (L_Y) and of emissions (Z). Total emissions (NZ) negatively affect the environment through:

$$E = e(NZ)\,, \qquad \text{where} \quad eN < 0. \tag{1}$$

Goods are produced according to:

$$X = L_X \tag{2a}$$

$$Y = F(L_Y, Z) \tag{2b}$$

$$G = NL_G \tag{2c}$$

We define a unit of X as the amount that can be produced using one unit of labor. The numeraire good is L, or equivalently X. The commodity Y is produced in a constant returns to scale function (F), using clean labor (L_Y) and emissions (Z). Emissions may include gaseous, liquid, or solid wastes that require some private costs for removal and disposal. These private costs must come in the form of resources, so we define one unit of emissions as the amount that requires one unit of private resources ($Z = L_Z$).[4]

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[3] Other models have analyzed uncertainty (Weitzman [36]), monitoring and enforcement costs (Russell [29]), and transactions costs (Stavins [32]). The large literature on such models is reviewed in Bohm and Russell [5]. Constant returns to scale in our model means that all firms are identical, but if abatement costs were to differ significantly among firms with different technologies, and if regulators have imperfect information about these differences, then imperfect CAC policies can be six to ten times as expensive as the minimum abatement cost made possible by incentive-based policies like taxes or permits (see Atkinson and Lewis [2], Seskin et al. [31], and other studies surveyed in Cropper and Oates [13]).

[4] Note that emissions are positively related to the use of these resources: L_Z is not to clean up or reduce emissions, but just to cart it away. Abatement is undertaken by substituting away from Z and into L_Y. This overall production function is still constant returns to scale, since Z is a linear function of L_Z. The

Thus, the private cost of Z is always 1. We define a unit of Y such that the marginal cost of production equals 1. Finally, some labor (L_G) is also used to produce the public good. The combination of these production relationships provides the overall resource constraint:

$$NL = NX + N(L_Y + L_Z) + G\ . \tag{3}$$

Individuals maximize:

$$= U(X, Y, L_H, G, E) + \quad \{(1-t_L)L + (1-t\ ) \quad - X - p_Y Y\} \tag{4}$$

by their choice of X, Y, and L_H, where t_L is the tax rate on resource (labor) supply, t is the tax rate on profits, and are profits. Economic profits can arise from two sources in this model. First, the cap and trade program provides scarcity rents for firms that receive permits (equal to the market value of the permits received). Second, profits will arise if Y is produced by a monopolist. In this section, we focus on profits arising from the cap and trade program. Later we introduce monopoly production and profits.

Our approach is to start at an initial competitive equilibrium with an existing tax on labor, but without any policy correction for the external effect of Z on E, and then to analyze small changes. Following the log-linearization approach used by Bovenberg and de Mooij [6], Fullerton and Metcalf [18], and others, we differentiate all equations above and re-express them in terms of proportional changes ($\hat{L} \equiv dL/L$). We then solve for the change in utility, dU, divide by λ to express it in dollars, and divide by L to get the dollar gain or loss as a fraction of income:

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private cost for emissions helps justify our assumption of an internal solution with a finite choice for Z, even without corrective government policy.

(5) $$\frac{dU}{ëL} = t_L \hat{L} - ì\left(\frac{Z}{L}\right)\hat{Z}$$

where $\mu = -NU_E e'/\lambda$ is the "social marginal damage" from pollution. A new environmental regulation can be represented by a small exogenous reduction in pollution ($\hat{Z}<0$). We then need to solve for the endogenous change in labor supply. Once we have $\hat{L}$, equation (5) says that welfare is lowered to the extent that this policy reduces labor supply (because of the pre-existing tax on labor, t_L). Also, welfare is raised to the extent that the policy reduces pollution.

Next, in order to derive an expression for the change in labor supply, $\hat{L}$, we need to trace the effect of the policy ($\hat{Z}<0$) on the price of emissions, the price of output, and thus on the real net wage. We also trace the effect of the policy on income flows that might affect labor supply. These income effects include the possibility that the policy generates private profits.

Any policy to reduce Z will raise the marginal product of Z above its private cost. In the case of the Clean Air Act, the limited number of permits are handed out for free (on the basis of historic energy use). Thus the scarcity rent goes to the permit recipient. These permits can be used to yield a marginal product greater than the private cost of emissions, or they can be sold. Either way, the policy has generated a private profit. We define these profits as:

(6) $$= (p_Z - 1)Z$$

The rules for the initial allocation of these permits does not matter in our model, because our N identical agents must own whatever firm or other entity is given the permits. The price p_z in equation (6) is the marginal value of emissions, and the private cost of emissions is 1, so $(p_Z - 1)$ is the market price of the tradable allowance.[5] Note that while the profits are initially given to the firms, they can be recovered by the government through taxation (t). As seen below, the tax rate on profits will be an important policy instrument.

We start at a competitive equilibrium with no environmental policy and zero profits. Thus, p_Z

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[5] Current prices for SO_2 allowances at the end of 1999 were roughly \$150 per ton of emissions. See U.S. Environmental Protection Agency [35]. If instead of creating restrictions through a cap and trade program, the government simply restricted emissions, then p_z would be a shadow price rather than a market price.

= 1, and in equation (6) is zero. When we introduce a new policy to restrict emissions, any generated profits might affect consumer behavior and government revenue.

The government budget constraint is:

$$G = Nt_L L + Nt \tag{7}$$

The environmental policy affects labor supply and profits, so it also affects government revenue. In order to hold spending on G constant, we assume that government adjusts the labor tax to balance the budget. We differentiate the government budget (7) and set dG=0 to calculate the necessary change in t_L. For notational convenience, it is expressed below as a proportion of the net wage ($\hat{t}_L \equiv dt_L/(1-t_L)$).

We set t to 1 for any case where government receives the scarcity rent, such as for sale of permits, and we set it to zero for the other extreme where private parties keep the rents. This specification also allows us to consider the case where a pre-existing corporate profits tax rate would take part of the firm's private profits. We do not adjust this tax rate endogenously to help maintain the necessary revenue to pay for G, but its existence greatly affects the amount by which the labor tax might have to be adjusted. Suppose, for example, that a permit or CAC policy generates profits but also reduces labor supply and thus labor tax revenue. If the tax on profits is zero, then the government has to raise the labor tax rate and exacerbate labor supply distortions. If t equals 1, then the government may be able to reduce the labor tax rate.

