Emissions Reduction Policies and Induced Technological Change:
Microeconomic Evidence and Macroeconomic Impacts of the Austrian Kyoto Policy Package

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Abstract

The ability to stimulate technological change might turn out to be one of the hidden treasures in the Kyoto Protocol. Based on the proposed *Austrian Kyoto Policy Package* we focus on the technological innovations induced by this program and analyze them in a macroeconomic framework. The results indicate that a well designed emissions reduction policy will not only achieve even ambitious reduction targets but also stimulate economic activity and yield net benefits.

Three key technologies are investigated: improvement of thermal structures of buildings, cogeneration technologies and shift to biomass technologies. The relevant policy actions comprise elimination of market barriers, dissemination of information about available technology options and shifts in the tax base. Building blocks of the comprehensive modeling approach are

- the explicit choice of technologies for consumption, production, and abatement decisions,
- the interaction of flows and stocks in these decisions of households and producers,
- a measure of welfare that besides flows takes also into account stocks that are relevant for consumers' benefits.

Keywords: Induced technological change, climate change policies

JEL classification: O31, O33, Q43; Q48

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1. Introduction

Emissions reductions policies for combating climate change seem to have currently nowhere a high priority on the political agenda. In contrast, issues as employment and innovation for increasing competitiveness get top attention both with voters and policy makers. We investigate therefore in this paper, to what extent policies that focus on technological change might also benefit the aims of reducing greenhouse gases.

Only recently the link between emissions reduction policies and the impact on technological change seems to have been discovered. Does the inclusion of policies that aim at stimulating certain technologies change the evaluation of the emission reduction policies required by the Kyoto protocol?

In order to clarify the issues of the underlying debates we develop the building blocks of a comprehensive modeling approach that emphasizes the deliberate choice of technologies not only for production but also for consumption decisions, the interaction of flows and stocks in these decisions and the relevance and causalities for knowledge capital. We also stress the relevance of the scope of a model and the measures applied for evaluating policy decisions.

Finally we put these concepts into the framework of a multisectoral energy input-output model and produce numerical estimates for the impacts of the proposed Kyoto Policy Package for Austria.

2. Building blocks of a comprehensive modeling approach

We develop the building blocks of a comprehensive modeling approach that contains the following key elements:

- The relevance of the choice of technologies not only for production but also for consumption decisions is revealed.
- The interaction of flows and stocks in these decisions of households and producers is emphasized.
- Knowledge capital that influences the productivity of physical capital and other factors is taken into account.
- The adequacy of various measures of welfare as to their relevance as policy target is discussed.

2.1 Production of gross output

The production function for gross output emphasizes stock of physical capital K^q and flows of intermediate products z as relevant inputs. Both factors generate the volume of gross output q:

$$(1) \qquad q = q(z, K^q) \quad \partial q / \partial z > 0 \quad \partial q / \partial K^q > 0$$

This specification reminds us that depending on the relevant elasticity of substitution flows of intermediate goods can be substituted by capital, thus lowering material flows in production. A typical example for this option is recycling of materials which otherwise would just generate useless waste.

2.2 Consumer services from flows and stocks

We postulate that the welfare of consumers depends not only on the flow of consumption goods c but also on consumer capital stock K^c. Both items generate consumer services s, as the services of housing, nutrition, mobility, and information:

$$(2) \qquad s = s(c, K^c) \quad \partial s / \partial c > 0 \quad \partial s / \partial K^c > 0$$

Essentially this specification emphasizes also for households the substitutional relationship between flows c and stocks K^c for generating a specified level of consumer services. The same thermal services of a building, for example, can be provided by a wide range of combinations of energy flows and capital stock that determines the thermal quality of this building.

2.3 Embodied technologies, knowledge capital and induced technological change

Two types of technology decisions are considered in this modeling framework. The first is the choice between flows and stocks to generate products and consumer services. This decision is already contained in specifications (1) for gross output and (2) for consumer services and we refer to it as the embodied technology available for production and consumption.

