Tax Interaction Effects, Environmental Regulation, and “Rule of Thumb” Adjustments to Social Cost

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Abstract. Preexisting distortions in factor markets complicate the estimation of the social welfare effects of regulatory interventions. The existence of these tax interaction effects (TIEs) suggests that general equilibrium (GE) approaches should be used to evaluate regulatory policies. However, formal GE analysis is not always feasible for the numerous environmental regulations proposed by federal, state, and local agencies. The question addressed in this paper is whether an empirically based “rule of thumb” upward adjustment factor is appropriate to properly scale social cost estimates in environmental policy. We argue that such rule of thumb adjustments are significantly less reliable than estimates based on a detailed general equilibrium analysis because of the uncertainty about both the magnitude and sign of the social cost distortion. In addition to addressing this question, the paper gives an overview of TIEs and their relevance to environmental policy.

Key words: general equilibrium, regulation, social costs, tax interaction effects

JEL classification: Q21, H00

Abbreviations: CGE – computable general equilibrium; GE – general equilibrium; PE – partial equilibrium; TIEs – tax interaction effects

1. Introduction

Regulatory analyses in the United States have traditionally relied on social cost estimates that are derived from partial equilibrium (PE) models of the regulated industries.1 PE measures ignore effects in all other markets except those directly affected by the regulation. Therefore, they ignore the effect that changes in the affected market might have on welfare costs – and potentially benefits – in other markets.

A significant challenge to PE estimates of social cost has come from recent literature that focuses on how environmental regulations interact with
tax-induced distortions in the labor market, often referred to as tax interaction effects (TIEs). Bovenberg and deMooij (1994a), Bovenberg and Goulder (1996), Goulder et al. (1999), Lithgort and van der Ploeg (1999), and Fullerton and Metcalf (2001) are notable examples. A related set of articles considers how environmental taxes interact with labor market distortions such as involuntary unemployment (see Bovenberg and de Mooij 1994b; Bovenberg and van der Ploeg 1996; Schneider 1997). Public finance economists since Harberger (1964) have known that welfare analysis of public policy can take place solely in the intervened-in market only when undistorted competitive conditions reign in all other markets. If one performs single-market analysis of a tax, for example, or an environmental regulation, then one assumes that there are no other-market distortions or that the exacerbation and amelioration of other-market distortions caused by the intervention in question cancel one another out. The TIE literature argues that, in the case of environmental policy (as well as agricultural policy and trade policy; see Parry (1999) and Williams (1999)), the other-market effects do not cancel out on average and are likely to be of significant magnitude. In particular, the nature of environmental regulation – through command and control, pollution taxes, or quota restrictions on pollution – systematically worsens the distortion in the labor market that arises from the existing income tax.

The literature on TIEs of environmental regulations has potentially important implications for estimating the social costs of environmental regulations. The literature suggests that even “small” regulatory actions raise prices, reduce the real return to factors (wage), and add to the deadweight loss caused by distortionary taxation (labor tax). It has therefore been argued that regulatory agencies should use computable general equilibrium (CGE) models to account for this effect in estimating social costs. However, CGE modeling may not be a practical alternative for all regulations subject to review. Consequently, there has been debate among environmental economists about whether, in the absence of CGE analysis, a uniform upward adjustment to direct costs is warranted to reflect the effect of a TIE on a regulation’s social cost. An upward adjustment of 25–35% has been suggested as (conservatively) reflective of the literature (USEPA 1999). In this paper, we argue that such ad hoc social cost adjustments for TIEs are sensitive to the inclusion or exclusion of key model factors. We provide examples in which empirically realistic deviations from the standard cases used to develop the benchmark estimates could lead to substantial reductions in the size – and even the sign – of the TIE. Our conclusion is that TIE adjustments to cost estimates for important regulations should whenever possible be based on estimates that consider the specific nature of individual regulations, and should examine a range of mechanisms by which the interaction of the tax system and the regulatory system cause significant changes in welfare.
Where *ad hoc* adjustments are used because better estimates are not available, they should be used with caution and less confidence should be placed on the estimated welfare effects.

2. A Basic Explanation of TIES

Economic analyses of the costs of pollution reduction have historically focused on firms’ direct expenditures on pollution control and on the effects of these expenditures on the markets in which these firms operate. For example, the cost of regulations affecting power companies would be measured by utilities’ expenditures on pollution control equipment and by the resulting change in the cost of producing electricity. Such analyses are generally referred to as PE analyses, meaning that they focus on a specific segment of the economy in isolation from all others.

Economists have recognized that such changes can have complex and far-reaching effects in other parts of the economy. Analyses that attempt to capture such interactions throughout the economy are known as general equilibrium (GE) analyses. There have been several efforts to systematically model and measure these GE effects (e.g., Kokoski and Smith 1987; Hazilla and Kopp 1990; Jorgenson and Wilcoxen 1990; Nestor and Pasurka 1995). The focus of the TIE literature is to capture extra-market effects that are thought to be important because they involve large distortions induced by government’s taxation of labor and investment.