To obtain specific effects on labor supply, we assume that utility is separable in the form U = U(V{Q(X,Y),L_H}, G, E), where Q is a homothetic function of X and Y. If p_Q is a price index on Q(X,Y), then the real net wage is w = $(1-t_L)/p_Q$. Differentiation yields $\hat{w} = -\hat{t}_L - \hat{p}_Q$. Also, $\hat{p}_Q = f\hat{p}_Y$, where ϕ is the expenditure share of the dirty good in the consumer=s budget, so:

$$\hat{w} = -\hat{t}_L - f\hat{p}_Y \tag{8}$$

The consumer's maximization of (4) yields a labor supply function that can be written as L = L(w, (1-t) /p_Q). If profits were always zero, then L depends only on the real net wage, and differentiation yields $\hat{L} = e\hat{w}$, where is the uncompensated labor supply elasticity. However, labor supply also depends on income effects from the change in real net profits. We differentiate all equations to show how the emission restriction raises the value of emissions p_Z, which affects profits and raises the price of output. This raises p_Q, which lowers the real net wage w, which affects labor supply L.

For the competitive model, Fullerton and Metcalf [18] consider a special case where the output Y itself generates externalities either in production or in consumption. In other words, they assume $Y = Z$ (and $L_Y = 0$).[6] Thus $\hat{Y} = \hat{Z}$, and $\hat{p}_Y = \hat{p}_Z$. In this case, they show that:

$$\text{(9)} \qquad \hat{L} = (1 - t_{\text{Đ}})\left\{\frac{(1 - t_L)f(\text{ç} - \text{å})}{(1 - t_{\text{Đ}})f(\text{ç} - \text{å}) - \text{ó}_Q(1 - f)(1 - t_L - \text{å}\, t_L)}\right\}\hat{Y} \equiv (1 - t_{\text{Đ}})\text{Ä}\hat{Y}$$

where is the income elasticity of labor supply, and $_Q$ is the elasticity of substitution between X and Y in consumption. This equation provides $\hat{L}$ as a function only of exogenous parameters and the policy shock.

The ratio in braces (denoted) will be positive if the following three assumptions hold: leisure is a normal good (<0); labor supply is not backward-bending (≥0); and < $(1-t_L)/t_L$. We assume these three conditions hold throughout.[7] Thus, labor supply moves in the same direction as production of the dirty good ($\hat{Y}$) when the cap and trade program is implemented.

In addition, equation (9) shows the importance of t. If government acquires all the rents for use in reducing labor tax rates (that is, if $t = 1$), then the policy will not affect labor supply and will not exacerbate labor tax distortions. Otherwise, labor supply will fall.

II. Results With Fixed Pollution Per Unit Output

Before continuing the derivations for the general case with variable emissions, we pause to

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[6] Examples include gasoline, and cigarettes, where the environmental problem is not from one of the inputs to production, but from the use of the final product. For these two examples, it is easy to see how a mandated reduction of every firm's output could generate private profits!

[7] The third condition will be satisfied if the initial point is on the normal side of the Laffer curve. Define revenue as $R = Lt_L$, totally differentiate, and rearrange to get $\hat{R}/\hat{t}_L = (1 - t_L)/t_L - \boldsymbol{e}$.

provide some numerical results for the special case with fixed emissions, where $\hat{Y} = \hat{Z}$. We substitute equation (9) into (5) to obtain the welfare impact:

$$\text{(10)} \qquad \frac{dU}{\text{ë}L} = \left\{ t_L(1-t_{\text{Ð}})\text{Ä} - \text{ì}\left(\frac{Y}{L}\right)\right\}\hat{Y} \equiv -\text{ø}\hat{Y}$$

Utility increases only if the cost of the larger labor supply distortion $(t_L(1\text{-}t\ )\ )$ is less than the benefits from reducing pollution (Y/L). Since $\hat{Y}$ is negative, the sign of indicates the net effect on welfare.

Consider plausible magnitudes for the various parameters in (10). For t_L, we want a tax rate that applies to income from all household resources (that is, national income). Total government spending in the U.S. is roughly 35% of national income, but incentives depend on a marginal tax rate that exceeds this average tax rate. We feel that $t_L = 0.5$ would be a reasonable choice to account for the progressive federal income tax, plus payroll tax, plus state and local income taxes, plus sales and excise taxes. All of these taxes apply to market goods and not to leisure. However, we actually use $t_L = 0.4$, because the rate in our model is both an average rate and a marginal rate.[8]

For the uncompensated labor supply elasticity , we need a single value to represent an aggregate of all potential workers and all labor supply effects from changes in wages. As discussed in Rosen [27], these effects include not only hours worked, but also participation decisions and effort on the job. Thus, the typical hours elasticity likely understates the overall impact of changes in the real net wage. The literature includes many estimates of the hours elasticity that are small or negative for men, and other estimates that are large and positive for women.[9] These estimates do not include participation decisions. Few have attempted to aggregate and summarize all such effects into one number. One such attempt is in Russek [28]. Taking into account both hours and participation, using many existing estimates for both men and women, he concludes that "the total wage elasticity for the labor supply of the economy

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[8] An overall labor tax rate of 0.4 has become a standard assumption in the literature on marginal excess burden, including Stuart [33] and Browning [8].

[9] In a questionnaire sent to labor economists, Fuchs et al. [17] find that the mean belief is that the hours elasticity is zero for men and 0.45 for women.

seems to range somewhere between zero and 0.3" (p.10).[10] In this study, we employ both 0.1 and 0.3 as reasonable alternatives for the overall uncompensated wage elasticity ( ).

Russek [28] also finds that the aggregate income elasticity is about -0.30 for women and about -0.10 for men. We use -0.2 for the aggregate income elasticity ( ), so the compensated labor supply elasticity (-) is either 0.3 or 0.5. Note, by the way, that CAC or permit polices will still affect non-environmental welfare, even if were 0, because profits have an income effect that reduce labor supply and thus still exacerbate pre-existing distortions.

Estimates for the elasticity of substitution in consumption, $_{Q}$, are not available for the specific aggregation in our model between a "clean" good X and a "dirty" good Y. We choose a base value of 1.0, which is broadly consistent with the empirical literature on substitution in consumption, and we test the sensitivity of results to alternative values.[11]

For ϕ, we want an aggregate expenditure share for all goods with externalities in production or consumption. Based on 1993 data in the *Statistical Abstract of the United States* [34], the industries most responsible for pollution include chemical and paper producers, mining and primary metals, electric utilities, petroleum and coal production and processing, and motor vehicles and equipment. Total production by those industries constitutes almost 15% of GDP, so we use 0.15 for Y/L.[12] Since ϕ is defined as $p_Y Y/\{L(1-t_L)\}$, and since $t_L = 0.4$, we must have $\phi = 1/4$. In other words, these polluting goods are primarily private goods, so 15% of total output represents a quarter of private consumption.

