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Integrating environmental taxes on local air pollutants with fiscal reform in Hungary: Simulations with a computable general equilibrium model

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ABSTRACT This paper describes the Fiscal Environmental Integration Model (FEIM) and its use to examine the merits of introducing a set of air pollutant emission taxes and stringent abatement requirements based on best commonly available control technology. These environmental protection strategies are examined both independently and in combination. In addition, Hungary has very high VAT, employment, and income tax rates and therefore might receive more than the usual advantage from using environmental tax revenues to reduce other taxes. We therefore also examine the economic and environmental implications of different uses of the revenues generated by the air pollutant emission taxes. FEIM is a CGE model of the Hungarian economy that includes sectoral air pollution control costs functions and execution options that allow examination of the key policy choices involved. We developed and ran a baseline and seven scenarios with FEIM. The scenarios centered on introduction of environmental load fees (ELF) on emissions of SO_2, NO_x, and particulates and emission abatement requirements (EAR) for these pollutants.

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This paper was prepared as part of a broader effort to develop analytical tools for examination of the interrelationships between fiscal and environmental policy. Contributors to this effort include Dr. Tihamér Tajthy, Dr. Péter Kaderják, Mr. András Kis and Ms. Éva Tar.

The EARs were based on the technically best commonly available process and end-of-pipe controls. We also examined several possibilities for 'recycling' the revenue from the ELF to test for a possible 'double dividend'.

We did not find a 'double dividend' – a combination of both net fiscal and environmental benefits – but use of ELF revenue to reduce existing tax distortions reduced the cost of reducing air pollutants by 66 per cent relative to a lump sum rebate to households. While the ELF reduced air pollution significantly, the EAR policy produced dramatic reductions in emission of pollutants from point source combustion: nearly 80 per cent for SO_2 and particulates. These reductions were achieved at quite a greater cost relative to the ELF: a five-fold reduction in emissions entailing over a 40 fold increase in costs. Combining EAR with ELF did little to reduce the ratio of the cost increase to the emission reductions. In one instance, with revenue recycling, it actually increased the ratio due to interaction effects. We compared these costs with a broad range of rough benefit estimates for emission reductions in Hungary and found that the ELF policy produced net benefits over the entire range. Scenarios with EAR resulted in costs substantially in excess of benefits when benefits were at the low end of the benefit range considered.

1. Introduction

Hungary has a developing, transition economy but one still characterized by high taxes on employment and incomes and a large government sector. It is also a country where, despite some improvements in environmental quality, due to the recent decline of the primary metals and heavy machinery industries, environmental protection investment is usually modest. In this paper we examine environmental protection policies that are under serious consideration in Hungary, estimate their impact on key economic and environmental indicators, and compare their merits on the basis of cost effectiveness and, initially, economic efficiency.

A key policy combination examined is the coordinated introduction of environmental taxes and use of the resulting tax revenues to support 'revenue neutral' reductions in existing tax rates. Many economists and policy makers have been intrigued over the last several years by the possibility that such applications of environmental taxes could even provide a 'double dividend'.[1] More modestly, such policies may allow attainment of

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[1] The term 'double dividend' refers to the notion that, aside from the benefits of improved environmental quality (the 'first' dividend), net benefits will derive from a reduction in the non-environment-related economic distortions when environmental tax revenues allow reductions in other taxes (the 'second' or 'fiscal' dividend). This second dividend may prove especially important for policy makers since it would obviate the need for more precise estimation of notoriously difficult-to-measure environmental benefits. The 'fiscal' dividend alone would justify the policy of environmental taxation and the environmental benefits, whatever their magnitude, would be 'gravy'. The conditions for, and likelihood of, a 'fiscal dividend' has spawned an extended discussion in the economics literature, cf. Terkla (1984)d, Pearce (1991), Repetto *et al*. (1992), Oates (1993), Bovenberg and de Mooij (1994), Goulder (1994), Parry (1995), Jaeger (1995), Bovenberg and Goulder (1996), FitzRoy (1996), and Fullerton and Metcalf (1996). We interpret this research as concluding that the conditions necessary for a 'fiscal' dividend are very unlikely to be met in most cases of such tax substitution but that initial conditions for such a result, e.g., large differences in marginal tax rates on different factors of production, are more likely to arise in transition economies than in developed, market economies.

very valuable improvements in environmental quality at very low or little cost. In either case, it is worth examining what the impact of policy designs involving environmental taxes in combination with commitments to use the tax revenues in different ways is likely to be, especially in a transition economy such as Hungary's.

In order to examine the prospects for such integrated polices, we developed the Fiscal Environmental Integration Model (FEIM). In this paper we summarize the basic structure and data of the model and develop applications of FEIM that examine the economic and environmental impacts of introducing emission taxes on SO_2, NO_x, and particulates in combination with various other changes to the tax system and with other environmental regulations. The Government of Hungary is seriously considering both such emission taxes, referred to as environmental load fees (ELF), as well as various general tax reforms and emission abatement requirements (EAR) based on the best commonly available control technologies. A principle objective of this work is to explore the implications of integrated environmental and tax policies given the ELF proposals for taxing air emissions and to provide results that are useful in informing debate on the merits of alternative policy combinations for improving air quality in Hungary and, perhaps, in transition economies generally.

2. Model description

2.1 Background

In structuring FEIM, we have tried to reflect not only the general analytic issues of environmental taxation, but the distinctive features of the Hungarian economy that may produce results substantially different from those derived in other contexts.

The model reflects our belief that most of the Hungarian labor market is very wage inelastic.

Most other western studies have focused attention on carbon dioxide or energy taxes but a broad array of emission taxes has a long history in Hungary and recent Hungarian environmental legislation directs the government to impose emission taxes at levels that are sufficiently high to promote emission reductions.

Hungary is a small, open economy: trade impacts are more important here than in the US or the larger countries of western Europe. While we do not expressly examine trade impacts in this paper, FEIM does include detailed and responsive trade characterizations.

Hungary has extraordinarily high rates of both direct and indirect taxation: VAT of 25 per cent on most goods and employment tax on gross wages of over 50 per cent.

In the course of discussing FEIM below we try to point out issues and potential problems arising from both the current structure and parameter estimates. In some cases we describe means for possible improvements in future versions of the model; in other cases merely identify the issue. We do this to insure that, in the policy analyses that follow, the reader maintains an awareness of the limitations and legitimate concerns regarding our representation of policy alternatives and economic relationships with FEIM.

2.2 General model description

In order to evaluate ELFs on emission of air pollutants in combination with other tax and environmental policy initiatives, we felt we needed a fairly broad characterization of the Hungarian economy. We accordingly structured FEIM as a CGE model and drew extensively on existing CGE models and databases of the Hungarian economy (Zalai, 1982; Zalai, 1984; Zalai and Révész, 1991; Zalai *et al.*, 1995; Zalai, 1998).[2]

FEIM distinguishes among 26 industrial sectors, two primary factors (capital and labor), and three agent classes (government, the rest of the world (ROW), and households). The household agent class is comprised of ten representative household types. The industrial sectors and household types are listed in table 1.