2.1. INEFFECTIENCES CAUSED BY LABOR TAXES

The first concept essential to understanding TIEs is the inefficiency engendered by raising revenue through distortionary taxes. The dominant economic models of labor supply assume that individuals work up until their last hour of work gives them the same amount of utility in the form of income as they get in the form of direct utility from their last hour of leisure. If there were no taxes on labor income, a small increase in leisure at the expense of labor would have very little effect on utility because they would be almost equally valuable.

However, labor taxation is common (e.g., at marginal rates of around 40% in the United States, taking into account federal and state income taxes and social security taxes). The value of that labor to society is reflected in what employers are willing to pay (i.e., the pre-tax wage); however, workers only receive (about) 60% of that value for every additional hour they work. Consequently, labor supply models indicate that workers work less and enjoy more leisure than they would without taxes, and they choose their hours
worked at the point where leisure is only worth the same as their after-tax wage (i.e., about 60% of their pre-tax wage in the U.S. case).

The value of labor to society at large (the value of the worker’s marginal product) is not directly affected by the tax. The divergence of the incentive to work and the value of that work causes a suboptimal amount of labor to be provided, thereby diminishing the total welfare of society. There is an extensive theoretical and empirical literature on the losses caused by taxation of both labor and investment (see, for example, Browning 1987). The literature broadly concludes that these effects are real and substantial. The loss is commonly expressed as the welfare loss that results from raising an additional dollar of tax revenue. Typical estimates are on the order of 10–35% (Ballard et al. 1985), meaning that raising $1.00 of tax revenue costs society $1.10–$1.35 in resources, thereby creating a deadweight efficiency loss of up to $0.35 per dollar.

2.2. WHY LABOR DECISIONS ARE AFFECTED IN SIMILAR WAYS BY POLLUTION CONTROL REGULATIONS AND TAXES

The logic of the TIE literature is that pollution control regulations, whether in the form of taxes, quantity restrictions, or technology standards, have effects similar to taxes on labor. This occurs because the regulations increase the price of goods and services in affected industries. Because an hour of labor buys less than it did before the regulation, workers perceive a drop in their real wage and choose to supply less labor and consume more leisure – exactly as they would if the tax on labor were increased.

If there were no existing distortionary taxes on labor, then the loss to society of this drop in the real wage would be small. However, the existence of distorting taxes means that there is already a significant difference between the marginal value of labor and the marginal value of leisure. The additional reduction in labor supply caused by the pollution control regulation therefore creates a large deadweight efficiency loss. If labor is taxed at 40%, then each unit of labor reduced by pollution control regulations through higher prices imposes an excess burden of about 40% of the pre-tax wage to society. This loss is a primary component of TIEs. The empirical significance of TIEs depends a great deal on the way this component is modeled and measured, as we address in detail below.

A separate effect occurs because of the government’s need for revenue. If regulation causes people to work less, then less revenue is collected from taxes on labor. This reduction in labor causes the government to receive lower income tax and payroll tax revenues. To make up for revenue shortfalls, the government must increase these taxes if it wishes to maintain revenue neutrality. This increase, once again, causes workers to choose to
work fewer hours, and a further reduction to the well-being of the average person results. It is important to recognize that this literature does not make judgments about the value of government expenditures to society. The problem is not that the expenditures are not necessary or good. The problem is that raising those revenues reduces the individual incentives to work, thereby raising the social cost of the expenditures.

2.3. A BASIC MODEL OF ENVIRONMENTAL REGULATION’S TIES IN LABOR MARKETS

The TIE literature has emphasized the interaction between changes in the market price for a “dirty” good subject to environmental regulation and preexisting distortions in the labor market. Although, as described later, some of the more interesting elements of the TIE literature relate to alternative market-based instruments (e.g., emissions taxes versus marketable permits) and the interplay between potentially positive revenue recycling effects and potentially negative TIEs, the example below relates to “command and control” regulatory approaches that have historically been at the core of environmental regulatory policy.

Goulder et al. (1999) developed a GE model of a representative consumer, producer, and government. In the case of a command-and-control policy to increase pollution abatement when labor is the only factor of production, Goulder et al. define the GE measure of the policy’s welfare cost as

\[
dW^G = c(a)X + \left[(1 + M)\tau - NP^X\right] + M's_G X (dP^X/da)
\]

where

- \(dW^G\) the change in welfare cost measured by GE means
- \(dW^A\) direct cost of abatement
- \(dW^T\) TIE
- \(a\) pollution abatement level
- \(X\) quantity produced (consumed) of the regulated commodity
- \(c(a)\) cost of abatement per unit of \(X\)
- \(M\) marginal (PE) efficiency cost of a dollar of funds raised from labor tax revenue for public consumption = \(|e^{\alpha}\tau/(1 - \tau)|/\left[1 - e^{\alpha}\tau/(1 - \tau)\right]\)
- \(M'\) the PE marginal excess burden = \(|e^{\alpha}\tau/(1 - \tau)|/\left[1 - e^{\alpha}\tau/(1 - \tau)\right]\)
- \(\tau\) labor tax rate
- \(e^{\alpha}\) uncompensated (Marshallian) elasticity of labor supply with respect to the change in the wage (or marginal tax rate)
\( e^c \) compensated (Hicksian) elasticity of labor supply with respect to the change in the wage (or marginal tax rate)

