Environmental Policy in the Presence of an Informal Sector

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Abstract

This paper demonstrates how the presence of an untaxed informal sector can sharply lower the cost of energy tax reforms through an expansion of the tax base. The effect occurs when energy tax revenue is used to lower labor tax rates, which on the margin will draw informal labor into the formal sector. While the energy tax itself is a narrow tax (and interactions with the rest of the tax system increase the distortionary cost even further) the expansion of the formal sector can more than offset the cost of the energy tax. We prove the result in a general framework and then use a simple computable general-equilibrium simulation to investigate its magnitude. Under our central set of parameters the cost of environmental tax reform is reduced by 68% in the U.S., implying an optimal tax well above the Pigouvian level. This result is even stronger at levels of informal production typical in developing economies.
1 Introduction

The size of the tax base plays a central role in the debate over environmental taxes in modern tax systems. Environmental economists have broadly supported environmental taxes or tradable permits as market-based mechanisms to internalize environmental externalities such as pollution. The revenue-raising potential of these taxes has also been emphasized, though the relatively narrow base on which energy taxes fall can make them costly sources of revenue. We investigate how these tax base effects enter, and in particular extend previous work to allow an informal sector in production.

The prior literature on energy tax reform generally separates the welfare effects into two parts: a “first” dividend from correcting an environmental externality, and a second or “double” dividend from using the revenue raised to offset other taxes. The swapping of environmental taxes for taxes on other goods has therefore offered policy makers the tantalizing prospect of two sources of welfare improvement simultaneously. However, a series of papers (Bovenberg and de Mooij 1994, Goulder 1995, and Bovenberg 1999) shows that the welfare benefits resulting from the broad-based tax cut are outweighed by the new distortion resulting from the narrowly based tax increase. This finding relates closely to work by public finance economists on optimal taxes and we draw heavily from each of these literatures in our results here.

We begin by observing that even the broadest taxes in any economy fail to cover a collection of sectors collectively labeled the “informal economy.” These sectors escape government scrutiny for a range of reasons: The activity may be illegal, as in the case of certain narcotics, or it may be too costly to track, as in the case of migrant labor or very disperse activities. The informal sectors compose a substantial portion of all modern economies. Using a variety
of measurement methods, Schneider (2011) reports that the informal economy was 8.4% of GDP in the U.S. and averaged 16.1% of GDP in 21 OECD countries in 2004. Even larger values are reported in developing economies, with 30.4% of GDP in Asia and 43.2% of GDP in Africa categorized as informal.

Our contribution investigates the interaction between this informal activity and energy taxes. In particular, and contrary to previous work, we show that an energy tax can actually broaden the tax base via changes in the size of the informal sector. Our paper is most closely related in the literature to Pigott and Whalley (2001). Pigott and Whalley overturn conventional prescriptions recommending broad-based taxes by showing how certain tax reforms fail to account for the role of the informal sector. They argue that when the tax base is extended to include services the resulting higher prices in the formal sector create additional demand for informal production. Therefore a tax reform meant to broaden the tax base instead narrows it by causing substitution into untaxed sectors.

We show, using very similar logic, that the reverse holds in the case of energy taxes: the narrowing pointed out by Pigott and Whalley runs the opposite direction under a very simple set of assumptions about energy input shares in the economy. As long as energy taxes fall more heavily on formal manufactured goods than on services the tax cuts associated with the reform will draw a larger share of the service sector into the formal economy. In spite of the apparent narrowness of the energy tax, it actually serves to broaden the total base over which taxes are collected. In the context of the environmental economics literature and the double dividend, this creates two sets of welfare benefits: it enhances environmental quality and improves the efficiency of the tax system at its core by expanding the tax base.

Our result is in contrast to earlier work on the double dividend in that we do not begin in
a setting with uneven or inefficient tax collection over the existing tax base. (The literature identifies a number of important inefficiencies of this type, including the use of taxes to favor certain classes of consumption in Parry and Bento (2000), the failure to fully tax fixed factors in Bento and Jacobsen (2007), and the existence of costly, uneven tax evasion in Liu (2011).) Instead of correcting inefficient use of the existing tax base, we consider ways that an energy tax can change the size of the taxable part of the economy overall. The welfare improvement available here requires the ability of a relatively narrow tax on energy to increase total demand in the formal parts of the economy through substitution in consumption.