The baseline economic activity levels of FEIM are for 1994 and the monetary unit is the 1994 Hungarian Forint (HUF).[3] Since the most recent input–output table for Hungary is for 1991, we used activity levels for 1994 and macrostatistics on value added and total output to adjust the input–output coefficients to 1994 using the RAS allocation method. Income distribution was updated to 1994 using a combination of available 1994 income data and proportions from 1991.[4]

Consumers are characterized as minimizing the cost of achieving any utility level as represented by an extended linear expenditure system (ELES) with Stone–Geary distinctions between fixed or essential consumption and discretionary or variable consumption. These distinctions are also used to represent assumptions about the degree to which final demand markets are price sensitive for the ten groups of Hungarian households.

Trade occurs with two types of rest-of-world trading partners: ‘western’ partners and ‘eastern’ partners. The model allows for different characterizations of the economic relationship depending on the source of imports or the destination of exports. In general, western and Hungarian goods are assumed to be imperfect substitutes (an ‘Armington’ specification) whereas eastern commodities are assumed to be perfect substitutes for Hungarian–western composite commodities. The model, however, introduces certain qualifications for eastern trade, allowing for additional friction in response to relative price changes.

The FEIM model has a well-developed characterization of government as a tax and transfer agent. Government collects taxes on incomes, products, employment, and trade, and distributes these revenues in the form of subsidies for social benefits (cash and in-kind or ear-marked benefits for households are distinguished), public consumption, and public investment as well as other transfers.

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[2] FEIM has its origins in an evolving model structure and data set that, in its most recent incarnation, has been referred to as HUMUS and is described most recently by Zalai (1998). The HUMUS model has a ‘monetary’ module but this module is not used in FEIM. Other modifications to HUMUS are implicit in the description of FEIM that follows.

[3] In 1994 the HUF-US dollar exchange rate was approximately 135 HUF per dollar.

[4] In most cases we were able to generate completely detailed estimates of activity levels and exchanges for 1994. An exception to this was the necessity of lumping together loans and other transfers provided by the state to industrial sectors.

Table 1. *Economic sectors and household types in FEIM*

No.	*Sectors' name in the 26 sector break-down*
1	coal mining
2	oil and gas extraction
3	electricity generation
4	oil refinery
5	gas production, distribution
6	other mining
7	black metallurgy
8	non-ferrous metallurgy
9	machinery
10	building materials
11	fertilizer production
12	organic and inorganic chemicals
13	manufacture of other chemicals
14	light and other industry
15	food industry
16	construction
17	forestry and agriculture
18	transportation
19	post and telecommunications
20	trade
21	water
22	other material activities
23	banks, etc.
24	personal services
25	social, cultural services, and insurance
26	public sector, community services, and research
27	residential (agent):
	ALL HOUSEHOLDS
	(A) ACTIVE
1.	rural, no children
2.	rural, children, high income
3.	rural, children, low income
4.	urban, no children
5.	urban, children, high income
6.	urban, children, low income
	(B) INACTIVE
7.	rural, high income
8.	rural, low income
9.	urban, high income
10.	urban, low income

The FEIM model is fundamentally and intentionally 'underidentified'; the modeler must specify a set of 'surplus' equations and/or variables exogenously in order for a market clearing solution to be computed. This design permits user selection of a wide variety of market or institutional 'closure' specifications. In the following section we describe in more detail

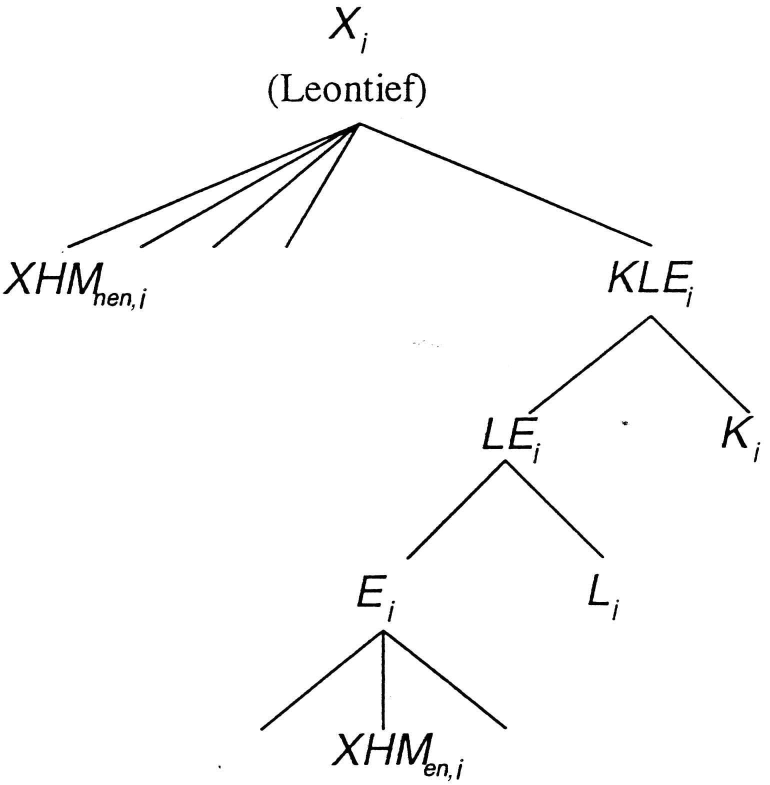

Figure 1 *Nested production design of FEIM*

the way in we have shaped FEIM to analyze policies with both fiscal and environmental components.

2.3 Specific features of FEIM

2.3.1 Production decisions

The sectoral production functions are multi-stage nested CES functions of the intermediate energy inputs, labor, and capital of the sort found in Hille, *et al.* (1993), van der Mensbrugghe (1994), and Capros, *et al.* (1995). Supporting a Leontief structure at the final or upper 'stage' as shown in figure 1, the *N* intermediate inputs entering into domestic production of sectoral commodity X_i, are sub-divided into energy inputs $XHM_{en,\,j}$ and non-energy inputs $XHM_{nen\,j.}$ Beginning from the bottom of Figure 1, energy sectors produce composite energy inputs in each sector according to a CES class production function. The composite energy input combines with labor to form a composite labor–energy input, *LE*, with a constant elasticity of substitution. Similarly, capital, *K*, is combined with *LE* to produce *KLE* assuming again a CES function. This latter composite is then used, in combination with the non-energy material inputs via a Leontief form to produce the domestic output X_j.

Producers are assumed to minimize their cost at any level of production, X_j, and input prices, $PHM_{i,o}$, PL_j, PK_j.[5] To be specific, on the top level of the sectoral production function we have a Leontief type function of the following form

$$X_j = \min\left\{\left(\frac{XHM_{nen1,j}}{AHM_{nen1,j}}\right),\left(\frac{XHM_{nen2,j}}{AHM_{nen2,j}}\right),\ldots,KLE_j\right\} \tag{1}$$

where $AHM_{nen\,k,j}$ is the input–output coefficient of non-energy product k in the production of X_j. The volume of the composite resource KLE is set during calibration in such a way that its level is equal to the level of production. The corresponding cost expression to be minimized at this level of the nested production function is

$$\left(\sum_{i\in nen} PHM_{i,o} \cdot XHM_{i,j}\right) + PKLE_j \cdot KLE_j \tag{2}$$

Solving this constrained optimization yields the following minimum unit cost, UC and demand functions for non-energy intermediate products, XHM and the composite resource KLE

$$UC_j = \left(\sum_{nen} PHM_{nen,o} \cdot AHM_{nen,j}\right) + PKLE_j \cdot KLE_j / X_j \tag{3}$$

$$XHM_{nen,j} = AHM_{nen,j} \cdot X_j \tag{4}$$

$$KLE_{\mathrm{j}} = X_j \tag{5}$$

These latter three equations (equations (3)–(5) are the forms actually used in the model.