Finally, we need a measure of marginal environmental damage ( ). Pearce and Turner [25]

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[10] Feldstein [14] points out *other* behavioral alternatives to taxable labor supply, and he finds that the relevant elasticity is at least 1.0 and could be higher.

[11] For the next section, we also need an elasticity of substitution in production, $_{Y}$. Again this parameter has not been estimated for our particular aggregation into two inputs. Caddy [12] and Hamermesh [20] provide extensive surveys of measured elasticities of substitution between capital and labor, and they each conclude that a value of 1 is reasonable. Berndt and Wood [4] and others estimate translog KLEM production functions (for capital, labor, energy, and materials). We cannot use all of these cross-price elasticities directly in our model, because our first input is resources (which includes both labor and capital), and our other input is emissions (which is not the same as energy). Again we feel this literature is broadly consistent with a unitary elasticity of substitution, but we present results for other values as well.

[12] In any case, as shown in Goulder et al. [19], results are not sensitive to this parameter.

review studies finding that damages from pollution are 0.5% to 0.9% of GNP in the Netherlands. Wicke [37] reports estimates that are 6% of GNP in Germany. Freeman [16] estimates that pollution damages would be about 1.25% of GNP or higher in the U.S. in the absence of environmental polices. Unfortunately, none of these sources provide a measure of marginal damages. Based on the figures just mentioned, we assume that total damages are 1.5% of total output. Then, since Y is 15% of total output, we have damages that are about 10% of Y. Again we use two alternatives. If this relationship were linear, then damages would be about 10% of marginal output (=0.1). Given the tremendous uncertainty associated with this number, and the belief that marginal damages probably exceed the average, we also provide results for "treble damages" (=0.3). However, since enters linearly into the final welfare impact (equation 9), readers can easily substitute any preferred value.

Table 1 shows the effects of a permit or CAC policy that mandates a small reduction in the quantity of the polluting good $(\hat{Y} < 0)$. The left-hand section shows assumed values for some of the input parameters. The first four rows show results for t_L =0.4, while we vary and . When marginal damage is 0.1, then column 1 shows that a 1% reduction in Y yields benefits from reduced pollution that are 0.015% of national income. In the first row where is also 0.1, and scarcity rents are not taxed (t =0), we find that = 0.09 (so a 1% reduction in output of Y induces a 0.09% reduction in labor supply). Multiplication by the tax rate (0.4) yields a welfare cost from the labor supply reduction that is 0.036% of national income. Taking into account both the environmental gain (0.015) and the labor market loss (-0.036), we find that the net effect is a reduction in welfare equal to 0.021% of national income.

With a 40 percent tax on rents (t $=t_L$), where those revenues are used to reduce the labor tax rate, the labor market distortion falls from 0.036 to 0.023. This latter figure still exceeds the 0.015 environmental gain, by 0.008 of national income. If we continued to increase the tax on rents, the loss from the labor distortion would continue to fall. The breakeven tax rate, the rate at which the environmental benefits of the permit policy are just offset by the increased labor market distortions, is 63 percent. In the limit, with 100 percent capture of scarcity rents (t =1), then labor supply is unaffected. An environmental policy that collects all of the scarcity rents can eliminate the negative effects on the pre-existing labor distortion. This policy can have unambiguously positive effects on welfare.[13] Notice, however, that 100 percent capture is necessary just to get all of the benefits from the environment.

The second row of Table 1 changes the labor supply elasticity from 0.1 to 0.3, so the negative effect on labor is enlarged. Welfare falls even more. The point is that when environmental controls raise production costs, the lower real net wage can reduce effort on the job, induce secondary workers to quit, or even shift the same effort from taxable to nontaxable forms like home production or the underground economy. As taxable labor supply becomes more responsive, the environmental policy is less likely to raise welfare. In this scenario, the breakeven tax rate on profits is over 80 percent.

The next two rows triple the marginal environmental damage (from 0.1 to 0.3). If the labor supply elasticity is back down to 0.1, then the environmental gain (0.045) exceeds the loss from the labor distortion (0.036). Even with "treble damages," this policy just barely raises welfare (by 0.009). Still, however, the taxation of scarcity rents can reduce the labor market loss and leave more of the environmental gain.

When both parameters are 0.3, the large environmental gain (0.045) is more than offset by the larger loss from labor distortions (0.062) when scarcity rents are untaxed. Since the environmental gain (Y/L) is linear in , it is easy to calculate that the marginal external damage would have to be over 40% of the firm's production cost for this environmental regulation to break even in terms of welfare. In particular examples, the externality might well be high, perhaps over 100% of the firm's production cost. The point remains, however, that even a large gain from correcting a large externality can be offset by losses from labor market distortions -- unless the government captures the scarcity rents. In the fourth row (where both parameters are 0.3), the 40% tax on rents converts the net loss (-0.017) into a small net gain (0.004).

The last three rows of Table 1 illustrate the effect of altering the initial labor tax rate (keeping and at 0.3). Consider column 3 (where t =0). If t_L is 0.3, instead of 0.4, the net welfare effect is a small net gain (0.007) instead of a loss (-0.017).[14] Note, however, that this 0.007 net gain

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[13] This case with t =1 corresponds exactly to the case of Bovenberg and de Mooij [6] where a tax on the dirty good generates revenues used to reduce the tax on labor income. See equation (13) in their paper, when their initial t_D equals 0.

[14] When we change t_L from 0.4 to 0.3, we assume that remains at 1/4, so $Y/L = \phi(1-t_L)$ must change (from 0.15 to 0.18).

is still only a small fraction of the 0.053 gain possible with government capture of the rents. If the initial tax rate is raised to 0.50, then the welfare loss is increased from -0.017 to -0.043. If scarcity rents are not taxed and the tax on labor income is 50%, then the marginal environmental damage ( ) would have to be over 60% of production cost before the regulatory policy could begin to improve welfare.

A permit policy like the Clean Air Act Amendments of 1990 creates a scarcity rent that is left in private hands. It does not necessarily improve welfare, in this second-best world, even when starting with a substantial uncorrected externality.

III. Model and Results with Variable Pollution per Unit Output

We now allow for factor substitution in the production of Y. The welfare impact of an environmental regulation still depends on how labor supply is affected, and equation (9) still provides us the effect on labor supply from a change in output of Y. The remaining step is to show the effect on Y of a mandated change in emissions.