We first offer an analytical proof in a general model and then impose specific functional forms in a set of simulations to test the magnitude of the effect. Our simulation model mirrors the analytical setup but allows calibration of energy shares and sector sizes to the U.S. economy. The distortionary cost of an energy tax is reduced by 68% when considering the existence of an informal sector that is only 8.4% of the overall economy. In settings with larger informal sectors the effect grows even stronger, completely offsetting the welfare cost (offering a strong form of the double dividend) in many developing economies.

Section 2 provides our general analytical model and derivations relating the energy tax to the size of the tax base. We describe the simulation model calibration and results in Section 3 and conclude in Section 4.

2 A Model of the Informal Sector

Pigott and Whalley (2001) introduce a model to capture substitution between the formal and informal sectors of an economy. We follow their three-good formulation throughout,
considering manufactured goods \( G \), market-traded services \( S^M \), and non-market services \( S^N \). They show that a revenue-neutral tax reform to expand the tax base from only \( G \) to include both \( G \) and \( S^M \) can actually narrow the tax base and worsen welfare as a result of substitution across the formal and informal sectors.

Our model introduces an energy input to the manufacturing sector and provides a simple illustration of the contrapositive of Pigott and Whalley’s result. Initially, a labor tax in our model falls both on \( G \) and \( S^M \). We impose a narrow environmental tax that falls only on \( G \) (via the energy input) and use the revenue to reduce the labor tax. The reduction of tax on \( S^M \) in particular causes substitution from \( S^N \) to \( S^M \), increasing the size of the tax base and improving welfare.

2.1 Model Structure

2.1.1 Firms

There are four kinds of firms: one producing energy \( E \), one producing manufactured goods \( G \), one producing market-traded services \( S^M \) and one producing non-market services \( S^N \).

Energy firms are part of the formal sector and create damages as a result of pollution in the amount \( \phi(E) \). Labor is the only underlying factor of production and production is constant returns to scale:

\[
E = L_E
\]  

Energy firms are taxed in two ways. First, they must pay labor taxes on the labor used \( \tau_L \). They must also pay an environmental tax proportional to production \( \tau_E \). Workers receive
an after tax wage normalized to 1, pre-tax wages are $1 + \tau_L$. Hence, the price of energy is:

$$p_E = 1 + \tau_L + \tau_E \quad (2)$$

Firms which produce manufactured goods $G$ use labor $L_g$ and energy $E_g$ as inputs. Production is increasing in inputs and constant returns to scale:

$$G = G(L_g, E_g)$$

Defining energy intensity at the optimal mix of energy and labor as $I_g$ we have:

$$E_g = I_g G$$

$$L_g = (1 - I_g) G$$

Energy intensity is a function of the prices of labor and energy: $I_g(\tau_L, \tau_E)$ making the price of $G$:

$$p_G = 1 + \tau_L + I_g \tau_E \quad (3)$$

Firms which produce formal sector services $S^M$ produce using only labor and again have constant returns to scale:

$$S^M = L_M$$
The price of formal sector services is:

\[ p_{SM} = 1 + \tau_L \]  \hspace{1cm} (4)

Finally, we have production of informal sector services \( S^N \). This again uses only labor, but we will now assume rising marginal costs of production and consequently an upward sloping supply curve. Early informal sector firms are efficient and can produce cheaply but as they proliferate it becomes more difficult to escape attention, resulting in rising marginal costs. We assume informal sector production follows:

\[ S^N = (L_N)^{\theta_L} \]  \hspace{1cm} (5)

where \( \theta_L \) is between 0 and 1 and controls the degree to which marginal cost rises as production increases.