The other production equations reflect cost minimization subject to CES production functions of the sort illustrated by equation (6) where composite input KLE is produced by the labor–energy composite (LE) and capital (K) with CES parameter $-\beta_j$

$$\mathrm{KLE}_j = \left(\mathrm{ALE}_j \cdot \mathrm{LE}_j^{-\beta j} + \mathrm{AK}_j \cdot \left(\frac{\mathrm{K}_j}{\mathrm{RK}_j}\right)^{-\beta j}\right)^{-1/\beta j} \tag{6}$$

The cost to be minimized *at the second stage* is $PLE_j \cdot LE_j + PK_j \cdot K_j$. Cost minimization here implies solving the following joint minimum unit cost price (PR) function and the corresponding implied price and derived demand functions

$$PR_j = \left[AK_j^{\sigma_j}\,(RK_j \cdot PK_j)^{1-\sigma_j} + ALE_j^{\sigma_j} \cdot \mathrm{PLE}_j^{1-\sigma_j}\right]^{1/1-\sigma_j} \tag{7}$$

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[5] $PHM_{i,o}$ stands for the user's price of intermediate input i in 'other use', meaning other than private consumption or investment. In the model there are three possible uses (u) of commodities of the same sectoral origin: private consumption (c), investment (i), and other use (o). The price of the same commodity may differ across uses because of differences in custom duties and other taxes applied according to use.

$$K_j = X_j \cdot RK_j^{1-\sigma j} \cdot (PR_j \cdot AK_j / PK_j)^{\sigma}{}_j \tag{8}$$

$$LE_j = X_j \cdot (PR_j \cdot ALE_j / PLE_j)^{\sigma}{}_j \tag{9}$$

where $\sigma_j = 1/(1+\beta_j)$. A similar approach and result applies to the equations surrounding production of the composite labor–energy product, *LE.* The final stage (bottom element of figure 1) of production involves a parallel approach and similar result for producing the composite energy product *E*. The difference in that particular instance is that all four energy sectors are combined in a single CES production function.

2.3.2 Pollution emissions and pollution abatement

FEIM includes data and equations that represent the economic processes associated with both production of emissions and abatement or control of those same emissions. Four air pollutants are included and represented by the PO index: particulates (PART), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and carbon dioxide (CO_2). These pollutants are produced as a byproduct of production (by each of the 26 production sectors) and consumption (by the ten representative households). Government is assumed to function only as a tax collector and transfer agent.

Baseline emissions

The baseline emissions of four air pollutants due to energy combustion for each sector and energy type have been estimated by Tajthy (1996a, b) for 1994. Tajthy's estimates were slightly modified in several sectors to better conform to the input–output coefficients we developed for 1994. These emission estimates reflect both economic activity levels and the extent of abatement controls prevailing in 1994. While some natural, non-energy, and non-pyrogeneous emissions occur, most emissions of the four pollutants that are man-made are associated with energy combustion. This proportion of energy combustion emissions to other emissions is shown in table 2.

Thus the vast majority of the four air pollutant emissions we are examining are associated with combustion of energy.[6]

The baseline combustion emissions were further decomposed by fuel type so as to obtain estimates of emissions originating with each of the energy types that entered into production of *j* or consumption of *g*. These pollutant and fuel-specific emission estimates were divided by the monetized input of each fuel used by each sector in the baseline yielding baseline emission coefficients for each fuel input. These coefficients, $CE_{po,en,j}$ and $CEH_{po,en,g}$ are used as parameters in the model. They allow for increasing emissions with increasing scale of production and associated increases in use of energy inputs. Even more important, these coefficients

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[6] Some serious air pollution is the product of complex atmospheric chemistry, sometimes involving both combustion and non-combustion sources of emissions. The primary example is the formation of atmospheric ozone from the reaction of organic chemicals that have volitized and nitrogen oxides with much of the latter arising from combustion.

Table 2. *Energy combustion emissions as a proportion of total emissions for selected years, 1985 and 1990–4*

	1993	*1994*
Total anthropogenic SO_2 emissions in kt.		
energy related	747.35	732.05
non-energy related	10	9.9
total	757.35	741.95
Total anthropogenic NO_x emissions in kt.		
energy related	174.9	175.3
non-energy related	10	9.5
total	184.9	184.8
Total anthropogenic solid particulates emissions in kt.		
energy related	106.55	107.43
non-energy related	50	48
total	156.55	155.43
Total anthropogenic CO_2 emissions in million tons.		
energy related	66.19	64.48
non-energy related	20.403	19.975
total	86.593	84.455

Note: Non-energy related CO_2 emission sources including the population, domesticated animals, undomesticated animals, residential refuse, and lime and cement production; lime and cement production as the only significant non-energy related industrial source accounts for approximately the one-sixth of non-energy related emissions.

link emissions to the mix of energy inputs used in production. Such 'inter-fuel substitution' is one of the principal ways in which producers may change emission of air pollutants.

Making reference emissions proportional to fuel use is not an entirely satisfactory approach in those sectors such as refineries and organic and inorganic chemicals which use some energy products as a process feedstock without combusting them. In such sectors we made rough adjustments downward to the emission coefficients while at the same time trying not to overstate the opportunity for emission reductions in that sector due to factor substitution or pollution abatement. The assumption of proportionality, while not perfect, does allow us to model emissions reductions via 'interfuel substitution' as an economic rather than administrative phenomenon. Other means of reducing emissions incorporated into the model by virtue of this assumption are via general reduction in energy use by domestic industry or consumers, i.e., 'factor substitution', and, as discussed below, abatement or emissions due to process modifications or extensions, e.g., addition of end-of-pipe pollution abatement equipment.

Emission control through abatement

The baseline emission coefficients $CE_{po,en,j}$ and $CEH_{po,en,g}$ represent the potential for pollutant abatement beyond existing levels of control for each pollutant, *po*, associated with energy input, *en*, in production of output *j*.[7]

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[7] In the special case of CO_2 'end-of-pipe' or process controls are not available at anything like reasonable costs so we do not estimate abatement cost functions for this pollutant.

Such abatement, however, is costly and the greater the extent of abatement, for example as a fraction of potential emissions, the more costly abatement becomes. Following Capros *et al.* (1995) we introduce decision variables $AEI_{po,j,}$ $0 \leq AEI_{po,j} < 1.0$, into FEIM. These variables are defined as the proportion of emission *po* abatement selected by the industry *j*. These proportions are embedded in average or unit cost of emissions-abated functions of the following sort

$$CAB_{po,j} = \left[-b_{po,j} \;/\; (1+\gamma_{po,j}) \right] \cdot (1-AEI_{po,j})^{\gamma_{po,j}+1} + K_{po,j} \tag{10}$$

These average cost emissions-abated functions are increasing and monotonic; $\partial CAB \;/\; \partial AEI > 0$ and $\partial^2 CAB \;/\; \partial AEI^2 \geq 0$. They come from a study of control technologies and cost estimates for abatement technologies performed by Tajthy (1996c) and Tajthy and Tar (1997).[8] These reports also provide a summary of the methods used to estimate costs, rank technologies, and estimate a set of points on air pollution abatement average cost functions for the sectors and major air pollutants in Hungary. These data were used to fit cost functions like equation (10) for each sector of the model.