The next equation adds factor substitution to our model. Let $_{Y}$ represent the elasticity of substitution in production of Y between the two inputs (L_Y and Z). Then, by definition:

$$\hat{\mathrm{L}}_{\mathrm{Y}} - \hat{\mathrm{Z}} = \text{ó}_{\mathrm{Y}}(\hat{\mathrm{p}}_{\mathrm{Z}} - \hat{\mathrm{p}}_{\mathrm{L}}) = \text{ó}_{\mathrm{Y}}\hat{\mathrm{p}}_{\mathrm{Z}} \tag{11}$$

In addition, competition ensures that $p_Y Y = p_L L + p_Z Z$. We totally differentiate this equation and the production function (2b). Substituting the results into other equations above leads to the key equation for labor supply:

$$\hat{L} = (1\text{-}t_{\text{Ð}})\left(\frac{(1-t_L)f(h-e)}{(1\text{-}t_{\text{Ð}})f(h-e)-\left[\text{ó}_Q(1-f)+\text{ó}_Y(L_Y/Z)\right]\left(1-t_L-\text{å}t_L\right)}\right)\hat{Z} \equiv (1-t_{\text{Ð}})\text{Ù}\hat{Z} \tag{12}$$

The welfare effects of the policy now can be written as:

$$\frac{\mathrm{dU}}{\text{ë}\mathrm{L}} = \left(\mathrm{t}_{\mathrm{L}}(1-t_{\Pi})\Omega - m\left(\frac{Z}{L}\right)\right)\hat{\mathrm{Z}} \equiv \text{-}y\hat{\mathrm{Z}} \tag{13}$$

This expression redefines the net effect on welfare, , for the more general case with variable emissions per unit output. Under what circumstances does this expression reduce to the previous one for fixed emissions? To help interpret these expressions, we note some special cases.

First, if t = 1, then again $\hat{L}$ in (12) is zero. A tax rate of 100 percent on the profits is equivalent to selling the permits; this policy has no effect on labor distortions, and the only welfare effect in (13) is the unambiguous gain from correcting the externality (Z/L).

Second, consider the case where $_Y = 0$. Then equation (12) shows that collapses to . Also, because of fixed coefficient production, $\hat{Y} = \hat{Z}$. This case is not quite comparable to the previous case, however, because Z is only part of the production of Y. If the externality arises only from Z, and not from all of Y, then the gain from correcting the externality (Z/L) is effectively cut from its previous size (Y/L). The loss from exacerbating labor supply distortions $\{t_L(1\text{-}t\ )\ \}$ is the same as before, so the net loss of welfare is larger than before.

Third, instead, suppose $L_Y = 0$. Then Y = Z, so $\hat{Y} = \hat{Z}$, and equation (12) also shows that reduces to . In this case, regardless of $_Y$, all numerical results must match the previous results. But this case is not "variable emissions per unit of output."

Fourth, however, we can still construct a case with variable emissions that will have results comparable to those of the previous model. We want pollution in the new model (Z) to be the same size as pollution in the old model (Y), so we double the size of Y while assuming that half of its input is Z. In other words, we set $L_Y = Z$, and double the share of Y in consumption, ϕ, from 0.25 to 0.50. Numerical results are shown in Table 2.

Again we consider a permit policy that mandates a small reduction in pollution ($\hat{Z} < 0$). The assumed parameter values all match the case above (where t_L=0.4, and = =0.3, but ϕ=0.50 in order for Z/L to match the previous Y/L at 0.15). Also, we now have the additional parameter, $_Y$. This parameter measures the ability to substitute clean inputs for dirty inputs. Because the size of this elasticity is so uncertain, we consider a number of values. Table 2 varies this parameter from zero to 2.0, and can be used to demonstrate several points.

First, in column 2, note that the welfare loss from this environmental regulation falls as the degree of factor substitutability ($_Y$) rises. The regulation is simply not as costly when emissions can more readily be avoided by using the other input instead. When factors are used in fixed proportions, and the government mandates a 1% cut in emissions, then the efficiency loss from the labor distortion is 0.122%

of national income. When the elasticity is increased to 0.5, this loss is reduced by 30%. Doubling the elasticity to 1.0, or again to 2.0, provide further reductions in the welfare loss. The net loss in column 3 changes to a small net gain. A similar story holds for the case where scarcity rents are taxed at 40%.

Second, look at the third row with $_{Y} = 1$. These results exactly match the corresponding case in our previous model (row 4 of Table 1). To explain this equivalence, note that the elasticity of substitution in consumption ($_{Q}$) is also set equal to one. Thus all expenditure shares are unchanged by policy shocks. Consumers do not change the fraction of income spent on Y, and producers of Y do not change the fraction of sales revenue spent on each input. The economy-wide fraction of income spent on pollution was set to 0.15 for both models, and this overall share is unchanged by policy, so the two models are functionally equivalent.

Third, as we showed in the previous section using "plausible" parameter values, the mandated reduction in pollution has a cost from worsening the labor distortion that offsets most or all of the gain from starting to fix the pollution problem. Results in this section show that this conclusion is not reversed by allowing for any reasonable degree of substitutability in production between clean inputs and dirty inputs.

IV. Model and Results with Monopoly Production

To this point, we have assumed that all markets are perfectly competitive, but we now explore how environmental policies affect welfare in the presence of imperfect competition. To be specific, we consider the case where the polluting good (Y) is provided by a monopolist.[15] In all other regards, we maintain the model developed in the previous sections. To keep the analysis simple, however, we revert to the fixed-emissions model in which Y = Z. Our economy now has three pre-existing distortions: a wage tax, a monopolist, and an uncorrected externality. As a consequence, the welfare effect of any

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[15] If instead the clean sector has monopoly power, then the regulatory reduction in Y will offset the monopolist's reduction in X, but it will reinforce the wage tax effect by reducing both goods relative to leisure. Also, the model could incorporate other forms of imperfect competition. Browning [10] uses a simple mark-up to represent an arbitrary degree of market power, but we wish to specify monopoly behavior in order to see how that mark-up changes. We believe that our results would not be substantially different with some other specific model of oligopoly or monopolistic competition, but we leave these questions for future research.

particular change cannot be known *a priori*. The initial production of Y may be too low because of monopoly, or too high because of the externality. Similarly, even the initial labor supply may be above or below the welfare-maximizing level. Any environmental policy that requires a reduction in Y will alleviate some problems and exacerbate others. We solve for the general equilibrium effect of a small policy on all three distortions.