We assume that formal sector services \( S^M \) and informal sector services \( S^N \) are perfect substitutes in consumption following Pigott and Whalley.\(^1\) Hence, informal sector firms will produce along their supply curve until marginal cost (and therefore price) equals that in the formal sector:

\[ p_{SN} = 1 + \tau_L \]  \hspace{1cm} (6)

As a result of rising marginal cost informal firms accumulate rents on inframarginal production.\(^2\) We assume these accrue to the representative household. If informal firms

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\(^1\)Keen (2008) uses a similar model.
\(^2\)We include the equation for completeness, but note that the rents will not influence welfare consequences at the margin.
have a marginal cost of labor given by the function \( MC(L) \), the rents are in the amount of:

\[
\pi_{SN} = \int_0^{MC^{-1}(p_{SN})} [p_{SN} - MC(L)] dL
\]  

(7)

### 2.1.2 Households

The representative consumer enjoys utility from manufactured goods \( G \), service goods \( S \), and leisure \( l \). Service goods are a combination of market-traded services and non-market, informal services:

\[
S = S^M + S^N
\]  

(8)

Leisure is equal to the consumer time endowment \( \bar{L} \) less the labor supply \( L \). Emissions from using energy \( E \) cause environmental damages in the form of reduced consumer utility. The household utility function is given by:

\[
U = u(G, S, \bar{L} - L) - \phi(E)
\]  

(9)

\( u(.) \) is the utility from non-environmental goods and is quasi-concave. \( \phi(.) \) is the disutility from emissions and is weakly convex. The separability restriction in (9) implies that the demands for \( G, S, \) and labor supply do not vary with changes in \( E \). In turn, emissions are generated by the energy inputs used in the production of these goods.

The individual budget constraint is:

\[
p_G G + p_S S = L + h + \pi
\]  

(10)
where $h$ is a per-household lump-sum government transfer and $\pi$ are the rents from the informal sector, also accumulating to households.

### 2.1.3 Government

The government collects taxes on formal sector labor supply and on energy taxes, when levied.

$$hN = \tau_L (L - L_N) + \tau_E E$$  \hfill (11)

where $N$ is the number of households in the economy.

### 2.2 Welfare Analysis

Using equations 9 and 10, we see that our household optimization problem is given by:

$$W = u(G, S, \bar{L} - L) - \phi(E) - \lambda[p_G G + p_S S - L - h - \pi]$$  \hfill (12)

Totally differentiating this equation with respect to $\tau_E$ and substituting in the envelope conditions yields the equation:

$$\frac{1}{\lambda} \frac{dW}{d\tau_E} = -\frac{1}{\lambda} \phi(E) - \frac{dp_G}{d\tau_E} G - \frac{dp_S}{d\tau_E} S + \frac{d\pi}{d\tau_E}$$  \hfill (13)

Our proposed tax reform involves the revenue neutral substitution of energy taxes for labor taxes. Totally differentiating equation 11 with respect to $\tau_E$ yields:

$$\frac{dhN}{d\tau_E} = \tau_L \frac{d(L - L_N)}{d\tau_E} + \tau_L \frac{d(L - L_N)}{d\tau_E} + E_g + \tau_E \frac{dE_g}{d\tau_E} = 0$$  \hfill (14)
We know that \( \frac{dG}{d\tau_E} = \frac{d\tau_L}{d\tau_E} \) and \( \frac{dSM}{d\tau_E} = \frac{d\tau_L}{d\tau_E} \) from equations 3 and 4.

We re-state profits, from equation 7, as \( \pi = \int_0^{p_{SN}} L_N(\tau) \, d\tau \), where \( L_N(\tau) \) is the demand for informal labor as a function of the labor tax rate. Since \( p_{SN} = 1 + \tau_L \), this implies:

\[
\frac{d\pi}{d\tau_E} = L_N \frac{d\tau_L}{d\tau_E}
\]  

(15)

Plugging in each of these parts, we can simplify equation 13 to:

\[
\frac{1}{\lambda} \frac{dW}{d\tau_E} = \left[ -\tau_E I_g \left( -\frac{dG}{d\tau_E} \right) - \frac{1}{\lambda} \phi'(E) \right] + \left[ \tau_L \frac{d(L - L_N)}{d\tau_E} \right]
\]

(16)

**Term 1** The first term in square brackets identifies the distortionary cost of the policy in the final goods markets balanced against the gain in utility from environmental quality improvements. The first part of the term is the tax distortion introduced directly in the manufacturing sector \( G \). The second part of the term describes benefits in utility accruing from the change in environmental quality via \( \phi \). The net effect is identical to the prior literature (e.g. Bento and Jacobsen 2007, Parry and Bento 2000) and is sometimes referred to as the “first” or “environmental” dividend from the policy.