The abatement cost functions are embedded in the model using the Capros *et al.*'s (1995) so-called 'cost–price' strategy. As noted earlier, this strategy assumes a fixed proportionality between energy use and emissions. These coefficients, introduced above, can be used to transform energy consumption into emissions levels. Then, using the cost functions of equation (10) the model converts the emission reductions into the total material input required to abate emissions due to energy use in the production of X_j. An expression for material inputs, $M_{po,j,}$ required to abate emissions of pollutant *po* in sector *j* to $AEI_{po,j}$ of its 'potential' or baseline rate is shown as equation (11)

$$M_{po,j} = CAB_{po,j} \times AEI_{po,j.} \left(\sum_{en} CE_{po,en,j} \cdot XHM_{en,j} \right) \tag{11}$$

By scaling the last term by composite energy use and generalizing to all pollutants one can derive an expression for the augmented price of energy input into X_j production. This augmented energy price, PEA_j, includes both the initial user price of composite energy E_j, PE_j, and the material input for abatement weighted by the price of materials. The equation for the augmented energy price for abatement of all pollutants is shown as equation (12)

$$PEA_j = PE_j + \sum_{po} PM_{po,j} \cdot M_{po,j} \;/\; E_j \tag{12}$$

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[8] These functions represent the weighted average costs of reducing baseline emissions in the cheapest fashion by the proportion $AEI_{po,j,}$ i.e., total costs divided by emission reductions. In other words, these are not the average costs of any given technology nor the average cost of the last technology used to achieve a level of $AEI_{po,j}$. The functional forms have the advantage that they approach 1 assymptotically and have a 'knee' reflecting the common result of engineering cost studies of pollution abatement.

In the above equation PM_{poj} is a price index of the pollution abatement basket for each pollutant in each sector, and is defined as follows

$$PM_{po,j} = \sum_{nen} PHM_{nen,o} \cdot ABC_{po,nen,j} \tag{13}$$

The $ABC_{po,nen,j}$ are input coefficients associated with abatement technologies showing the share of non-energy input XHM_{nen} in abating pollutant *po* in sector *j*.

The augmented price in (12) is used in FEIM. More generally, the augmenting component of the price is non-zero when either pollution abatement is implemented or emission taxes are introduced (see below). With this augmented price, the variables $AEI_{po,j}$ become decision variables. The producers problem is a constrained cost minimization with augmented energy prices. In the model equations as implemented, more implicit forms of $AEI_{po,j}$ are used in order to assist numerical solution.

$ABC_{po,nen,j}$ are also used to compute augmented input requirements for the constrained optimization problem with augmented energy prices. These augmenting inputs, $ABI_{nen,j}$, are computed using equation (14)

$$\mathrm{ABI}_{nen,j} = \sum_{po} ABC_{po,nen,j} \cdot CAB_{po,j} \cdot AEI_{po,j} \cdot \left(\sum_{en} CE_{po,en,j} \cdot XHM_{en,j} \right) \tag{14}$$

The $ABC_{po,nen,j}$ input coefficients were based on emission control technology input cost data contained in sources used by Tajthy (1996c) to construct input costs and recommended to us by him. In FEIM these input shares are fixed across levels of pollution abatement for a given pollutant. A shortcoming of the model as currently formulated is that energy inputs are not directly included among the input shares. Another accommodation made in order to operationalize FEIM is the characterization of investments in pollution abatement as first amortized and then included as a cost along with current material inputs.

2.3.3 Environmental emissions

Equations like equation (15) are accounting identities that compute the emissions of a given pollutant in sector *j*. These can be summed across sectors to obtain total emissions of any pollutant. Such relationships can be used to specify exogenous restrictions on emissions in either an absolute or proportional manner for either specific sectors or the production economy as a whole.

$$EM_{po,j} = (1 - AEI_{po,j}) \cdot \sum_{en} CE_{po,en,j} \cdot XHM_{en,j} \tag{15}$$

2.3.4 Environmental load fees

We model ELFs as pollutant emission taxes. We compute the ELF payments of each sector as the product of the pollutant's ELF tax rate and the sectors pollutant emissions.

We therefore characterize the ELFs as excise taxes with a single, uniform rate. The ELF revenues are inversely related to the abatement ratios, $AEI_{po,j}$. The payments of ELF are perceived as higher costs associated with using energy, therefore they can be folded into the augmented price of energy shown as equation (12). This augmenting component in energy price for emission taxes, $PEATX_{en,j}$, is shown as equation (16)

$$PEATX_j = \sum_{po} TXENV_{po,j} \cdot (1 - AEI_{po,j}) \cdot (\sum_{en} CE_{po,en,j} \cdot XHM_{en,j}) \ / \ E_j \quad (16)$$

Thus, in selecting cost-minimizing levels of $AEI_{po,j,}$ the producers of the sector implicitly select optimal pollution abatement levels such that the marginal cost of a pollutant's abatement is equal to the marginal savings from reductions in that pollutants ELF payments. This model structure allows one to specify different ELFs (tax rates) for each pollutant and each production sector.

2.3.5 Labor supply

The reaction of labor to changes in real wages has been a key component in many analyses of the economic impacts of CO_2 or carbon-content taxes on fossil fuels, especially since taxes on labor are often singled out for reduction under 'revenue recycling' schemes. In CEE countries like Hungary the extent to which wages and labor supplies are a product of market forces or administered agreements is often debated. The relative strength of market forces and administered wage agreements is especially uncertain in production sectors in which state enterprises are prominent and the labor force is represented by a powerful union. Because we believe that there is some room for market forces to work in the labor market, especially across sectors, we specify that labor supply adjusts to the real wage rate, albeit inelastically, with a real wage elasticity of 0.5.

3. Policy simulations and results

Under the 1995 Environmental Framework Law, the Ministry of Environment and Regional Policy in Hungary was tasked with transforming the existing emission fine system, with its very low fine rates and complicated enforcement regime, into a system of environmental load fees (ELF) whose magnitude would be sufficient to 'encourage the users of the environment to reduce the utilization and loading of the environment' (Hungarian Parliament, 1995). At the same time, Hungary is reforming its tax system and actively considering increasing stringency and enforcement of its source-specific EAR. These policy initiatives, alone and in combination, are the basis for the scenarios developed for use with FEIM.

3.1 Scenarios

As a policy exercise for FEIM we ran a calibrated baseline and seven fiscal-environmental policy scenarios as summarized in table 3.

3.1.1 Environmental load fees (ELF)

ELF tax rates on air pollutant emissions are being discussed by the government of Hungary. A recent proposal offered two alternatives levels of tax for three of the air pollutants in our model. Table 4 shows the rates

Table 3. *FEIM scenarios: key features*

Scenario name[a]	*Air emission tax (ELF)*	*ELF tax revenue disbursement*	*Emission abatement requirements*	*Comments*
Baseline	No	–	No	Calibrated to 1994 activity and emission levels in combination with adjusted 1991 input–output coefficients
LumpHH\ No EAR	Yes	Lump sum rebate to households	–	All environmental tax revenues are returned to households lump sum but total government revenues will adjust to the new equilibrium solution
LTxRed/ NoEAR	Yes	Offsetting environmental tax revenues by reductions in the employment tax rate	–	The employment tax rate is made endogenous with the sum of environmental and employment taxes equaling baseline employment taxes
LumpEn/ NoEAR	Yes	95 per cent rebate to industrial sectors in proportion to energy use	–	Environmental tax revenues used to reduce the ‘financial burden’ of energy-using sectors
EAR	No	–	Sector and pollutant-specific emission abatement requirement	A command and control approach based on anticipated concentration limits achievable with best commonly available control technologies.
LumpHH/ EAR	Yes	Lump sum rebate to households	Sector and pollutant-specific emission abatement requirement	All environmental tax revenues are returned to households lump sum and all industries are subject to abatement requirements.
LTxRed/ EAR	Yes	Offsetting environmental tax revenues by reductions in the employment tax rate	Sector and pollutant-specific emission abatement requirement	The employment tax rate is made endogenous and all industries are subject to abatement requirements.
LumpEn/ EAR	Yes	95 per cent rebate to industrial sectors in proportion to energy use	Sector and pollutant-specific emission abatement requirement	Environmental tax revenues used to reduce the ‘financial burden’ of energy-using sectors and all industries are subject to abatement requirements.