The production relationships are linear as in our first model above. The household budget constraint in (4) is unaffected, but after-tax monopoly profits (1-t) exist prior to the implementation of any environmental policy. These profits are defined by:

(14) $$= (p_Y - 1)Y$$

If Y is produced in a competitive market, then the initial equilibrium price of Y (p_Y) equals 1. If Y is produced by a monopolist, then the firm maximizes profits by choosing Y (or equivalently p_Y, given the demand curve). We define $_Y$ as the absolute value of the price elasticity of demand for Y, so the firm's first-order condition for profit maximization is:[16]

(15) $$p_Y - 1 = \frac{p_Y}{e_Y}$$

The degree to which the price of Y exceeds marginal cost depends on the elasticity of demand for Y. The higher is $_Y$, the less distortion (mark-up) is created by monopolization of Y. Equation (15) can only be satisfied if the monopolist produces in the portion of the demand curve where the elasticity is greater than one.[17]

Totally differentiating the definition of profits in (14), and using the first order condition for the monopolist in (15) yields:

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[16] Totally differentiate (14), set d to zero, and re-arrange.

[17] We set parameters below such that the initial p_Y is 1.2, so profits are 20% of the cost of producing Y. This is consistent with the estimates of market power reported in Office of Policy [22]. Equation (15) then implies that $_Y$ is six. We also derive the corresponding value of $_Q$, which also must exceed one.

(16) $$\hat{\Pi} = \hat{Y} + e_Y \hat{p}_Y .$$

Also, along a demand curve where income and other prices are constant, the consumer's behavior is defined by:

(17) $$\hat{Y} = -e_Y \hat{p}_Y .$$

The firm uses the demand curve in (17) to arrive at its maximizing behavior in (16), so substitution yields $\hat{\Pi} = 0$. That is, the firm cannot increase profits by movement in either direction along the demand curve. We use (16) to calculate a change in profits that is *not* zero, however, for an environmental regulation that shifts the demand curve by changing income and other prices. Also, occasionally, it will be useful to write profits as:

(18) $$\Pi = (p_Y - 1)\, Y = \frac{p_Y Y}{e_Y}$$

where the first equality reflects the definition of profits in (14) and the second equality reflects the firm's behavior in (15). The far right expression for profits is written in terms of $_Y$, the demand elasticity for Y. Next, we express $_Y$ in terms of $_Q$.

Differentiating the household budget constraint (holding income constant) yields:

(19) $$\hat{X} = -\frac{f}{1-f}(\hat{Y} + \hat{p}_Y).$$

Then, combining equations (17), (19), and the definition of the elasticity of substitution in consumption, we have:

(20) $$å_Y = f + (1-f)\, ó_Q .$$

Since $_Y$ must exceed 1, the monopoly solution also requires that $_Q$ exceed 1.

To obtain an expression for the welfare impact of regulation in the presence of monopoly, we follow steps similar to those in the derivation of $dU/\lambda L$ above. We totally differentiate utility and use first-order conditions from the consumer’s maximization problem, but we also use the definition of profits. These steps yield:

$$\frac{dU}{\text{ë}L} = t_L \hat{L} - \text{ì}\left(\frac{Y}{L}\right)\hat{Y} + \left(\frac{\text{Đ}}{L}\right)\hat{Y} \tag{21}$$

As before, the environmental policy lowers welfare to the extent that it reduces labor supply and raises welfare to the extent that it reduces production of the polluting good. The third term represents the monopoly distortion. Since a monopolist inefficiently restricts production of its good, further restrictions from the environmental policy reduce welfare. The usual partial equilibrium model might compare the last two terms to see if the monopolist raises price toward (or above) the social marginal cost of output. For example, if the initial p_Y is 1.2, then profits are 20% of the cost of production of Y. If this Y is still 15% of total output, then (/L) is 0.03 in the equation above. The policy $\hat{Y}<0$ has a negative effect on welfare from exacerbating the monopoly distortion. But if =0.2, then (Y/L) is also 0.03 in equation (21), and these two effects exactly offset. The monopolist already raises price to 1.2, which exactly reflects the social marginal cost of production (1+). However, that partial equilibrium model neglects the effect of $\hat{Y}$ on $\hat{L}$ in the first term of (21). We show below that labor supply, and thus welfare, must fall. The implication is that the reverse policy with a forced increase in output would *raise* welfare (despite the negative externality).[18]

These results depend entirely on whether the monopolist has left the price of output below the social marginal cost of production or has already raised it above the social marginal cost of production. Therefore, in numerical results below, we use $p_Y = 1.2$, and set to 0.1 or 0.3.

To find the general equilibrium effect on labor supply, we again start with the government's balanced-budget adjustment to the tax rate on labor. Any pre-existing tax rate on profits is not adjusted. The government budget constraint in equation (7) is unchanged, but now profits exist prior to the imposition of any new policy. Moreover, the change in profits is driven by equation (16). We

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[18] An important issue is how to specify the counterfactual. Under one scenario, we could take Y/L from the previous competitive model, and suppose that Y were to become monopolized. We would then calculate a new lower Y/L for the monopoly case, and a new lower benefit from reduction of pollution (Y/L). Under a different scenario, Y/L is an observed value like 0.15, and we ask what would happen if that outcome represented a monopolized sector instead of a competitive sector. We take this latter course, since it maintains the size of the polluting sector (and thus Y/L) across the two models.

differentiate equation (7), use the expression for profits in equation (18) as well as the change in profits in equation (16) to obtain:

$$\hat{t}_L = -\left(\frac{t_L}{1-t_L}\right)\hat{L} - \left(\frac{f\, t_{\text{Ð}}}{\mathring{a}_Y S_L}\right)(\hat{Y} + \mathring{a}_Y \hat{p}_Y). \tag{22}$$

where S_L is the share of after-tax labor income in total after-tax household income.

Next, labor supply is a function of the real net wage and real nonlabor income. Thus environmental regulations affect labor supply both through the effect of $\hat{t}_L$ on $\hat{w}$ and the effect of $\hat{Y}$ on $\hat{\Pi}$. We differentiate the labor supply function and use equation (16) to get:

$$\hat{L} = \mathring{a}\hat{w} + \text{ç}\, S_{\text{Ð}}(\hat{Y} + (1-f)\,\text{ó}_Q\, \hat{p}_Y) \tag{23}$$

where S is the share of after-tax profits in after-tax income. The expression in parentheses is the proportional change in real profits. Labor supply is affected by changes in the real after-tax wage through (including both substitution and income effects) as well as changes in real profits through (effect of nonlabor income).