**Term 2** The second bracketed term in (16) is the combined revenue recycling effect and tax interaction effect, which as decomposed here comprise the core argument of our paper.

In prior work, where all production occurs formally, this term incorporates the entire labor supply \( L \) in the numerator. Goulder (1995) and other authors show conclusively in their models that the effect on \( L \) is negative due to interactions between the energy tax and a pre-existing labor tax.
In contrast, our model yields an effect that includes in the numerator only the portion of labor supply that is taxable: $L - L_N$. When labor supply moves out of the informal sector the untaxed labor $L_N$ will shrink, at least partially offsetting the decrease in overall labor supply $L$.

In sum, the presence of an informal sector makes the second bracketed term less negative indicating smaller welfare losses:

**Proof:**

\[
\pi_{SN} = p_{SN}S^N - p_{LN}L_N \\
= L_N^{\theta_L} - (1 - \tau_L)L_N \\
\frac{d\pi_{SN}}{dL_N} = \theta_L L_N^{\theta_L - 1} - (1 - \tau_L) = 0 \\
L_N^{1-\theta_L} = \frac{\theta_L}{1 - \tau_L} \\
\frac{d\left(L_N^{1-\theta_L}\right)}{d\tau_E} = \frac{\theta_L}{(1 - \tau_L)^2} \frac{d\tau_L}{d\tau_E}
\]

Since the first part of the right-hand side of the last line is positive, and the second part is negative, the informal labor supply $L_N$ shrinks with the energy tax swap. Intuitively, the environmental tax has been levied on the manufacturing sector which has relatively few informal substitutes. The revenue is used to lower the labor tax, which lowers the tax rate on the formal services sector. In turn, labor shifts away from the informal sector creating a beneficial effect as the tax base is broadened.
3 Simulation

In this section we conduct a simple simulation to demonstrate the magnitude of tax-induced base broadening under a variety of settings. The version of the simulation here replicates our analytical model exactly, continuing to abstract from energy consumption in the services sector and the use of informal energy sources. We are currently extending the simulation to include both of these factors, and also to consider alternative elasticities more typical of developing regions.

3.1 Households

For the numerical simulation we employ a nested constant elasticity of substitution (CES) functional form for utility:

\[ U = \left( \alpha_{UG} C^{\frac{\sigma_U}{\sigma_U-1}} + \alpha_{Ul} l^{\frac{\sigma_U}{\sigma_U-1}} \right)^{\frac{\sigma_U}{\sigma_U-1}} \]  

(17)

\[ C = \left( \alpha_{GG} G^{\frac{\sigma_G}{\sigma_C}} + \alpha_{GS} S^{\frac{\sigma_G}{\sigma_C}} \right)^{\frac{\sigma_C}{\sigma_C-1}} \]  

(18)

where \( l \) is leisure and \( C \) is the utility derived from consuming goods. \( G \) represents the manufactured good and \( S \) services. \( \sigma_U, \sigma_C, \alpha_{UG}, \) and \( \alpha_{CG} \) are calibrated and control the substitution elasticities and sizes of the various sectors.

Market-traded services \( (S^M) \) and informal sector services \( (S^N) \) are perfect substitutes:

\[ S = S^M + S^N \]  

(19)
The household budget constraint is:

\[ p_G G + p_S S = L + h + \pi \]  

(20)

where \( p_i \) is the price of good \( i \), \( L \) is the hours worked at an after-tax wage normalized to 1, \( h \) is the per-household government transfer, and \( \pi \) are rents from the upward-sloping supply of informal goods. Since \( S^N \) and \( S^M \) are perfect substitutes, the price of each is \( p_S \).

### 3.2 Firms

There are four types of firms: one producing energy (\( E \)), one producing manufactured goods (\( G \)), one producing formal sector services (\( S^M \)), and one producing informal sector services (\( S^N \)).