Note: [a] The scenario name is based on the following pneumonics based on the key features of the model scenarios: environmental tax rebate schemes (*lump* sum, offsetting *l*abor *tax red*uctions, *lump* sum rebate to *en*ergy use in the Baseline), and *e*mission *a*batement *r*equirements based on best commonly available control technology or no such requirement (*no e*mission *a*batement *r*equirement). Thus, the scenario with offsetting labor taxes, and no emission emission abatement requirement is referenced by the ordered pneumonic LTxRed/NoEAR.

Table 4. *Hungary's proposed environmental load fees*

Air pollutants	*Environmental Load Fees (10^3 '94 HUF/Mg)*	
	Low	*High*
SO_2	7.7	15.4
NO_x	15.4	30.8
Part.	7.7	7.7

proposed; the higher ELF rates are used in all our scenarios that include ELFs.[9]

All are valued in 1994 HUF. In the baseline and emission abatement requirement (EAR) scenario the ELFs are all zero. We examine the impact of the ELFs by introducing them both independently and in combination with the other policy options. We always assume that the monitoring and enforcement of the ELFs is 5 per cent of ELF revenues and have 'wired' this cost and revenue use into the six scenarios with ELFs. Reporting, monitoring, and enforcement of a system of fines for exceeding air emission limits has been implemented in Hungary for many years with relatively minor transactions costs and, while performance of this historic system has been far from perfect, it may be refined and scaled up and used as a rough basis for both organizing implementation of the ELFs and estimation of ELF transactions costs.[10]

3.1.2 ELF revenue disbursement

All the ELF scenarios include some form of 'revenue neutral' disbursement of the associated revenues. In the two 'LumpHH' scenarios, LumpHH/NoEAR and LumpHH/EAR, we specify a lump sum rebate of environmental tax revenues (net of transactions costs) to households. This policy choice is unlikely in practice, but it is a conventional way of isolating the effects of the ELFs *per se* from ELF revenue disbursement policies and abatement requirements.

Other scenarios reflect two ways of disbursing the ELF revenues so that the revenues are not used to support expansion of the government sector in the economy. The 'LTxRed' scenarios offset the governments ELF

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[9] Emission taxes were also proposed for CO and two classes of toxic air pollutants. No emission tax on CO_2 was proposed. While the rates proposed for the two classes of toxic air pollutants were high in absolute terms, emission of these pollutants is relatively small. The rates will yield little revenue and, we suspect, result in few reductions independent of reductions in other emissions, especially particulates.

[10] The cost of emissions measurement is likely to be extremely expensive if each source must be continuously monitored. If implementation can only proceed with widespread continuous monitoring, then our estimate of monitoring costs would require dramatic upward adjustment. As noted above, we think that an effective, if not perfect, system of administration can be designed, e.g., an elaborated system of self-reports and spot-checks, without recourse to continuous monitoring except in special circumstances.

revenue by reducing labor or employment taxes. This is done by endogenizing the labor tax rate in FEIM and solving the model for the tax rate that just equates the sum of labor tax and ELF revenues with the baseline level of labor taxes. In this sense these scenarios are revenue neutral. We chose this particular way of disbursing ELF revenue because Hungary's very high labor taxes rates are considered exceptionally distortionary, and reducing the labor tax has a great deal of political appeal in Hungary. Other government revenues will increase or decrease relative to the baseline depending on the level of economic activity obtained by the economy as it adjusts to the new policies but these are adjustments to relative prices and do not use ELF revenues to expand the role or extent of government in the economy.

The 'LumpEn' scenarios rebate ELF revenues as a lump sum to energy-using industrial sectors in proportion to their baseline fossil energy use.[11] The rationale for this disbursement strategy is that those industries that are most impacted should be granted some relief from the 'double burden' of environmental tax payment and investment in emission abatement. This mimics the approach pioneered in Sweden and other Nordic countries which offer tax relief, funded by the environmental tax revenues, to those industries that are heavy energy users.[12]

3.1.3 Emission abatements requirements (EAR)

We represent command approaches to control of air pollutants by specifying minimum fractions (abatement ratios) of emission reduction per unit of output. While economists usually view emission taxes as an alternative to command approaches, most environmental protection regimes that have emission taxes implement them in combination with some technical requirements. This seems to be the joint policy design envisaged by Hungary's environmental framework legislation and MERP management. We constructed estimates of abatement ratios for each sector and pollutant based upon broad knowledge of the concentration limits of effluent gases and best commonly available control technologies entertained or accepted

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[11] Electricity use is subtracted from the sum of overall energy use when calculating the energy share parameters that determine each sector's lump sum rebate. Estimates of non-combustion use of fossil energy are also subtracted for other sectors. For example, only 10 per cent of baseline oil refining energy use is credited for the purpose of calculating the rebate received by that sector. The corresponding percentages are 25 and 75 per cent in the fertilizer production and the organic–inorganic chemicals sectors.

[12] The draft Hungarian ELF does propose financing tax relief for firms from environmental tax revenues but it bases this relief on rebate of a fraction of environmental taxes paid conditional on, and proportional to, the firm's environmental investments. This scenario does not capture the potentially important link between the decision to invest in abatement and the amount of money rebated as tax relief that is at the heart of the draft ELF rebate provision. This scenario should not, therefore, be viewed as a representation of the proposed Hungarian rebate provision but as a representation of the broader strategy of using ELF revenues to financially buffer those industrial sectors which are most burdened by the ELF.

Table 5. *Emission abatement requirement estimated for sectors and pollutants with command and control regulatory scenarios*

Sectors' name in the 26 sector break-down	*Sector No*	*Emission abatement requirement*[a] *SO_2*	*NO_x*	*Particulates*
coal mining	1	0.42	–	0.68
oil and gas extraction	2	0.42	–	0.27
electricity generation	3	0.83	0.30	0.83
oil refinery	4	0.62	–	0.16
gas production, distribution	5	0.62	–	0.16
other mining	6	0.42	–	0.82
black metallurgy	7	0.33	–	0.79
non-ferrous metallurgy	8	0.33	–	0.79
machinery	9	0.48	–	0.68
building materials	10	0.49	–	0.68
fertilizer production	11	0.62	–	0.16
organic and inorganic chemicals	12	0.62	–	0.16
manufacture of other chemicals	13	0.62	–	0.15
light and other industry	14	0.48	–	0.68
food industry	15	0.56	–	0.51
construction	16	0.62	–	0.10
forestry and agriculture	17	0.40	–	0.63
transportation	18	0.33	–	0.15
post and telecommunications	19	0.33	–	0.15
trade	20	0.24	–	0.69
water	21	0.40	–	0.63
other material activities	22	0.24	–	0.69
banks etc.	23	0.24	–	0.69
personal services	24	0.24	–	0.69
social, cultural services, and insurance	25	0.24	–	0.69
public sector, community services, and research	26	0.24	–	0.69
residential (*agent*): *all households*	27	0.00	0.00	0.00

Note: [a] These abatement ratios are based on estimated levels of sector emission control commonly in pace in 1994. The NO_x abatement reflects our assessment that as of 1994 most facilities in all but one sector (Electric Generation) had already met anticipated concentration requirements.

by MERP engineers.[13] In scenarios EAR, LumpHH/EAR, LTxRed/EAR, and LumpEn/EAR; we run FEIM with abatement ratio requirements for each sector and pollutant as shown in table 5.