Finally, we need an expression for the change in the price of Y attributable to the environmental policy. We can use the equilibrium relationship between Y and p_Y to obtain this expression. Totally differentiate the household budget constraint:

$$\hat{X} = -\frac{p_Y Y}{X}(\hat{Y} + \hat{p}_Y) + \frac{(1-t_L)L}{X}(\hat{L} - \hat{t}_L) + (1-t_{\text{Ð}})\frac{\text{Ð}}{X}\hat{\text{Ð}}. \tag{24}$$

Substitute this equation into the definition of the elasticity of substitution in consumption ($_Q$), and use equations (16), (20), and (22) to get:

$$\hat{p}_Y = -\frac{\hat{Y}}{\mathring{a}_Y} + \frac{S_L}{(1-t_L)(\mathring{a}_Y S_L - f\, t_{\text{Ð}})}\hat{L} \tag{25}$$

At this point, if we take $\hat{Y}$ as an exogenous policy parameter, we have four equations that are linear in four unknowns. By successive substitution, or Cramer's Rule, the four equations (8), (22), (23), and

(25) can be solved for $\hat{p}_Y$, $\hat{t}_L$, $\hat{w}$, and $\hat{L}$. The long expression for $\hat{L}$ is not worth repeating here, but we use it to measure the welfare impact of a required reduction in Y. Thus welfare in (21) can be re-expressed as $-y\,\hat{Y}$.

For parameter values, we cannot use all the same selections as before. In the competitive model, where $p_Y = 1$, we set (Y/L)=0.15 and t_L=0.40, so government provision must be 40% of output and X must be the remaining 45% of output. These ratios generate ϕ=0.250 for the expenditure on Y as a share of the consumer's budget. In the monopoly model, we first assume that the monopolist has set p_Y =1.2, so that profits are 20% of the output of Y. Second, we choose to match the share of Y in total output (Y/L) across models, to keep the pollution impacts comparable. But then the higher price on Y in the monopoly model means that consumers must be spending more of their income on Y. We derive ϕ as the spending $p_Y Y$ = (1.2)(.15) as a fraction of total spending {(1.2)(.15)+.45}, so ϕ must be 0.286 in the monopoly model. Third, we can no longer assume a unit elasticity of substitution between X and Y. Since p_Y=1.2, equation (15) says that $_Y$ must be 6, and equation (20) says that $_Q$ must be 8. These values may seem high, but our model only has two commodities. The reality that constrains the price charged by a monopolist from being even higher is that some other good can serve as a reasonably close substitute. To be able to compare results, we use this value ($_Q$=8) in both the competitive model and in the monopoly model.[19]

Finally, in cases where the pre-existing t is positive, then the initial monopoly profits must be generating some tax revenue. In those cases, we keep government spending at 40% of national output by reducing the *initial* tax on labor supply according to:

$$t_L = \frac{G}{NL} - t_Đ \frac{Đ}{L} \tag{26}$$

Table 3 presents results for these parameters when Y is provided by a monopolist and for purposes of comparison, also in a perfectly competitive market. All rows assume that the labor supply elasticity is 0.3, and the first two rows vary the externality (=0.1 and 0.3). We first analyze results for the perfectly competitive model. Note that the results for this competitive model differ from those

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[19] When $_Q$ is fixed across the two models, but ϕ is not, equation (20) says that $_Y$ must be 6.25 in the competitive model and 6 in the monopoly model.

in Table 1, primarily by assuming a greater degree of substitutability between X and Y in consumption. And because consumers have this greater ability to substitute in consumption, the forced reduction in Y has less impact on raising the price of Y. The consequence is a smaller decrease in the real net wage and a lower loss from increasing the labor market distortion. To see the impact of increasing $_Q$ from 1 to 8, compare the first row of Table 3 to the second row of Table 1 (with the same =0.3 and =0.1). The labor market loss is cut by more than 80%, from 0.062 to 0.010. Since this loss is so much smaller, and the environmental gain is still 0.015, this change in $_Q$ has converted the overall effect on welfare from negative in Table 1 to positive in Table 3. The next row in Table 3 shows that increasing the marginal environmental damage from 0.1 to 0.3 also increases this net gain.

The remaining rows of Table 3 keep =0.3 and show the effect of alternative values for the initial tax on profits. As in Table 1, a higher tax on profits reduces the handout of scarcity rent, which blunts the fall in labor supply attributable to that income effect. With 100% profits tax, in the last row, all incremental labor market distortions are eliminated. Then the net welfare effect is simply the gain from correcting the externality.

The right half of Table 3 presents results from the monopoly model. First note that the tax rate on wage income is no longer fixed at 40%. With pre-existing profits, a higher initial profits tax implies that a lower initial labor tax is required to raise 40% of national income. The first two rows present results for the case where profits are untaxed (and the labor tax is 40%). The reduction in labor supply in the monopoly model is 70% of the reduction in the perfect competition model (as evidenced by the loss from the labor market distortion in columns 3 and 7). Households do not reduce labor supply as much in the monopoly model because the environmental policy reduces monopoly profits, and leisure is a normal good. When is only 0.1, however, the net welfare effect of the regulation turns from positive in the competitive model to negative in the monopoly model. The reason is that this monopolist has already raised price ($p_Y = 1.2$) above social marginal cost (1+). The loss from exacerbating the monopoly distortion combined with the loss from exacerbating the labor distortion then exceeds the environmental gain.

When = 0.3, the monopolist with $p_Y = 1.2$ has not restricted output "enough." In this case the loss from the monopoly distortion (0.03) is less than the environmental gain (0.045). Now the net welfare effect depends on the labor distortion! In the monopoly model, however, the loss from the labor distortion is a paltry 0.007. Why? First, the impact on labor is reduced substantially by the use of $_Q$

= 8, as mentioned above, in both the competitive model and the monopoly model. When consumers can substitute into other goods, the policy has smaller effect on the price of Y. It therefore has smaller effect on the real net wage and on labor supply. Second, in the monopoly model, the environmental policy reduces pre-existing profits. The loss of income has a positive effect on labor, since leisure is normal, which provides a "partial offset" to the negative effect from the lower real net wage. These factors shrink $\hat{L}$ to only -0.016, which is multiplied by t_L=0.4 to get the loss in welfare (0.007).

The last three rows of Table 3 show that changes in t have virtually no effect on the paltry 0.007 loss from the labor distortion (column 7).[20] Why? First, a higher initial profits tax means that the income effect (from the change in monopoly profits) is smaller. Thus the "partial offset" just mentioned is smaller, and labor supply does fall a bit more. The real wage falls by about -0.058 in all three rows, and profits fall by about -0.038 in all three rows, but the higher tax on profits makes the income effect smaller. With 100% profits tax, and no income effect to offset the wage effect, labor supply falls by the full $e\hat{w}$, which is (0.3)(-0.058) = -0.017. Second, even though the higher profits tax enlarges the effect on labor supply (slightly), it reduces the initial required labor tax. The net effect on welfare is the product, $t_L \hat{L}$, so these two effects offset each other, and the loss from the labor distortion is essentially unchanged.