\( P_X \) (demand) price of the regulated commodity

\( N^X \) change in the quantity of labor \((N)\) supplied with respect to a change in the price of \( X \)

\( N = \) labor = time allotment \((T^0)\) – leisure \((L)\)

\( s_G = \) share of government transfers in household income.

The two components of \( dW_A \) are, first, the increment in distortion in the labor market caused by the increase in the price of consumer goods and, second, the increment in distortion due to the requirement that the government raise tax rates after the pollution regulation to make up for reductions in labor tax revenue.

To estimate the size of the TIE, one needs representative parameter values for \( \tau, e^u, e^c, P_X, \partial L/\partial P_X \) (to compute \( N^X \)), and \( s_G \). Values for \( \tau \) and \( s_G \) are readily available from government data sources. Labor supply elasticities can be gleaned from the literature. Goulder et al. (1999) use values of \( e^u = 0.15 \) and \( e^c = 0.40 \) based on a survey of labor economists by Fuchs et al. (1998). The validity of assumed labor market parameters is an important issue for analysts to consider, but a more detailed discussion of these parameters is outside the scope of the present paper.

The TIE literature is virtually unanimous that GE effects are important for understanding the costs and benefits of environmental regulation. The literature is not unique in this regard; both traditional neoclassical environmental economists and ecological economists have recognized that it is economy-wide effects on welfare, and not narrow market-specific effects, that ultimately are important. Given the complexity of macroeconomic relationships and the associated uncertainties in both theory and measurement, however, there has not been any broad consensus on how best to quantify economy-wide effects. One well-known early example of using CGE models to quantify supply-side effects in environmental policy is Hazilla and Kopp (1990). However, while few would argue that GE effects are unimportant, PE analyses based on single-market or sector-level analyses have remained the norm for analyzing the social costs of environmental regulation.

The TIE literature is important for two related reasons. First, it focuses on a very specific mechanism for GE effects that has theoretical and empirical backing from the general literature on tax distortions. Second, it uses CGE models and tractable analytical methods to generate quantitative predictions about the magnitude of welfare losses in a fairly transparent way. It marks a significant and influential effort to move social cost estimation for environmental regulation out of a PE framework.
2.4. THE RELATIVE MAGNITUDE OF GE AND PE COSTS

Regarding the hypothesis that GE costs always exceed PE costs – thereby warranting a uniform upward adjustment of PE costs to adequately account for TIE – two observations are made here. First, the hypothesis lacks generality. Parry and Bento (2000) find that when the tax system is distorted to favor certain goods such as housing and medical care, then environmental taxation has ambiguous effects on efficiency and may even enhance it. In addition, Williams (2000) considers health and productivity effects of environmental regulation. When improvements in environmental quality enhance the ability of workers and firms to produce goods and services, then these efficiency-enhancing effects interact with the tax system to create (potentially large) gains in welfare. In essence, benefits that occur in production, as opposed to consumption, are magnified by TIEs. Schwartz and Repetto (2000) get similar results and also interpret evidence from US air quality regulation as indication that these welfare gains are in fact significant.

A second observation is that the empirical estimation of TIEs for regulations that increase production costs depends critically on the structure of specific abatement technologies, markets, and the general substitutability of leisure and the output of the regulated sector. Whereas the economic logic of these supply-side effects is compelling, the existing models may not adequately take account of the real state of production–consumption relationships. This causes some concern that the structure of the CGE models used magnifies the empirical significance of TIEs. Kahn and Farmer (1999) have argued that the assumption that output from pollution industries and leisure are substitutes is central to these models’ results and is likely not to hold in a number of important cases. West and Williams (2002) tested this for the relevant case of a gasoline tax and found that gasoline and leisure are complements. This implies that making gasoline more expensive increases labor supply, causing a welfare gain from interaction with the tax system. Goodstein (2002) argues that the empirical literature on labor supply response to specific price increases generally supports the finding that such increases are labor-increasing – which, again, implies such increases generate welfare improving TIEs.