The second technology decision determines the efficiency with which an embodied technology is used. We postulate that this efficiency is dependent on the knowledge capital of an economy and identify two sources that generate knowledge capital: learning by doing and investments into research and development. For simplicity we do not distinguish between different types of knowledge capital for production and consumption activities. We represent available knowledge capital by a technology efficiency index K^h that is improved both by learning by doing - approximated by economic activity q - and research and development - determined by explicit investments i^h in knowledge capital:

$$K^h = K^h(q, i^h) \tag{3}$$

Thus both production and consumption activities need to be complemented with the impact of available knowledge capital:

$$q = q(z, K^q, K^h) \quad \partial q/\partial z > 0 \quad \partial q/\partial K^q > 0 \quad \partial q/\partial K^h > 0 \tag{4}$$

$$s = s(c, K^c, K^h) \quad \partial s/\partial c > 0 \quad \partial s/\partial K^c > 0 \quad \partial s/\partial K^h > 0 \tag{5}$$

Two channels become visible that enable us to induce technological change. First embodied technological change can be induced by measures that change the volume and composition of physical capital both with producers and households. Second changes in knowledge capital can be stimulated by policies that influence investments into research and development. Both types of policy measures comprise information activities, elimination of institutional barriers and changes in relative factor prices.

2.4 Distribution of gross production to demand and income

Gross production q in this modeling framework can be distributed to the following demand components:

z	intermediate input for production
c	consumption commodities for consumer services
i^q	investments for production capital
i^c	investment for consumption capital
i^h	investment for knowledge capital
$x - m$	net exports

Therefore the following identity holds between gross production and demand:

(6) $$q = z + c + i^q + i^c + i^h + x - m$$

Gross domestic product is defined as

(7) $$y = q - z$$

Thus, investments are split between additions to the physical capital stock for producers i^q and consumers i^c and additions to knowledge capital i^h. The following relations describe the dynamics of physical capital stock accumulation:

(8) $$K^c = (1 - d^c)K^c_{-1} + i^c$$

(9) $$K^q = (1 - d^q)K^q_{-1} + i^q$$

It is assumed that specification (3) for knowledge capital takes into account the depreciation of accumulated past learning by doing and knowledge investments.

Both consumption c and investment flows i^q and i^c may reflect the influence of income variations:

(10) $$c = c(y)$$

(11) $$i^q = i^q(y\ )$$

(12) $$i^c = i^c(y\ )$$

2.5 Emissions from economic activity

Emissions b, in particular those of greenhouse gases, are linked to economic activity q:

(13) $$b = b(q)$$

For greenhouse gases their concentration B in the atmosphere is most relevant and specified by the following dynamic relationship:

(14) $$B=(1-d^B)B_{-1}+d^b b$$

2.6 Measuring benefits and costs

A wide range of measures for benefits and costs are available that have a decisive impact on the evaluation of different policy options together with the scope of the model.

Following the arguments of Heal (1998) that are based on the perspective of sustainable development we postulate that consumers' welfare is determined both by flows c and stocks K^c of consumer goods and allow welfare of future periods to be discounted by a discount function $d(r_t)$. Thus consumers' welfare is measured by the amount of consumer services available:

(15) $$W = \sum_t W(c_t, K_t^c)d(r_t) = \sum_t W(s_t)d(r_t)$$

This specification has far-reaching implications. It emphasizes that it is both the flow and stocks of consumer goods that provide the relevant services of housing, nutrition, information, mobility, etc. In the spirit of sustainability attempts should be made to substitute gradually consumer flows by consumer stocks. Energy flows for heating a building, for example, can be substantially decreased by improving the thermal quality of the building - the relevant consumer stock - thereby maintaining the desired welfare. It is the elasticity of substitution between flows and stocks that determines the cost effect of such a switch. To the extent that flows are substituted by stocks for generating the desired welfare a decoupling occurs of economic activity - measured e.g. by GDP - and economic welfare.

Our specification of the discount function comprises any desired case, e.g. no discounting at all, discounting at a constant or at a variable rate.

More conventional measures of economic welfare take into account either only the flow of consumer commodities or the flow of gross domestic product. Modeling approaches with a narrower perspective often only focus on the costs of certain policies.

3. Extensions to a multisectoral framework

The comprehensive modeling approach for an integrated assessment of emission reduction policies can be embedded into a multisectoral framework. Basic feature is a partitioned input-output model, which allows to differentiate between the set of *energy* commodities or activities and the set of *non-energy* commodities or activities (Fontela and Lo Cascio, 1993)). Emissions are linked to the throughput of energy commodities, and emission abatement requires the input of non–energy commodities.