The results from this section illustrate a couple of points about environmental policies that restrict output. First, the exacerbation of distortions arising from imperfect competition can be very important and could potentially more than offset any gains from improving the environment, even ignoring effects on labor supply. This point may be particularly important for energy-producing industries, those most likely to fail conditions for perfect competition. Second, these monopoly results affect the previous result in the competitive model where we emphasized that government could prevent the fall in the real net wage if it were to capture all of the scarcity rents by 100% profits tax, or by sale instead of handout of permits. This result does not hold in a model with pre-existing profits, because the environmental policy reduces those pre-existing profits. In the case of complete profits taxation, for a 1% output restriction,

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[20] When the profits tax rate is zero, the 40% labor tax raises enough to provide spending that is 40% of total output (L). The penultimate row finds the single tax rate on both profits and labor (38.8%) that raises the same revenue for the initial equilibrium. The last row considers a 100% profits tax, so the same spending is possible with a labor tax of only 37%. (We assume the firm continues to maximize profits despite a 100% tax rate).

profits fall by -.038%. This change requires government to increase the tax on wages to make up lost tax on profits. The result is that a 1% output restriction does reduce the real net wage (by 0.058%).

V. Conclusion

This paper has shown an application of a simple analytic general equilibrium model to evaluate the welfare impact of implementing a cap and trade program such as the tradable allowance program developed in the Clean Air Act Amendments of 1990. Numerical results can be obtained with a relatively small number of parameters. The model is sufficiently flexible to allow for competitive markets in the production of the good associated with pollution as well as a market dominated by a monopolist.

In both the competitive model and the monopoly model, the government's capture of rents created by giving allowances to private firms is important if the policy is to have a positive welfare impact. In all three tables of numerical results, whether the creation of an allowance program that restricts pollution raises welfare or not depends importantly on the extent of tax on (or capture of) the rents generated by the allowance give-away.

The capture of rents from the permit program is somewhat less important in the monopoly model, however, because the environmental policy reduces monopoly profits in a way that offsets the generation of scarcity rents from the emission restriction. These two income effects on labor supply offset each other: reduced monopoly income tends to increase labor supply, while new scarcity rent income tends to reduce labor supply.

Thus we find two offsetting effects on prior labor tax distortions, and only numerical analysis can allow us to compare the relevant magnitudes. While the net income effect on labor supply is reduced, in the monopoly model, we find that the price effect is enlarged. The introduction of a cap and trade program in a market characterized by imperfect competition is more likely to reduce welfare, even after taking the environmental benefits into account. The intuition is straightforward: market power raises price and curtails production of a commodity (relative to the production in a competitive equilibrium). A cap and trade program further raises price and curtails production; the labor market distortions arising from a decrease in the real net wage are exacerbated, and the environmental benefits of reducing pollution are offset by greater distortions elsewhere.

Table 1
Welfare Effect of a Small Cut in Pollution:
Fixed Pollution per Unit of Output

Assumed Parameter Values				Gain from Externality Correction	t = 0		t = t_L	
					Loss from Labor Distortion	Net Effect on Welfare	Loss from Labor Distortion	Net Effect on Welfare
				(1)	(2)	(3)	(4)	(5)
t_L			Y/L	(Y/L)	t_L(1-t)		t_L(1-t)	
.4	.1	.1	0.15	0.015	0.036	-0.021	0.023	-0.008
.4	.3	.1	0.15	0.015	0.062	-0.047	0.041	-0.026
.4	.1	.3	0.15	0.045	0.036	0.009	0.023	0.022
.4	.3	.3	0.15	0.045	0.062	-0.017	0.041	0.004
.3	.3	.3	0.18	0.053	0.045	0.007	0.034	0.019
.5	.3	.3	0.13	0.038	0.081	-0.043	0.048	-0.011

The four parameters in the first part of the table are: tax rate on labor income (t_L), uncompensated labor supply elasticity ( ), social marginal damage of pollution ( ) and the production of the dirty good as a fraction of total output (Y/L). Other parameter values are as follows: elasticity of substitution in consumption ($_Q$) equals 1.0, income elasticity of labor supply ( ) equals -0.2 and the expenditure share of the dirty good in consumption (ϕ) equals 0.25. See text for details.

Table 2
Welfare Effect of a Small Cut in Pollution: Variable Pollution per Unit of Output

	Gain from Externality Correction	t = 0		t = t_L	
		Loss from Labor Distortion	Net Effect on Welfare	Loss from Labor Distortion	Net Effect on Welfare
	(1)	(2)	(3)	(4)	(5)
$_Y$	(Z/L)	t_L(1-t)		t_L(1-t)	
0.00	0.045	0.122	-0.077	0.092	-0.047
0.50	0.045	0.082	-0.037	0.057	-0.012
1.00	0.045	0.062	-0.017	0.041	0.004
2.00	0.045	0.041	0.004	0.027	0.018

The parameter in the first part of the table is the elasticity of substitution in production ($_Y$). Other parameter values are as follows: tax rate on labor income (t_L) equals 0.4, uncompensated labor supply elasticity ( ) equals 0.3, social marginal damage of pollution ( ) equals 0.3, elasticity of substitution in consumption ($_Q$) equals 1.0, income elasticity of labor supply ( ) equals -0.2, and the expenditure share of the dirty good in consumption (ϕ) equals 0.5. See text for details.

Table 3
Welfare Effects of a Small Cut in Pollution: Monopoly Production of the Polluting Good

Assumed Parameter Values			Perfect Competition			Monopoly			
		Gain from Externality Correction	Tax Rate on Labor	Loss from Labor Distortion	Net Effect on Welfare	Tax Rate on Labor	Loss from Monopoly Distortion	Loss from Labor Distortion	Net Effect on Welfare
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
t		(Y/L)	t_L	$t_L \hat{L}$		t_L	/L	$t_L \hat{L}$	
0	0.1	0.015	0.40	0.010	0.005	0.40	0.030	0.007	-0.022
0	0.3	0.045	0.40	0.010	0.035	0.40	0.030	0.007	0.008
t_L	0.3	0.045	0.40	0.006	0.039	0.388	0.030	0.007	0.008
1.0	0.3	0.045	0.40	0	0.045	0.37	0.030	0.006	0.009

Government spending is 40% of total output, the uncompensated labor supply elasticity is 0.3, the labor supply income elasticity is -0.2, and the elasticity of substitution in consumption $_Q$ is 8. The pollution generating good comprises 15% of total output. Prior to the mandated restriction, the price of Y is 1 in the competitive model, and 1.2 in the monopoly model. The share ϕ is 1/4 in the competitive model and .286 in the monopoly model. $_Y$ equals 6.25 in the competitive model and 6 in the monopoly model.