Researchers active in this field have recognized the points made here. Goulder and Parry (2000) summarize many of these limitations in an essay on TIEs. The point is that TIE is a new and rapidly changing branch of economics literature, with new work offering stark changes in policy prescriptions from those recommended earlier. The literature is interesting and important, but its recognition of the dependence of TIEs on key parameters that can vary widely across different cases suggests to us that caution is called for in making ad hoc adjustments to partial equilibrium estimates of pollution control costs.
3. Empirically Realistic Factors that Can Mitigate the Size and Sign of the TIE

The magnitude of welfare losses resulting from TIEs depends on a number of key empirical relationships – a critical one being the extent to which producers react to pollution control regulation by restricting output and raising consumer prices. The induced price increase depends on substitution in consumption, trade, and other market-wide factors. Another key factor in the magnitude of the TIE is the interaction of a policy’s environmental benefits and labor supply decisions, which depends on whether environment and leisure are substitutes or complements. These two factors are now discussed in turn.

3.1. RETURNS TO SCALE AND THE INDUSTRY COST FUNCTION

An empirical consideration in TIE measurement is the nature of the industry cost (supply) function, particularly the returns to scale and corresponding slope of the function. Profits for the firm subject to the environmental regulation can be specified as follows:

$$\Pi(X, a) = P^X X - C(X) - A(a, X),$$

where $C(X)$ represents the cost function for nonpollution-related production costs, $A(a, X)$ is the pollution abatement cost function, and all other variables are as previously defined. For any given level of abatement, $a$, the profit-maximizing condition for the firm is

$$P^X = C_X(X) + A_X(a, X).$$

Consider three possibilities for the second derivative (slope) of industry production cost function:

- constant returns to scale (CRS): $C_{XX}(X) = 0$,
- decreasing returns to scale (DRS): $C_{XX}(X) > 0$, and
- increasing returns to scale (IRS): $C_{XX}(X) < 0$.

The analytical and numerical models referenced by Goulder et al. (1999) in developing equation (1) and most of the other contributions to the TIE literature rest on the first possibility, CRS. Under CRS, industry profits are zero and all abatement costs are passed on to consumers in the form of a higher price for $X$. For the remainder of this section, we assume that abatement cost is linear in $X: A(a, X) = c(a) X$. This is done to simplify the mathematics and keep the focus on the production cost function characteristics.\(^3\)

Following standard assumptions of producer theory, marginal costs are nonnegative $[C_X(X) \geq 0]$ and nondecreasing in output $[C_{XX}(X) \geq 0]$. An
increase in the abatement requirement, then, has the following effect on the price of good $X$:

$$dP_X = C_{XX}(X)\, dX + c_a(a)\, da. \quad (4)$$

The term $dX$ represents the change in the GE output level of good $X$ in response to the change in market conditions (prices) caused by the abatement requirement. Specifically, under CRS, equation (4) reduces to

$$dP_X = c_a(a)\, da. \quad (5)$$

Here $c_a$ is the change in the unit cost of abatement with respect to the change in abatement level. Under CRS in production, consumers of good $X$ absorb the full brunt of the abatement cost increase, and the TIE caused by consumption price-induced reductions in the real wage is maximized. This is the scenario Parry (1997) and Goulder et al. (1999) model when computing the empirical range of TIE mark-ups on social cost used as a point of reference for this discussion.\(^4\)

This result begs the question, however, of the applicability of CRS for regulatory analysis. Microeconomic theory provides ample reasons why an industry marginal cost function (and competitive supply curve) might not be constant throughout the range of output considered in a modeling exercise. They include scarce factor inputs (due to capital fixity, fixed natural resource endowments, or specialized labor) and technological heterogeneity across suppliers. To some extent, these are short-run phenomena that can be overcome by investment in capital, research and development (R & D), and resource discovery, for example, thereby making the long-run supply function flatter than the short-run function and, in the extreme, perfectly flat (CRS). However, if the industry facing the regulation cannot adjust all factors of production by the time the regulation comes into effect, then some deviation from CRS is warranted for the purposes of evaluating regulatory price effects. Even if these are transitory, time preference and discounting suggest that transitory effects could have a significant effect on the present value of social costs.\(^5\)

Suppose production is subject to fixed factors and DRS.\(^6\) Then following equation (4) the change in price will depend not only on the abatement cost, but also on the equilibrium change in the quantity of $X$. With standard Marshallian downward-sloping demand functions for $X$, the equilibrium quantity will decline ($dX < 0$) subject to the higher equilibrium price. Under DRS, $C_{XX}(\lambda) > 0$; therefore, the decline in the aggregate output will result in a decline in the marginal cost of production. Thus, the first term in equation. (4) is negative, and the change in price is less than the change in abatement cost:

$$dP_X < c_a(a)\, da. \quad (6)$$

Consider the case of DRS with a unitary elastic supply function and a unitary elastic Marshallian demand function. Under these conditions, it can
easily be shown that price rises by exactly one-half of the abatement cost increment. The remainder of the burden is imposed on producers, whose abatement costs rise more than the price they can recover in the markets, and thus their profits fall. To fully capture TIE under DRS, then, some accounting for the drop in producer income must be considered.