3.1 Structure of the partitioned input-output model

Starting point is the postulated equilibrium for the supply components gross domestic production q and imports m with intermediate demand z and final demand f, all variables being now vectors with appropriate dimensions:

$$q + m = z + f \tag{16}$$

A linear technology matrix A links intermediate demand z with gross production q:

$$z = A\, q \tag{17}$$

Final demand f comprises the components private consumption c, public consumption g, investments i, and exports x:

$$f = c + g + i + x \tag{18}$$

Accordingly gross domestic product by sectors y follows as

$$y = f - m \tag{19}$$

It is worth mentioning that final demand *f* contains energy flows with a very high import content and construction investment with a very high domestic content in contrast. Substituting energy flows by investing into energy efficient buildings creates obvious GDP effects.

Partitioning into energy components, superscripted with *e*, and non-energy components, superscripted with *n*, we obtain the following structure of the multisectoral model:

$$(20) \qquad \begin{bmatrix} q^e \\ q^n \end{bmatrix} + \begin{bmatrix} m^e \\ m^n \end{bmatrix} = \begin{bmatrix} A^{e,e} & A^{e,n} \\ A^{n,e} & A^{n,n} \end{bmatrix} \begin{bmatrix} q^e \\ q^n \end{bmatrix} + \begin{bmatrix} f^e \\ f^n \end{bmatrix}$$

3.2 Energy flows and emissions

The first set of equations (20) describes the energy model.

$$(21) \qquad q^e + m^e = A^{e,e} q^e + A^{e,n} q^n + f^e$$

Energy commodities q^e are either untransformed $q^{e,u}$ or the output of conversion process $q^{e,t}$:

$$(22) \qquad q^e = q^{e,u} + q^{e,t}$$

Distinguishing between energy commodities, superscripted by *e*, and energy processes, supercripted by *b*, the technology for energy transformation is described by

$$(23) \qquad A^{e,e} = A^{e,b} D^{b,e}$$

The following activities are singled out as energy commodities:

Coal and coke
Oil and gas extraction
Gas distribution
Refined oil
Electricity

The following conversion processes with corresponding volumes q^b are considered:

Coke production
Blast furnace gas
Refinery

Gas works

Steam

Thermal power plants

Hydro power plants

Biomass production

Thus, the energy balance is

(24) $q^{e,u} + q^{e,t} + m^{e} = z^{e} + f^{e}$

with

(25) $z^{e} = A^{e,e}\, q^{e} + A^{e,n}\, q^{n}$

The vector of various kinds of emissions *b* is linked to net energy flows via an emissions factor matrix $A^{b.e}$:

(26) $b = A^{b,e}\, (z^{e} + f^{e} - q^{e,t})$

3.3 Imports and final demand

The basic equations (16) to (20) of the multisectoral model are complemented by structural specifications for the components of final demand and imports.

For imports a system of import share equations is specified as a two step *adding-up* demand system (according to an *Almost Ideal Demand System*, AIDS) as lined out in Anderton, Pesaran, Wren-Lewis (1992). The weak separability condition of this two step demand model implies that in a first step total demand by commodities is determined and in a second step is split up into domestic and imported demand. Import shares s_i^m yield together with total demand (equal to the inner product of a one-vector with *q*) the commodity imports:

(27) $m_i = s_i^m\, 1'q, \quad i \in n$

The import shares are modeled according to the error correction mechanism proposed by Phillips and Loretan (1991):

(28) $s_i^m = s_i^m\, (q_i), \quad i \in n$

Similarly private non-energy consumption c^n is specified as a dynamic *Almost Ideal Demand System* (Deaton and Müllbauer, 1980). Total non-energy consumption (equal to the inner product of a one-vector with c^n) is split up by consumption shares s_i^c into its components c_i^n:

(29) $$c_i^n = s_i^c \, 1'c^n, \quad i \in n$$

Again the static AIDS model is dynamized using the Phillips-Loretan approach:

(30) $$s_i^c = s_i^c \, (1'c^n), \quad i \in n$$

Behavioral equations were estimated for public consumption and investment categories which are bridged again via fixed shares to their sectoral components.