Production is given by:

\[ E = L_E \]  

(21)

\[ G = \gamma_G \left( \alpha_{LG}^{1/\sigma_G} L_G^{\sigma_G-1} + \alpha_{EG}^{1/\sigma_G} E_G^{\sigma_G-1} \right)^{\sigma_G/\sigma_G-1} \]  

(22)

\[ S^M = L_M \]  

(23)

\[ S^N = \gamma_N (L_N)^{\theta_L} \]  

(24)

Only manufactured goods \( G \) use energy and we again use a calibrated CES function. According to BEA input-output tables of the U.S. in 2002, industrial sectors\(^3\) have an energy intensity, as measured by use of electricity and natural gas divided by total output value,\(^3\)

\(^3\)For the purposes of this paper’s energy intensity calculation, the industrial sectors include mining, construction, and manufacturing, and exclude utilities. The services sector includes agriculture and services.
of 1.55%. Service sectors have an energy intensity of 0.87%, making them roughly half as energy intensive as industrial production. In an extension, we increase the realism of the simulation by calibrating to both of these values explicitly.

\[ \sigma_G, \alpha_{LG}, \text{ and } \alpha_{EG} \] govern input shares and elasticity in production of \( G \). \( L_E, L_G, L_M, \) and \( L_N \) comprise total labor supply:

\[ L = L_E + L_G + L_M + L_N \] (25)

### 3.2.1 Informal Firms

The parameters \( \gamma_N \) and \( \theta_L \) control the relationship between informal sector labor \( L_N \) and informal sector production \( S^N \). As in the analytical model, informal sector services are produced with increasing marginal cost implying that \( \theta_L < 1 \). Informal services are therefore produced up to the point where their marginal cost equals that of formal sector services. Formal sector services meet remaining demand.

The upward sloping supply curve in the informal sector results in inframarginal rents that accrue back to the household:

\[ \pi_N = p_S S^N - L_N \] (26)

### 3.2.2 Government

The government receives taxes from labor and from the pollution tax when levied. It transfers all funds received back to households in a lump-sum fashion. The tax reform we consider holds the size of government transfers fixed, recycling revenue from the energy tax to lower
the labor tax:

\[ \tau_L L + \tau_E E = H = hN \] (27)

Here, \( \tau_L \) and \( \tau_E \) are the tax rates on labor and energy, respectively. \( H \) is all government revenues, \( h \) are per-household transfers, and \( N \) is the number of households.

### 3.3 Model Solution

When an emissions target is chosen, the government holds \( H \) fixed and adjusts the emissions tax and the labor tax until emissions levels are brought down to their target. The numerical model is solved by setting taxes and prices such that consumers make decisions about leisure and goods purchases, the government budget balances, and the factor market for labor clears. Government transfers are held constant in real terms.

### 3.4 Model Calibration

The baseline for these simulations is a very simplified version of the U.S. economy with just three sectors (manufactured goods, formal services, and informal services) and taxes on labor and energy inputs.

The most important choices in calibration are the two parameters that govern production in the informal sector and elasticities between formal and informal production.\(^4\) For the first of these, the baseline size of the informal sector, we follow Schneider (2005) who estimates this figure at 8.4% for the U.S. economy. We vary this value between zero and 20% in

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\(^4\)Using the size of the informal sector and the parameter \( \theta_L \), the quantities \( L_N \) and \( \gamma_N \) are calibrated using two equations: equation 24 governing production, and the first-order profit-maximizing condition of informal sector services firms.
alternative simulations.

The second parameter, \(\theta_L\), governs the elasticity in production between formal and informal sources. In our central case we again follow Pigott and Whalley using a baseline specification of \(\theta_L = 0.4\), corresponding to an elasticity between the tax rate and the size of the informal sector of about 0.2. By contrast, Peter (2009) uses a global panel of tax rates and informal sector activity and estimates a much larger elasticity of between 0.7 and 0.9. This implies that our estimate of the welfare gain from changes in the informal sector is quite conservative. We again employ a variety of sensitivity analyses, with our most elastic case \((\theta_L = 0.67)\) being closest to the Peter (2009) result.