Full household income is the amount that can be spent on leisure and consumption. It equals the after-tax value of the time allotment \( T^0 \) and profit distributions \( \Pi \), plus the lump-sum redistributions from the government on labor and profit taxes:

\[
Y = wT^0(1 - \tau) + \Pi(1 - \tau) + \tau w(T^0 - L) + \Pi \cdot \tau = w(T^0 - L) + \Pi.
\]  

(7)

Differentiating equation (2) with respect to changes in \( P^X \), \( X \), and \( a \), the change in profits due to imposition of abatement costs for \( X \) is

\[
d\Pi = \left[ dP^X - c_a(a) \right] dX + \left[ P^X - C_X(X) - c(a) \right] dX.
\]  

(8)

The first-order condition in equation (3) indicates that the second bracketed term is zero, thus

\[
d\Pi = \left[ dP^X - c_a(a) \right] dX.
\]  

(9)

As indicated in equation (6), under diminishing returns, the bracketed term is negative. Thus, the environmental regulation reduced profits \( d\Pi < 0 \) under DRS. Under CRS, \( d\Pi = 0 \). Because firm profits are simply redistributed back to households, the direct burden on society is just re-channeled, it does not disappear. However, the effect on the labor market distortion is different than with the pure \( P^X \) effect. The Marshallian demand function for leisure is a function of the leisure price (after-tax market wage), \( P^X \), and income, \( Y \):

\[
L = L \left[ w(1 - \tau), P^X, Y \right].
\]  

(10)

Assuming the tax rate remains constant, the change in leisure demand can be expressed as a function of the change in the wage, goods price, and income:

\[
dL = L_w(1 - \tau) dw + L_{P^X} dP^X + L_{Y} dY,
\]  

(11)

where the subscript indicates the argument of the derivative. It is generally assumed that leisure’s own price effects \( L_w \) are negative and cross-price effects with consumption \( L_{P^X} \) are positive (leisure and consumption are substitutes). Assuming that leisure is a normal good, its income effect \( L_{Y} \) is also positive. The full contribution of changes in the market for good \( X \) in the leisure/labor decision are illustrated in Figure 1. The leisure demand function is inverted to create the labor supply function \( S_N \). The labor demand function is \( D_N \). First consider the shift in the labor supply function from baseline, \( S_N(P^X_0, Y_0) \), to the farthest away function,
$S_N(P_X^C, Y_0)$. This reflects the shift in response to a price change equal to the full abatement cost increase ($P_X^C = P_X^0 + c_a(a) da$ (i.e., that which is found under CRS). This is tantamount to the TIE identified by Goulder et al. (1999) under the command-and-control instrument. The reduction in equilibrium labor quantity from $N_0$ to $N_C$ generates a TIE measured by the entire gray-shaded area, adeh. Under DRS, however, the price of $X$ rises to $P_D^X$, an increase less than the full abatement cost. Holding income fixed at the baseline level, $Y_0$ the labor supply function shifts only to $S_N(P_D^X, Y_0)$ yielding a smaller TIE (acfh) than under CRS. Then, allowing for the effect of declining profit distributions on household income, assuming that leisure is a normal good, there is a shift back out in the labor supply function to $S_N(P_D^X, Y_D)$. Here the TIE is abgh, which is smaller than the original TIE estimate.

By using the DRS example, we refer to a situation that might not be uncommon in actual industry settings. But we do not mean to imply that TIE estimates based on CRS always overstate costs. If an industry exhibits increasing returns to scale, the results discussed above are reversed and TIES will be larger than under CRS. However, the critical point is that the assumed returns to scale matters. This underscores the importance of taking account of the particular structure of the regulated industry in either performing GE analyses or in making ad hoc cost adjustments to account for TIEs.

### 3.2. TAX INTERACTION EFFECTS OF ENVIRONMENTAL BENEFITS

As discussed above, the TIE literature has, until recently, focused on GE effects that result from real price increases caused by environmental regulation. This section formalizes an argument that is more expansive in that regulatory analysis should include the GE effects of environmental benefits as well. In a setting where agents in the economy have preferences over...
environmental quality, both the consumption of market goods and the demand for and supply of labor will be affected directly by environmental quality. Further, environmental quality can augment the productivity of labor. When one considers these effects, the overall effect on the welfare of the TIE is not clear. Whereas a PE analysis of the costs of environmental regulation is incomplete, as Parry, Goulder, and others argue, bringing in GE concerns while still focusing only on regulatory costs can be misleading from the GE perspective.