3.4 Employment

For the non-energy sectors the adjustment process of sectoral employment l_i^n to sectoral output q_i^n is estimated by applying the two step procedure of Engle and Granger (1987) for the error correction mechanism:

(31) $$l_i^n = l_i^n \, (q_i^n ,), \quad i \in n$$

Employment in the energy producing activities l_i^e is determined by labor input coefficients $a_i^{e,q}$ which are adjusted to their trends:

(32) $$l_i^n = a_i^{e,q} \; q_i^e , \quad i \in e$$

3.5 The energy submodel

3.5.1 Energy demand and embodied technical change

The final energy demand model constructed here is based on the combination of a translog cost function for fuel allocation with single equations for total energy demand (in energy units) by activities as lined out in the work of Harvey and Marshall (1991). The activity classification (12 industries and households) is an aggregate version of the 32 industries of the multisectoral model E3ME (for correspondence between the 32 industries of E3ME and the 12 activities see Appendix A). An extensive description of this model can be found in Kratena (1999).

In the model for total energy demand we assume, that firms in the different activities produce output with inputs of the variable factor energy and of the fixed factor capital. These firms face a (short run) variable cost function, which depends on given factor prices (the price of energy), the output level, the capital stock and a trend component. Technical change is like in the work of Berndt, Kolstad and Lee (1993) specified by an embodied component represented by the capital stock and an un-embodied component represented by the linear deterministic trend. At this level of total energy demand for a bundle of fuels total costs can be split up in variable costs for the variable factor energy and fixed costs for the fixed factor capital. The derived factor demand equation in terms of energy input coefficient contain the capital coefficient, the price of energy and the number of heating degree days as explanatory variables.

3.5.2 Inter-fuel substitution and embodied technical change

Total energy demand consists of a bundle of (short run) variable energy inputs and a bundle of fixed energy inputs. The emphasis is on fossil fuel use, so that variable energy input is the sum of the fossil fuel inputs of coal, derived oil, gas, electricity, and fixed energy input is the sum of the non-fossil fuel inputs of biomass and heat/steam. The idea behind this specification is that embodied technical change occurs by the introduction of certain technologies with a fixed non-fossil fuel input.

Total energy cost is further split up into variable energy costs for the variable energy inputs and fixed energy costs for the fixed energy inputs. (Berndt, Kolstad and Lee, 1993). The average (short run) variable energy costs are a function of all input prices for the variable factors, of the quantity shares of the fixed factors and of the deterministic trend for un-embodied technical change. Technical change is therefore the sum of the embodied component and of the un-embodied component.

For each of the 13 activities (12 industries plus households) a translog cost function for the aggregate price of the variable energy-bundle (the average costs of total energy input) in the corresponding activity is set up. The shadow price of the fixed factor is determined by the impact of the fixed factor input on variable costs. This impact can at the level of certain variable inputs be positive or negative. One could think of fossil fuels saving technologies as well as of joint technologies of biomass/fossil fuels or higher electricity input for using equipment with steam/heat input.

For the price of total energy inputs we use the corresponding price (cost) index of the translog specification which - as Harvey and Marshall (1991) point out - is the Divisia–price index. We assume that this is set as a mark up on the average variable cost for fossil fuel input. This reflects the fact that the prices of fossil fuels and non-fossil fuels are linked in a certain manner, which can be expressed by a fixed relationship of the movement of the total energy price and the price of the fossil energy bundle with the constant mark up.

From that a share equation system for the singular fuels with a shadow value equation and the energy input equation and the price equation for this energy input can be derived for estimation. Detailed results are reported in Kratena (1999).

3.6 Data sources and parameter estimates

The data characterize this multisectoral model as a *hybrid* energy input-output model (see Miller and Blair, 1985, pp. 201-208), since the variables of the non-energy set are measured in volume units (Austrian Schillings at constant prices) and the variables of the energy set are measured in energy units (Terajoule). Conversion factors for transforming energy units in Austrian Schillings at constant prices are used to link the energy to the non-energy part. The classification used consists of the 32 activities of the E3ME model (see Appendix A).

The input-output statistics used are based on the provisional 1988 input-output table of the Austrian Institute of Economic Research (WIFO), which has been deflated to 1985 prices. The technical coefficients have been extrapolated to 1994, which allowed to construct together with final demand, gross and net output data for 1994 a *projected* input-output table for 1994 at constant prices of 1985.

