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Endogenising emission taxes A general equilibrium type optimisation model applied for Turkey

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Abstract

This paper presents a modelling attempt to endogenise the level and timing of environmental taxes within an optimisation framework. First, a base model of energy–economy–environmental interactions is extended to allow for exogenous tax analysis. Two types of environmental taxes, one on the sulphur content of fuels and the other on the level of emissions, are exogenously included in the model as alternative instruments to mitigate pollution. Next, the base model is modified to endogenise pollution abatement. This has been achieved by incorporating a preference rate, depending on an index of emissions, into the utility function. Finally, the emission index and emission tax are taken as substitutes and modelled within a CES form to endogenise the emission tax. Results for all cases, obtained with Turkish data, are discussed. It is found that a tax on SO_2 emissions is more effective in reducing SO_2 emissions than a tax applied on the sulphur content of fuels. It is also found that a gradually increasing tax is more effective in reducing emissions than a constant tax. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Energy–economy modelling; Emission taxation; Endogenous pollution abatement

1. Introduction

Triggered by the commitment to take environmental considerations into account in their social and economic policies and to implement measures for mitigating transboundary air pollution under the 1979 UN Convention, a series of international agreements have focused on SO_2 and NO_x emission reduction, as for example the 1988 Sofia and 1994 Oslo Protocols, and have proposed a variety of targets and timetables for abatement. The aim of the Sofia Protocol to stabilise NO_x emissions at their 1987 level by 1994 has largely been achieved. The Oslo Protocol entered into force in August 1998 and, based on regional emission densities, foresees a 40–80% SO_2 emission reduction by the year 2010 relative to emissions in 1980.

There exists various measures for reducing pollutant emissions; emission charges, tradable permit systems, environmental taxes, performance bonds, liability payments and non-compliance fees can be stated as some examples. Environmental taxes emerge from the IPCC report (Watson et al., 1996) as potentially effective market instruments and have been suggested as a market-based programme to encourage continued innovation in energy efficient and cleaner technologies. The Commission of the European Communities has suggested in an Information Note on 27 May 1992 (see Nellor, 1997) that environment taxes be used to replace taxes on labour because environment taxes will impose lower social costs boosting economic activity and promoting employment.

The environmental effectiveness of taxation, economic effects and associated welfare implications are of primary importance for policy-makers who decide on environmental and economic policies. The international scientific community devotes therefore much research effort to find out about interactions between industrial development and environmental degradation. These interactions are based on an inter-play between key elements of the energy and the economic system like energy consumption patterns, the technological structure and flexibility of the energy system, fuel properties, energy security, capital stock, import composition, foreign exchange availability, household income, available investment capital, etc. The complexity of the interdependencies and the long time scales needed to

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Nomenclature

C_t	consumption
CG_t	imports of consumption goods
EC_t	energy cost
EF_t	cost of fuel imports
EI_t	emission index
$EITX_t$	emission index-tax aggregate
EN_t	incremental electric energy
F_t	foreign capital inflows
$FUEL_{j,k,t}$	use of j type fuel in activity k
GDP_t	gross domestic product
I_t	investment
ID_t	domestic investments
IF_t	investments made with foreign capital goods
$INPUT_t$	production function input factors
$INPUTN_t$	incremental $INPUT_t$
INT_t	imported intermediates
$INTN_t$	incremental INT_t
KDN_t	incremental domestic capital
KFN_t	incremental foreign capital
LN_t	incremental labor
M_t	total imports
NO_{x_t}	amount of NO_x emitted
NX_t	net exports
PN_t	incremental oil and gas
$PR_{x,a,j,k,t}$	pollutants reduced (installed a type abatement technology for reducing pollutant type x produced through the use of j type fuel in activity k)
SN_t	incremental solid fuels
SO_{2_t}	amount of SO_2 emitted
$TAX1_t$	total emission tax
$TAX2_t$	total sulphur tax
TAX_t	total emission and sulphur taxes
U	utility
W_t	factor incomes from abroad
X_t	exports
Y_t	production
YN_t	incremental production
$\alpha(EI_t)$, $\beta(EIT_t)$	preference rates
Parameters	
a, b	scale parameters
$c_{j,k,t}$	unit cost of using j type fuel in activity k
p	period length
$prc_{x,a,j,k,t}$	unit cost of $PR_{x,a,j,k,t}$
s_j	percentage sulphur contained in fuel type j
$skd, skf, sk, sl, se, sp, ss$	value shares of production factors
t_{NO_x}	tax per unit NO_x emitted (this parameter becomes a parameter in Section 3.3 where the tax is endogenised)
t_{SO_2}	tax per unit SO_2 emitted (this parameter becomes a parameter in Section 3.3 where the tax is endogenised)
$t_{sulphur}$	tax per unit sulphur contained in fuels
EI_{max}	max EI
$EITX_{max}$	max EITX
TP_{base}	base year pollution
wx	weight of pollutant type x
χ	clean-up rate
Δ_t	discount factor
λ	annual survival factor
$\rho, \alpha_t, \alpha_0, \alpha_1\alpha_2, \alpha_3, \beta_t, \eta, \phi, \mu$	model parameters
Indices	
a	abatement technology type
j	fuel type
k	activity type
t	time
x	pollutant type

observe them make it difficult to handle the problem. It is therefore not easy to determine an appropriate tax policy and to measure its impacts. It requires some difficult value judgements as well as a consistent and efficient modelling paradigm capturing energy–economy–environmental three way interactions and including the necessary level of detail in the representation of energy and economic activities.

2. Pollutant emissions and environmental taxes

The relationship between pollution, welfare and economic impacts has caused various research activities to address environmental issues. Integrated Assessment Models were successfully used to develop rational pollutant abatement strategies. Various modelling approaches ranging from optimisation to general