References

1. P. Asch and J. J. Seneca, Monopoly and External Costs: An Application of Second-Best Theory to the Automobile Industry, *J. Environ. Econom. Management* **3**, 69-79 (1976).

2. S. E. Atkinson and D. H. Lewis, A Cost-Effectiveness Analysis of Alternative Air Quality Control Strategies, *J. Environ. Econom. Management* **1**, 237-250 (1974).

3. A. H. Barnett, The Pigouvian Tax Rule Under Monopoly, *Amer. Econom. Rev.* **70**, 1037-1041 (1980).

4. E. Berndt and D. O. Wood, Technology, Prices, and the Derived Demand for Energy, *Rev. Econom. Statist.* **57**, 259-268 (1975).

5. P. Bohm and C. F. Russell, Comparative Analysis of Alternative Policy Instruments, *in* "Handbook of Natural Resource and Energy Economics" (A. V. Kneese and J. L. Sweeney, Eds.), Elsevier, New York (1985).

6. A. L. Bovenberg and R. de Mooij, Environmental Levies and Distortionary Taxation, *Amer. Econom. Rev.* **94**, 1085-1089 (1994).

7. A. L. Bovenberg and L. H. Goulder, Optimal Environmental Taxation in the Presence of Other Taxes: General Equilibrium Analyses, *Amer. Econom. Rev.* **86**, 985-1000 (1996).

8. E. K. Browning, On the Marginal Welfare Cost of Taxation, *Amer. Econom. Rev.* **77**, 11-23 (1987).

9. E. K. Browning, The Non-tax Wedge, *J. Public Econom.* **53**, 419-433 (1994).

10. E. K. Browning, A Neglected Welfare Cost of Monopoly--And Most Other Product Market Distortions, *J. Public Econom.* **66**, 127-144 (1997).

11. J. M. Buchanan, External Diseconomies, Corrective Taxes, and Market Structure, *Amer. Econom. Rev.* **59**, 174-177 (1969).

12. V. Caddy, "Empirical Estimation of the Elasticity of Substitution: A Review," Working Paper OP-09, IMPACT Project, Industrial Assistance Commission, Melbourne, Australia (1976).

13. M. Cropper and W. Oates, Environmental Economics: A Survey, *J. Econom. Lit.* **30**, 675-740 (1992).

14. M. Feldstein, The Effect of Marginal Tax Rates on Taxable Income: A Panel Study of the 1986 Tax Reform Act, *J. Polit. Economy* **103**, 551-572 (1995).

15. J. J. Fialka, "Energy Secretary Says He Has Evidence Some Utilities Use Monopoly Power," *Wall Street Journal*, March 8, 2000, p. A4.

16. A. M. Freeman, "Air and Water Pollution Control: A Benefit-Cost Assessment," John Wiley and Sons, New York (1982).

17. V. R. Fuchs, A. B. Krueger and J. M. Poterba, Economists' Views about Parameters, Values, and Policies: Survey Results in Labor and Public Economics, *J. Econom. Lit.* **36**, 1387-1425 (1998).

18. D. Fullerton and G. E. Metcalf, Environmental Controls, Scarcity Rents, and Pre-Existing Distortions, *J. Public Econom.* forthcoming (2000).

19. L. H. Goulder, I. Parry and D. Burtraw, Revenue-Raising vs. Other Approaches to Environmental Protection: The Critical Significance of Pre-Existing Tax Distortions, *RAND J. Econom.* **28**, 708-731 (1997).

20. D. Hamermesh, "Labor Demand," Princeton University Press, Princeton, NJ (1993).

21. W. S. Misiolek, Effluent Taxation in Monopoly Markets, *J. Environ. Econom. Management* **7**, 103-107 (1980).

22. Office of Policy, "Horizontal Market Power in Restructured Electricity Markets," DOE/PO-0060, Office of Economic, Electricity and Natural Gas Analysis, U.S. Department of Energy, Washington, DC (2000).

23. I. W. H. Parry, Pollution Taxes and Revenue Recycling, *J. Environ. Econom. Management* **29**, S64-S77 (1995).

24. I. W. H. Parry, Environmental Taxes and Quotas in the Presence of Distorting Taxes in Factor Markets, *Resour. Energy Econom.* **19**, 203-220 (1997).

25. D. Pearce and R. K. Turner, "Economics of Natural Resources and the Environment," Johns Hopkins Press, Baltimore (1990).

26. A. C. Pigou, "The Economics of Welfare," MacMillan and Co., London (1932).

27. H. Rosen, What is Labor Supply and Do Taxes Affect It?, *Amer. Econom. Rev.* **70**, 171-176 (1980).

28. F. S. Russek, "Labor Supply and Taxes," CBO Memorandum, Congressional Budget Office, Washington, DC (1996).

29. C. Russell, Monitoring and Enforcement, *in* "Public Policies for Environmental Protection" (P.

R. Portney, Ed.), Resources For the Future, Washington, DC (1990).

30. R. Schmalensee, P. L. Joskow, A. D. Ellerman, J. P. Montero and E. M. Bailey, An Interim Evaluation of Sulfur Dioxide Emissions Trading, *J. Econom. Perspecitives* **12**, 53-68 (1998).

31. E. Seskin, R. J. Anderson and R. O. Reid, An Empirical Analysis of Economic Strategies for Controlling Air Pollution, *J. Environ. Econom. Management* **10**, 112-124 (1983).

32. R. N. Stavins, Transaction Costs and Tradeable Permits, *J. Environ. Econom. Management* **29**, 133-148 (1995).

33. C. Stuart, Welfare Costs per Dollar of Additional Tax Revenues in the United States, *Amer. Econom. Rev*. **74**, 352-362 (1984).

34. U.S. Bureau of the Census, "Statistical Abstract of the United States: 1998," U.S. Government Printing Office, Washington, DC (1998).

35. U.S. Environmental Protection Agency, Allowance Prices, U.S. EPA. Accessed March 20, 2000. Available From http://www.epa.gov/docs/acidrain/ats/pricetbl.html.

36. M. Weitzman, Prices vs. Quantities, *Rev. Econom. Studies* **41**, 477-491 (1974).

37. L. Wicke, Environmental Damage Balance Sheets, *in* "Maintaining a Satisfactory Environment: An Agenda for International Environmental Policy" (N. Akerman, Ed.), Westview Press, Boulder CO (1990).

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