These sector-specific EAR are partial representations of regulatory policy since such emission limits usually apply to individual facilities rather than sectors or the economy as a whole. The sectoral emission con-

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[13] Estimates were developed with the assistance of Dr Tihamer Tijthy and staff at MERP. Since they are based on effluent gas concentration requirements as transformed into abatement ratios, they do not correspond to a requirement that some absolute level of emission abatement is required. Lower levels of economic activity do not, therefore reduce the abatement required at any active facility.

straints, in combination with the abatement cost estimates, more resemble emission limits in combination with a 'bubble' policy in which facilities within sectors can trade individual facility emissions reductions to meet a more global emission reduction at least cost. If our cost estimates are accurate, our treatment thus tends to underestimate the economic burden of a facility-specific EAR policy designed without such bubbles.[14] At the same time, this EAR representation in FEIM does not reflect the economic and distributive impacts of intrasector trades that would take place with a bubble policy; it treats emission trades as if all are performed voluntarily without side payments.

3.1.4 Closure

In order to just identify FEIM we adopt the following 'closure' conditions in the baseline. Some of these conditions are modified to conform to the conditions specified by the scenarios described above.

> Fixed savings/disposable income ratio. Personal savings are determined as a fixed proportion of disposable income. This latter measure includes adjustments for earmarked government subsidies and other real financial investment activities on the part of households.
>
> Total capital capacity and utilization are fixed. There is, however, free mobility of capital across sectors so that the fixed capital available is assumed to be allocated efficiently.
>
> The trade balance is fixed at baseline levels. In combination with more stringent direct and indirect environmental protection requirements this is likely to force adjustment through changes in domestic prices.
>
> Government consumption is fixed at the levels used in model calibration.
>
> Investment adjusts to 'balance' incomes and expenditures in the economy in keeping with Walras' Law.

3.2 Impact measures

There are a variety of measures that are useful to understanding how and why the Hungarian economy, as represented by FEIM, responds to the ELF, revenue uses, and abatement requirements. It is important to remind ourselves, however, that the model does not, as currently structured, take into account or reflect the value of associated changes in environmental services to either households or producers. The impact measures we discuss here and present in tables 6, 7, and 8 might be viewed in this light.[15]

Aggregate measures of economic activity selected for examination are gross domestic product (GDP), discretionary household consumption, and gross investment. Gross domestic product measures aggregate, monetized economic activity. Discretionary consumption measures the amount of

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[14] As a further simplification and perhaps overoptimistic characterization of EAR, we do not make any special allowance for additional administration or monitoring cost connected with the specified emission limits.

[15] The results and summary measures can also vary as an artifact of the closure choices used in the model. For these scenarios we have kept the closure choices fixed except for changes required by the scenario itself.

Table 6. *FEIM simulations: selected aggregate economic and fiscal impacts*

	Scenarios							
Impacts	*Baseline*	*LumpHH\ no EAR*	*LTxRed\ No EAR*	*LumpEn\ No EAR*	*EAR*	*LumpHH\ EAR*	*LTxRed\ EAR*	*LumpEn\ EAR*
Aggregate economics (10^9 HUF/year)								
Gross domestic product	3,921.1	3,915.1	3,919.4	3,914.9	3,894.8	3,892.0	3,889.1	3,891.9
Discretionary household consumption	863.4	867.7	863.3	857.5	839.1	841.4	833.3	836.9
Gross investment	878.5	870.6	877.4	879.7	847.7	844.5	849.9	848.5
Economic welfare[a]	1,741.9	1,738.3	1,740.7	1,737.2	1,686.8	1,685.9	1,683.2	1,685.4
Equivalent variation[b]		3.6	1.2	4.7	55.1	56	58.7	56.5
Fiscal (10^9 HUF/year)								
Environmental tax revenue								
SO_2	0	7.85	7.85	7.84	0	1.87	1.87	1.87
NO_x	0	3.93	3.93	3.93	0	3.33	3.32	3.33
PART	0	0.32	0.32	0.32	0	0.09	0.09	0.09
Total	0	12.10	12.11	12.09	0	5.28	5.28	5.29
Other taxes	1,826.5	1,820.7	1,813.9	1,819.0	1,802.2	1,800.0	1,802.3	1,799.2
Labor tax index[c]	100	100	98.21	100	100	100	101.1	100

Notes: [a] Defined as the sum of discretionary household consumption and gross investment evaluated at baseline prices. No allowance is made for economic welfare improvements arising from improved air quality.

[b] Defined as the difference between the economic welfare measures of the baseline and the selected scenario.

[c] Labor tax index ≡ [Labor tax in scenario/Labor tax in baseline]*100.

Table 7. *FEIM simulations: primary resources and resource prices scenarios*

	Scenarios							
Impacts Baseline	*Baseline*	*LumpHH\ no EAR*	*LTxRed\ No EAR*	*LumpEn\ No EAR*	*EAR*	*LumpHH\ EAR*	*LTxRed\ EAR*	*LumpEn\ EAR*
Labor utilization	100	99.88	100	99.87	99.47	99.42	99.33	99.42
Real wage	100	99.76	99.99	99.73	98.94	98.85	98.67	98.84
Return to capital	100	99.16	99.58	98.83	95.65	95.37	94.77	95.23
Foreign exchange rate	100	99.53	99.71	99.71	100.55	100.32	100.30	100.39
Composite energy price index for sector 3[a]								
Coal	100	151	152	151	213	225	225	225
Natural gas	100	100	100	100	101	101	101	101
Electricity	100	102	102	102	105	105	105	105
Oil	100	114	114	114	131	135	135	135

Note: [a] Electric energy sector 3. The composite energy price is the composite of energy, abatement costs and ELF payments associated with energy consumption in this particular sector.