This last point is acknowledged in a paper by Williams (2000). In analysis consistent with, but different from, the approach discussed here, he takes into account benefit-side interactions with the tax system. He concludes that the sign of the TIE is ambiguous and hinges critically on the way in which environmental improvement affects labor supply. Two of Williams’ conclusions are particularly relevant. The first is that if environmental improvement enhances labor productivity, then the benefit-side tax interaction works to counterbalance the cost-side interaction and can more than offset it. This point is captured in the stylized model to follow here. Williams’ second conclusion is that if environmental improvement does not improve labor productivity on the job but, instead, reduces workers’ health care expenditures, then the benefit-side interaction is negative, offsetting some of the direct benefits from regulation. The model presented here also introduces the role of complementarity between environmental improvement and market goods.

Consider the welfare analysis of an environmental regulation given benefits-side interaction between environmental regulation and the tax system, both through production and consumer preferences. (More detailed analysis of the model can be found in an earlier version of the current paper, Murray et al. 2002.) In the economy, a representative agent derives utility from consuming an aggregate market good \(X\), hours of leisure \(L\), and environmental quality \(E\). Markets for the consumption good and for labor are competitive. The level of environmental quality is exogenous. It is a public good, both nonrival and nonexcludable.

The production side of the economy is represented by a production function that relates employment of effective labor \(N^*\) and a second input \(Z\) to the production of the market good:

\[
X = f(N^*, Z).
\]

The quantity of effective labor, \(N^*\), is related to the quantity of labor employed, \(N\), and to environmental quality:

\[
N^* = g(N, E).
\]

Environmental quality influences effective labor most directly for those changes in environmental quality that are linked to health status. For example, reducing sick days and increasing the productivity of workers
subject to chronic disease are effects that increase the effective units of labor employed. The function \( g(N, E) \) is increasing in \( E \). The nonlabor input, \( Z \), is perfectly elastically supplied from outside the economy. A representative firm hires labor from within the economy and \( Z \) from without, selling its output to consumers and returning to them all profits.

The environmental issue in the economy is that employment of \( Z \) degrades the environment; that is, there is an inverse relation between \( Z \) and \( E \):

\[
E = h(Z),
\]

where \( h'(Z) < 0 \). The goal of the analysis here is to account, in general equilibrium, for the effects of a regulation that reduces the use of \( Z \). The role of the government in the economy is to tax all forms of income at the proportionate rate \( \tau \) and use the revenue to finance transfer payments in the amount \( G \). The government is assumed to balance its budget, both initially and after any changes brought about by environmental regulation.

In this setting, price-taking consumers face a full budget constraint allocating endogenous labor income plus firm profits and government transfer payments to market good purchases. Due to the tax on income, consumers equate the marginal rate of substitution between \( X \) (the market good) and \( L \) (leisure) to the distorted price ratio:

\[
\text{MRS}_{X_L} \equiv \frac{U_L}{U_X} = \frac{w(l - \tau)}{P_X}.
\]

This first-order condition and the budget constraint give Marshallian demands for \( X \) and \( L \). The supply of labor is the difference between the agent's time endowment and the quantity demanded of leisure.

Finally, the behavior of firms is modeled as the maximization of profits, which is accomplished by setting each factor's value marginal product equal to its market price. But the profit-maximizing conditions for firms do not take into account the two external costs from the employment of \( Z \): increased employment of \( Z \) reduces \( E \), which imposes direct costs on consumers and which reduces the productivity of labor by reducing the number of effective units of labor. Thus, the social value marginal product of the employment of \( Z \) is less than the private value marginal product. This fact is illustrated in Figure 2, where \( Z_0 \) is the privately chosen employment of \( Z \) and \( Z^* \) is the level of \( Z \) corresponding to a PE optimum (i.e., one that does not take into account interaction with preexisting tax distortions.) The Pigovian tax of \( \varphi \) would result in the PE efficient outcome and would result in a net welfare gain of the shaded area by PE accounting.

Now consider the GE effects of imposing a tax on \( Z \). Comparative static results are presented in Murray et al. (2002). A graphic depiction of the effect appears in Figure 3, which displays the equilibrium in the labor market. The initial equilibrium is formed by the initial supply of labor, \( S_N \), the initial value of marginal product of labor, \( \text{VMP}_N \), and the income tax rate, \( \tau \). In
that equilibrium, \( N_0 \) units of labor are employed. The market wage is \( w_0 \). The wage net of income tax is \( w_0 (1 - \tau) \).

Suppose that the tax is levied on \( Z \), the polluting input, and that the proceeds of the tax are returned as a lump sum by increasing \( G \), the government’s transfer payment.\(^{10}\) If there were no production benefit from environmental quality, the polluting-input tax would only shift left the supply of labor, say from \( S_N \) to \( S_N' \), increasing the preexisting distortion in the labor market by \( \tau w \) times the reduction in equilibrium labor employed. This is the TIE discussed in the bulk of the literature. But with an increase in environmental quality brought about by the reduction in \( Z \), the effective labor input is enhanced. This shifts the demand for labor to the right from \( VMP_N \) to \( VMP_N' \), which offsets to some degree the reduction in equilibrium employment of labor. The final equilibrium wage rates, before and after tax, are \( w_1 \) and \( w_1 (1 - \tau) \).