Finally, the baseline size of the polluting sector is 2.7% of the economy, consistent with the size of the energy sector according to BEA statistics. The elasticities of substitution \(\sigma_U\) and \(\sigma_G\) are set at \(\sigma_U = 0.9\) and \(\sigma_G = 1.01\), implying close to average substitution and similar to prior work. We assume a benchmark labor tax of \(\tau_L = 0.4\), also following the previous literature (for example Bento and Jacobsen [2007]). Following these baseline tax and substitution rates makes the magnitude of our welfare estimates here more easily comparable with the literature. A full sensitivity analysis (in progress) reports the influence of these additional parameters.

### 3.5 Simulation Results

#### 3.5.1 Central Case

Prior policy analysis has neglected the impact of the informal sector in calculating the cost of “double dividend” energy tax reform. To provide an initial baseline consistent with earlier work we first set the size of the informal sector to zero and simulate a revenue-neutral
environmental tax reform that cuts production of the dirty good by 10%, recycling revenue back to the labor tax. The welfare cost in the absence of an informal sector is 0.021% of GDP, providing a benchmark against which to compare the (smaller) costs of policy that we demonstrate in the presence of an informal sector.

Our central case simulates the same environmental policy, but now in the presence of an informal sector comprising 8.4% of GDP. The environmental tax revenue under this policy affords a small cut in the labor tax rate from 40% to 39.6%. This in turn makes formal sector services cheaper relative to informal sector services, causing substitution away from informal production. The induced reduction in the informal sector is 0.19%; the informal labor supply shrinks by 0.48%. The welfare cost of the tax reform is now just 0.007% of GDP: a reduction in cost of 68% relative to the baseline. Even when the informal sector is a relatively small part of the economy (as in the U.S.) the costs of policy decline dramatically.

3.5.2 Robustness Checks

Figure 1 exhibits the degree of switching to the formal sector under a wide variety of parameter assumptions. Each point of each line on this graph represents the result of a separate simulation. As before, simulations are the result of a 10% cut in emissions where the revenue is recycled to hold the real size of government to be constant. Labor tax rates are cut during the course of reform. As a result, the tax advantage of informal production declines slightly and there is a shift of labor into the formal sector (shown on the vertical axis). This movement further expands the tax base, allowing even greater labor tax cuts. The extent to which informal labor moves into the formal sector is governed by $\theta_L$ in (24); we allow this parameter to vary between 0.33 and 0.67 creating the four different lines on the graph.
Greater elasticity (larger $\theta_L$) corresponds to more rapid movement of labor across sectors.

Figure 2 translates this expansion of the tax base into effects on welfare. In short, the more labor is transferred from the informal sector to the formal sector, the greater the welfare improvement (or smaller the cost) of the energy tax reform. Moving along the $\theta_L = 0.4$ line from zero to 8.4% informal production graphically illustrates the 68% reduction in welfare cost we find in our central case. As the informal sector grows even larger, or for more elastic values of $\theta_L$, the distortionary cost of the energy tax is fully offset, implying real welfare gains as a result of the reform.

4 Conclusions

We argue that energy tax reform, when used to reduce pre-existing labor taxes, has the benefit of inducing substitution into the formal sector. This broadens the tax base and reduces the welfare cost of an energy tax, the contrapositive of the result demonstrated in Pigott and Whalley’s (2001) work. We first demonstrate the unambiguous direction of our result in a general analytical model, then employ a calibrated simulation to investigate the magnitude of the effect in a stylized version of the U.S. economy. It turns out to be quite large, reducing by 68% the distortionary cost of an energy tax. In the broader context of environmental policy, this suggests an optimal tax on energy that lies well above the Pigouvian level.

Future work will extend the model to allow differential rates of energy use across sectors of production, and calibrate to developing economies where we expect the effect to be even greater in magnitude. Greater detail on substitution rates across sectors, and on the compo-
sition of informal production in particular, would allow even more detailed simulations that could feed directly into tax policy.

References


Figure 1: Tax-Induced Substitution Into the Formal Sector
Figure 2: Welfare Impact of a 10% Tax Reform as the Size of the Shadow Economy Varies