Table 8. *FEIM simulations: emissions reductions and environmental abatement costs*

Impacts	*Scenarios*							
	Baseline	*LumpHH\ no EAR*	*LTxRed\ No EAR*	*LumpEn\ No EAR*	*EAR*	*LumpHH\ EAR*	*LTxRed\ EAR*	*LumpEn\ EAR*
Emissions								
SO_2 – (10^3t)	633.6	509.8	510.5	509.7	126.8	121.6	121.5	121.6
NO_x – (10^3t)	139.1	127.8	127.9	127.7	111.7	108.1	108.0	108.1
PART – (10^3t)	58.2	42.1	42.2	42.2	11.7	11.1	11.1	11.1
CO_2 – (10^6t)	46.7	42.0	42.0	42.0	38.4	37.5	37.5	37.5
Total abatement costs (10^9 HUF)	0	0.03	0.03	0.03	29.7	28.98	28.96	28.98
Average abatement costs (10^3 HUF/ton)								
Electric energy production (Sector 3) – SO_2	15.59	15.59	15.59	15.59	40.1	40.1	40.1	40.1
Electric energy production (Sector 3) -NO_x	43.20	43.20	43.20	43.20	130.8	130.8	130.8	130.8
Electric energy production (Sector 3) - PART	0.05	3.77	3.77	3.77	67.7	67.7	67.7	67.7
Abatement ratio								
Electric energy production (Sector 3) – SO_2	0.0	0.0	0.0	0.0	0.83	0.83	0.83	0.83
Electric energy production (Sector 3) – NO_x	0.0	0.0	0.0	0.0	0.30	0.30	0.30	0.30
Electric energy production (Sector 3) – PART	0.0	0.10	0.10	0.10	0.83	0.83	0.83	0.83

such consumption valued at baseline producer prices. Gross investment, also measured as a composite at baseline producer prices, is the amount invested to support future consumption. A negative balance of trade is fixed at −282 billion HUF (the 1994 level) in these scenarios, so the results reflect price adjustments necessary to keep export and import markets in roughly the same competitive balance as in the baseline. The sum of discretionary consumption and gross investment, given their valuation at baseline prices and the fixing of the trade balance and government consumption, provides an approximation of an equivalent variation measure of economic welfare change under the scenarios: the additional resources required if economic welfare, exclusive of environmental changes, is to be maintained at baseline levels.

The size and composition of environmental tax revenues are of special interest in these FEIM scenarios. Also of interest is the total of other tax revenues and the 'labor tax index'. This index measures the new, revenue-neutral labor tax as a proportion of the labor tax rate in the baseline, e.g., 0.98 means that the new labor tax rate is 98 per cent of its original value, and is of particular interest in the cases of the LTxRed scenarios.

The economic impacts of ELFs occur in FEIM as a result of different costs resulting in new prices and associated patterns of resource utilization. Primary resource utilization rates and key factor and sector prices provide more detail on such changes as projected by FEIM. Clearly also of interest are the simulated impacts of the scenario conditions on abatement costs and the different environmental emissions. These help determine the environmental benefits of the various scenarios and the relative roles of abatement, energy substitution, and factor substitution when ELFs are used. In general, although the disaggregation to sectors was essential to obtain reliable macroeconomic indicators, we will not present the sectorial results due to size limits of the paper.

3.3 Selected results

3.3.1 Aggregate activity and fiscal impacts

The selected aggregate and fiscal impact measures are presented in table 6. These impact measures show that introduction of any of these policies, alone or in combination, will reduce GDP and economic welfare exclusive of environmental benefits. The equivalent variation (EV) measure – the additional income needed to achieve baseline levels of economic welfare – ranges from 1.2 billion HUF to 58.7 billion HUF. We also observe that even policy scenarios that use ELF revenues to reduce Hungarian labor taxes do not produce a 'double dividend'.

While we find no 'double dividend' in our scenarios, the aggregate measures, especially the EV, do show that the different environmental protection policy combinations impose different burdens on the economy in exchange for the environmental benefits they help secure. Considering only the introduction of the ELFs without EAR for a moment, recycling of ELF tax revenues through labor tax reductions reduces the cost of the emission reductions relative to a lump sum rebate to households by 66 per cent. These two policies also result in differences in the time pattern for receipt of economic welfare: the LumpHH scenario results in more current consumption and less investment for future growth and consumption than LTxRed. This difference is even more exaggerated for lump sum rebate to energy-using sectors (LumpEn). The aggregate economic welfare of LumpEn is lower than either LumpHH or LTxRed, but under the assumption that the sectors will use their rebate to enhance investment, the gross investment of this scenario is higher than either of the other rebate scenarios.[16]

The ELF scenarios without EAR all collected roughly 12.1 billion HUF; not an insignificant amount but still less than 0.7 per cent of baseline government revenues. In LTxRed/NoEAR, the labor tax index is reduced by only 1.8 per cent. ELFs may well be worth introducing, but air quality ELFs at this scope and level cannot be expected to make much of a contribution to a major restructuring of taxes.

The EAR scenarios impose much greater costs on the economy than any of the scenarios involving only an ELF. For EAR there is a 26.3 billion HUF (−0.67 per cent) drop in GDP, a 24.3 billion HUF (−2.8 per cent) drop in discretionary consumption, and a 30.8 billion HUF (−3.5 per cent) drop in gross investment. This results in a combined 55.1 billion (−3.2 per cent) loss in economic welfare as measured by equivalent variation. The EAR scenarios, when combined with ELF, (LumpHH\EAR, LTxRed\EAR, LumpEn\EAR) show that the EARs dominate sectoral pollution abatement choices; few instances occur in which the ELF stimulates pollution abatement beyond that of the EAR. More importantly, FEIM indicates that such 'hybrid' policies further reduce economic welfare. In particular, and somewhat surprisingly, the EAR places such a burden on the economy that, in order to maintain baseline levels of employment tax revenue when recycling environmental taxes (LtdRed\EAR), the employment tax index must rise by 1.1 per cent to maintain baseline labor tax revenue! With EAR taxable emissions and, therefore, ELF revenues are dramatically reduced by about 56 per cent for each of the joint ELF-EAR scenarios.

3.3.2 Primary resources and resource prices

Table 7 lists selected results for factor and energy prices under each scenario.[17] Labor utilization and wage rates are tied to one another in FEIM. Real wages and labor utilization are virtually at baseline levels under LTxRed. Reductions in utilization and real wage are quite small in the other ELF scenarios without EAR; when EAR is in the policy mix, real wages drop by roughly 1 per cent. Since capital is supplied perfectly

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[16] The results for the LumpEn scenario are conditional on the use the energy-using sectors make of the revenues transferred to them. There is no 'natural' way to specify how sectors use the lump sum transfers as was the case when lump sums were distributed to households in LumpHH. For example, we could have specified that the EFL revenues would have been used by sectors to meet the producer price 'markups' that are part of the calibrated model. In this case, the lump sum transfer acts as a lump sum production subsidy and this would have stimulated consumption of the more energy intensive products.

[17] Some table 7 values are rounded up and disguise the very small, but non-zero, effects of environmental taxes in some scenarios.

inelastically, the return on capital is much more affected by the scenarios. Under EAR scenarios, the return to capital deteriorates by 4–5 per cent relative to the baseline.

The foreign exchange rates (HUF per unit of foreign exchange) are lower with ELF alone: the current balance between exports and imports (which is fixed in the closure for each scenario) is maintained by an increase in the real value of the HUF. This reflects the reduced use of energy, which is import intensive, under the ELF scenario. The EAR scenarios, on the other hand, show increases in the foreign exchange rate. This arises from the extensive investment program required under EAR; that program has a large import component. This effect overwhelms any reductions in imports due to reduced energy use; the foreign exchange rate rises to reduce imports other than those required for pollution abatement and encourage exports and thereby maintain the trade balance.

The bottom half of table 7 shows *augmented* energy prices for one of the key sectors of the economy: the electric energy production sector 3. These are real energy price indices after associated ELF and/or abatement costs have been rolled into them. Other sectors, of course, have different composite energy prices because of their different initial conditions and opportunities for abatement of air emissions when these fuels are combusted. They are, in effect, the real user cost experienced by the electric energy production sector for use of the different energy types under each scenario. As one would expect, the price of coal use is sharply higher, increasing by over 50 per cent for policies with only ELFs and over 100 per cent when EARs are part of the policy mix. The corresponding price increases for oil are 14 per cent and over 31 percent. Combining EAR and ELFs results in the highest price increases for energy inputs: 125 per cent for coal and 35 per cent for oil.