There is another effect in the present model, and implicit in Figure 3, beyond what is captured in a model like Parry’s: by explicitly including environmental quality in the consumer’s utility function, there is the scope for complementarity between environmental quality, \( E \), and the market good, \( X \).\(^{11}\) From the consumer’s perspective, there are then two offsetting effects on the supply of labor: (1) an increase in the equilibrium price of market goods, which induces a shift toward leisure (a leftward shift in the
supply of labor), and (2) an exogenous increase in $E$, which might be complementary with some market goods. If higher levels of environmental quality induce expenditures on complementary market goods then, to some extent, there is a rightward shift in the supply of labor: workers have incentives to work harder to earn the money to spend on goods complementary with environmental quality.\textsuperscript{12} If higher levels of $E$ were complementary with leisure – for example, if additional outdoor recreation became more desirable as air quality improved – then this effect would tend to shift labor supply downward.

Figure 3 focuses on the TIE and not the complete welfare calculation. Further, it is not calibrated with any particular empirical measures of the effects discussed. However, if the VMP\textsubscript{N} and $S\textsubscript{N}$ curves were to shift as drawn, such that the post-pollution-tax quantity of labor were larger than the pre-tax quantity, then the TIE would be a welfare gain equal to the size of the shaded parallelogram. Added on to the PE measure of Figure 2, the TIE would provide an added benefit from the pollution tax. As in Harberger (1964) the sign of the TIE, the extra-market distortion, is entirely dependent on the sign of the change in the quantity of labor.

Once one considers an integrated analysis of the costs and benefits of environmental regulation, it is not clear on which side of the ledger GE welfare accounting falls. To introduce preexisting distortions only while considering the costs of environmental policy is a partial application of GE methodology and can be misleading.\textsuperscript{13}

4. Summary and Directions for Future Research

This paper identifies two significant challenges to the straightforward application of an upward correction to account for TIEs in social cost estimation. The first is that TIE calculations depend critically on the assumed relationship between environmental regulations and changes in the real wages of workers. The model presented in Section 3 shows how the size of theorized efficiency losses depend on how abatement and output markets are modeled and measured. In particular, we have shown that decreasing returns to scale will cause systematically smaller TIEs than the usual constant returns assumption used in CGE models, while increasing returns will cause larger TIEs than in these models. While the assumed direction of returns to scale can push the TIE effect in either direction, some have argued that the assumptions in much of the existing literature tend to increase the estimated size of efficiency losses. We do not resolve that argument here. However, more empirical studies of specific regulations and markets can help to establish just how large these effects are in practice, and how wide the range of estimates is.
The second significant challenge involves the general equilibrium effects of environmental benefits. If the environment is understood as an essential input to economic production, and not simply as a consumption good, then effective environmental regulation can be expected to have important interactions with the tax system that can cause social costs to be lower than those found in PE analyses. A model of how this occurs in specific instances was presented and interpreted in Section 3 and echoes the concerns of Schwartz and Repetto (2000) and Williams (2000). Our model also demonstrates an additional important mechanism: if environmental quality is a complement (substitute) to market goods, then labor supply will be increased (decreased). Further, the consideration of environmental benefits calls into question the sign of other-market corrections to be made to PE measures. There is no presumption that the TIE effect is positive.

We hope that progress in the understanding of environmental economic phenomena will move toward a consideration of economy-wide effects, just as we hope that intertemporal efficiency and ecological service flows (to name just two examples of important phenomena characterized by limited economic knowledge) will be similarly incorporated. Environmental policymakers should fully support these efforts. However, caution should be used in treating interesting, but largely theoretical, results as empirical fact in applying economics to specific policy questions. Empirical estimates of TIEs will be the most useful and reliable for policy analysis when they consider the full range of mechanisms by which regulation interacts with labor-leisure choices. In addition, confidence in the results will be enhanced when TIEs are customized to the specific commodities and industries affected by the policy of interest, thereby taking into consideration the technology and preferences specific to those markets. Taken together, the theory and empirical evidence on TIEs suggests that ad hoc adjustments to partial equilibrium control costs, while presumably better than ignoring these GE effects altogether, should be used and interpreted with caution.

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Notes

1. This is largely true throughout analyses done for the US Environmental Protection Agency, except in (the not infrequent) cases where market behavior is not modeled at all.
In those cases, an estimate of the “engineering” costs of compliance are used as proxies for the social cost. Typically, the engineering cost and PE social cost estimates are of similar magnitude. Therefore, the engineering cost estimates of social cost will also be referred to as “PE” measures for the purposes of this discussion.

2. See the Goulder et al. (1999) paper for more detail on the derivation of equation (1). In this example, their parameter $\theta$ is set to 1.0, indicating the least cost abatement technology is mandated.