3.3.3 Emission reductions and abatement costs

Thus far we have focused much of our attention on the estimated costs of air pollution abatement policies. We now examine the air pollutant reductions they achieve; the 'first dividend' of these policies. The various ELF scenarios without EAR show significant reductions in emissions: just over 27 per cent for particulates, 19 per cent for SO_2, and in the neighborhood of 8 per cent for NO_x. Recycling emission tax revenue made little difference in the level of emission reductions obtained. Given the lower costs of LTxRed, it appears that an ELF policy that uses revenues to reduce employment taxes can substantially improve the cost effectiveness of the policy relative to a lump sum rebate to households or the energy using production sectors.

Table 8 shows that while policy scenarios including EAR will cost more, they will dramatically reduce SO_2, NO_x, and particulate emissions by 80 per cent, over 19 per cent and nearly 80 per cent respectively. These are much stronger air pollutant reductions than we estimate would be achieved by the ELFs alone, regardless of the revenue recycling scheme. When we compare the proportionate changes in cost and emission reductions in moving from ELF to EAR policy scenarios, however, we find that estimated costs, as represented by EV, increase much faster than emissions

Table 9. *Sources of emission reductions – labor tax reduction scenarios*[a]

Scenario and air pollutant	*Abatement processes (%)*	*Energy substitution (%)*	*Factor substitution (%)*
LTxRed/NoEAR			
SO_x	1	97	2
NO_x	<1	90	9
Part	34	58	8
LTxRed/EAR			
SO_x	87	12	1
NO_x	41	45	14
Part	86	14	<1

Note: [a] Due to interaction affects, these are approximate contributions of each source to emission reduction.

Table 10. *Estimated benefit–cost ratios for selected scenarios*

Benefit estimates	*LTxRed/NoEar*	*EAR*	*LTxRed/Ear*
Low, perfectly elastic demand	5.1	0.32	0.31
Low, linear demand	6.4	0.37	0.35

reductions. The proportionate changes are so different, in fact, that the ratio of cost to effectiveness is an order of magnitude or greater for EAR scenarios, with or without ELF, than for ELF scenarios alone. Addition of ELF to EAR increases the ratio of cost to effectiveness for SO_2 and particulates but reduces it slightly for NO_x.

As noted in the model description, emission reductions can be obtained by process changes (abatement), substitution of capital or labor for energy (factor substitution), substitution across energy types (energy substitution), and general reduction in economic activity. In order to get some idea of the contribution of each of these sources of emission reductions, we ran the LTxRed/NoEAR with the various sources of substitution 'turned off'. While interaction effects make it impossible to exactly allocate the sources of emission reduction, an approximate allocation is shown in table 9. For ELF without EAR, the principal means of reducing emissions was energy substitution; abatement technology only played a significant role in reducing particulates.

When we examine the same scenario with EAR, the lower production levels account for non-trivial reductions in emissions. Focusing, however, on the other sources of emission reductions with EAR we find a very different allocation than under ELF alone: SO_2 and particulates are reduced mostly through abatement with energy substitution playing a much minor role. In the case of NO_x, with its relatively higher abatement costs, the source of change is more balanced and even factor substitution accounts for roughly 14 per cent of the change in emissions reduction.

Table 8 also provides summary information on economy-wide abatement costs and more detailed information on abatement costs and abatement ratios for the electric energy production sector (sector 3). For the economy as a whole, additional annual abatement costs beyond the baseline are estimated to be exceedingly small under the ELFs (0.03 billion HUF annually) without EAR. Sector 3 has baseline abatement activities in the baseline. FEIM estimates that, with ELF alone, sector 3 will abate particulates by an additional 10 per cent using abatement technology. For this sector, there would be no additional such abatement of SO_2 and NOx; all reductions in their sector's emissions of SO_2 and NO_x in these scenarios were obtained by energy substitution or factor substitution for energy.

Table 8 also shows that, as expected, EAR requires substantial additional investment: annualized costs of 29.7 billion HUF per year for the economy as a whole. The introduction of ELF in combination with EAR reduces abatement cost very slightly (by 0.70 billion HUF per year) due to changes in the economy that they induce. The addition of ELFs to the policy mix, however, have no effect on the abatement levels or abatement costs of sector 3. The requirements of EAR are so stringent that the ELF becomes in essence a revenue-raising tool applied to sector 3 and most other sectors.

3.3.4 Benefit–cost ratios

If one has information with which to monetize the value of emissions reductions, then the relative merit of the policy options can be represented more completely and directly. For example, we do not have to consider cost-effectiveness one pollutant at a time. Kaderják (1996) surveyed various monetized estimates of the benefits of reducing air pollutants in Hungary, including taking international estimates and adjusting them to better reflect Hungary's economic circumstances. As Kaderják himself notes, the estimates are crude. Still, they are the best (and best documented) monetized air pollutant benefit estimates available for Hungary at this time. For our examination, we have selected 'low-end' benefit measures from Kaderják to be conservative but also because we believe these are probably a better reflection of Hungarian's willingness-to-pay for reductions in air pollutants. In table 10 we compiled benefit–cost ratios for pollution abatement for three scenarios using the equivalent variation estimates of FEIM as the measure of policy cost and two different ways of computing benefits from Kaderják's data. The first of these two computations employs a constant marginal benefit estimate; the second, and more in the spirit of Kaderják's approach, uses a linear demand function for air pollutant reductions that declines to zero when emissions are eliminated.

Table 10 shows that all the ELF scenarios have a benefit–cost ratio greater than one, the threshold value for supporting the policy combination on efficiency grounds. In fact, the ratios for LTxRed/NoEAR show benefit estimates that are five or more times greater than the costs when the benefit of reduced air pollution is taken into account. Under either benefit estimation method, the scenarios with EAR show benefit–cost ratios in the neighborhood of 0.33: the cost of such policy combination is more than three times the estimated benefits even when including the benefit of reduced air pollution. Although at this level of resolution the differences are slight, the least attractive policy is the combination of EAR with ELFs.

4. Conclusions

The ELFs under consideration by Hungary are sufficient in themselves to result in significant reductions in emission of SO_2 and particulates. NO_x is less impacted. Since the principal mechanism for this reduction is energy substitution rather than investment in additional abatement technology, there are also modest reductions in CO_2. The economic cost of ELF can be substantially reduced by ear-marking use of tax revenues to reduce employment tax rates or similar distortions associated with the tax system. Moreover, the ELF with offsetting labor tax reductions yields estimated benefit–cost ratios greater than five. These results, however, depend on the assumption that the ELF can be successfully implemented with modest levels of administrative and enforcement cost.

Policies involving EAR sharply increase the overall level of air pollutant reductions. As we move to increase pollutant emissions reductions via EAR, however, the costs rise more than in proportion to either the air pollutant reductions or our rough benefit estimates. Benefits–cost ratios for EAR scenarios using the low-end benefit estimates compiled by Kaderják are substantially less than one. The wisdom of instituting policies involving stringent and widespread use of EAR, especially in combination with ELFs, is suspect. This result argues that to be economically efficient, EAR policies should be less restrictive or, at least, more selective with respect to sectors, technologies, or sites than those characterized in these policy scenarios.

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