3. The linear for $A(a, X)$ means that the abatement cost part of an additional unit of output is constant for all levels of output. One can think of pollution control that is not well represented by this functional form. For instance, many abatement technologies require a large fixed cost or investments in research and development that are independent of the output rate. This could have important effects in the tax-interaction CGE models if the fixed nature of these costs impedes their recovery in the output price (i.e., they are absorbed by producers in the form of reduced rents). The effects of cost distribution between consumers and producers is addressed below.

4. Parry (1997) does indicate in footnote 7 that his model generalizes to upward-sloping supply curves (DRS). Yet the numerical results estimating the relative magnitude of TIE clearly depend on the CRS assumption used to generate them, to the extent that the TIE depends on the size of the price change which, in turn depends on whether CRS or DRS is assumed.

5. If an industry is operating under IRS ($C_{XX} < 0$), then CRS results would be biased in the opposite direction. However, IRS is not sustainable except in rare cases that are unlikely to be broadly applicable in industries facing environmental regulations (e.g., natural monopolies). Therefore, our discussion focuses on CRS and DRS.

6. Williams considers the possibility of DRS in the context of TIEs with trade tariffs (1999) and labor productivity improvements from pollution control (2000). Parry (1999) also considers fixed factors (land) and DRS in the context of agricultural policy. None of these analyses specifically addresses the question about the effect of DRS (versus CRS) on the magnitude of TIE.

7. Somewhat contrary to most depictions in the TIE literature, $D_N$ is illustrated here as sloping downward, exhibiting the potential for diminishing returns to labor and/or final good price feedbacks under labor (output) expansion.

8. In related work, Schwartz and Repetto (2000) discuss the effects of environmental benefits that work through consumers’ preferences for leisure and goods. The development here also represents such utility-based benefits but emphasizes the possible production side effects of environmental regulation.

9. In a representative agent model, transfer payments are hard to motivate. But, following Parry, they are used here to introduce a balanced budget requirement and the reality of distortionary taxation.

10. An alternative assumption would be to adjust the rate of income tax to keep the government budget balanced as in Parry (1997) and Fullerton and Metcalf (2001). By balancing the budget through lump-sum rebates, there is no revenue recycling effect (as referred to by Parry) but there remains a TIE. The assumption of lump-sum rebates of the Z-tax also makes the analysis formally similar to an analysis of a system of pollution quotas in which the quota rights are sold by auction to private firms.

11. Goulder et al. (1997) also model environmental quality in a representative consumer’s utility function, but restrict utility to be strongly separable between environmental quality on the one hand and market goods and leisure on the other. This restricts environmental quality to be a substitute individually with all goods, so complementarity cannot arise (see Deaton and Muellbauer 1980).
12. West and Williams (2002) examine empirically the case of a Pigouvian tax on gasoline and find weak empirical evidence for complementarity between leisure and gasoline. Thus, taxing gasoline reduces leisure and reduces the excess burden of the income tax.

13. A related issue concerns the sequence of market distortions. There are two interventions contemplated in the TIE literature: an income tax and an environmental regulation. The analytical stance is that the income tax is the incumbent policy, which has generated a deadweight loss. The environmental regulation is proposed as an incremental policy. The TIE literature then proceeds to calculate the change in social welfare from the imposition of the regulation, the central point being that the two policies interact and in a negative way.

If one takes the negative interaction as fact, there is an issue as to which policy one charges for the interaction’s cost. One logical possibility, with strikingly different welfare conclusions from the usual TIE approach, is as follows. Suppose that in an initial no-policy state there were an environmental externality and no income tax. If from this state one proposed a Pigovian tax on the externality, the true social gain could be calculated entirely in the taxed market. Even though the increase in the market price of the taxed good would shift the supply of labor, there would be no increment in distortion from the labor market because there is no distortion to begin with.

If one next imposed an income tax, the standard PE calculation of its welfare cost would be complete and accurate as well. Even though the tax shifts demand, and perhaps supply, for the polluting good, there is no divergence between marginal social cost and marginal social benefit in that market because of the correction due to the pollution tax. Thought of this way, there is no TIE because the environmental tax or regulation is being applied to an undistorted economy. The sum of the welfare effects of the income and pollution taxes is independent of the order in which the policies are applied (income effects aside). But, if one analyzes the pair of policies by first considering the income tax and, second, the pollution tax, then the TIE reappears as a necessary adjustment to the cost of the pollution tax. A seemingly unnoticed implication of this order of measurement is that there is an “externality interaction effect” (EIE) due to shifts in the distorted market induced by the income tax. If the TIE is negative, the EIE is positive and roughly the same size. The advice for policy analysts from the TIE literature should, then, not only be that cost–benefit analysis of environmental regulation should be reconsidered and adjusted for extra-market effects, but that so should the excess burden of taxation be recalculated to consider interactions with externality-distorted markets. One might expect that any particular EIE is small in relation to the deadweight loss of an economy-wide tax, but the sum of EIEs might not be.

References