The energy data are based on the national energy balances of Austria and data about monetary expenditure for energy by activities.

All econometric parameter estimates are based upon time series from 1976 to 1994 or 1995, which have been collected for E3ME in Austria. The model can then be used for a baseline forecast to 2005 and for simulations of economic policy measures.

4. Simulating technological change

The integrated multisectoral modeling approach enables to simulate a variety of technological changes. A first set of measure is targeted to a reduction of redundant energy services and the corresponding energy flows. A second set of policies aims at providing incentives for changing the embedded technologies of the existing capital stock. A third technology program is aimed at factor substitutions, in particular the reduction of energy intensities and a shift to fuels with a lower carbon content. All policy actions involve besides changes in relative prices the dissemination of relevant information and the elimination of institutional barriers. Two typical emission reduction measures, the improvement of the thermal structure of buildings and the expansion of cogeneration technologies, serve as case studies for explaining the simulation capabilities of the multisectoral model.

4.1 Case study 1: Improvement of the thermal structure of buildings

Improving the thermal structure of buildings requires an increase in physical capital stock of buildings in order to lower energy consumption. Basically this means a move on the curve for a given level of energy services, an iso-energy services curve.

Under perfect market conditions the energy-capital mix for a required thermal service should be determined by the relative price of energy and capital. Two implications follow from this postulate. If we observe that current prices would call for lower energy intensity, then the barriers have to be identified that prevent this change of technologies. If on the other hand social and political targets require a lower energy intensity then relative prices need to be adjusted by energy taxes and/or subsidies for investments.

Activities in improving the thermal structure of buildings require investments in their physical capital stock. These are induced changes that stimulate non-energy investments i^n, in particular construction. The cost effect of such a program would crucially depend on the elasticity of substitution between energy and capital. There is ample evidence - at least for Austria - that this elasticity is at the margin at least one, thus enabling the same energy services without increasing their costs. It should be mentioned that the costs of thermal improvements are reduced considerably if they are part of a general renovation activity of a building.

At least to some extent energy consumption for heating services can be lowered by better adjustment of the heating services to the needs of the inhabitants. A public awareness program that emphasizes better controls for existing equipment would require modest expenditures for public consumption g^n and result in lower energy flows for consumption c^e without sacrificing energy services.

Another measure for inducing technological change in the context of heating buildings would be activities in R&D, for example transparent insulation materials. In our multisectoral model these activities would show up in public expenditures, investments for equipment and construction and finally in a shift of consumer expenditures from energy to non-energy commodities.

4.2 Case study 2: Cogeneration of electricity and heat

Cogeneration of heat and electricity is growing rapidly in Europe. In the industrial sector of Austria it has almost exhausted its potential. In most industrial processes where heat and baseload electricity is needed, cogeneration technologies have proven to be very cost efficient. Additional cogeneration as a device for emission reduction therefore means an extension of cogeneration to other industrial users and to domestic use.

As with the thermal improvement of buildings the expansion of cogeneration requires investments in physical capital stock. In order to avoid stranded investments, whenever decisions for replacement investments of conventional equipment for generation of electricity or heat come up, incentives should be provided to switch to cogeneration technologies. The only incentive necessary seems to be the elimination of institutional barriers, in particular the right to sell surplus electricity over the public grid at avoided costs. Cogeneration seems to be especially profitable if peakload electricity can be either substituted or sold.

In our multisectoral modeling framework this means investment activities of non-energy commodities i^n and changes in the technological coefficients of the technology matrix for energy transformation. The impact on energy costs is influenced by the rate of depreciation on existing and new equipment, by the equipment costs and energy prices. For the residential sector cogeneration could mean crowding out effects on other fuels that are used in conventional technologies for heating.

Cogeneration technologies become even more attractive if they are supplemented by heat pumps. The overall energy efficiency with respect to primary energy inputs may then reach 130 to 180 percent.

5. Application to the Austrian Kyoto Policy Package

Austria is committed under the Kyoto Protocol and the EU cooperation to a 13 percent reduction of greenhouse gases and currently in the process of designing policies that make this commitment operational. The Austrian Kyoto Policy Package, summarized in Appendix B, is a detailed proposal which lists measures together with the amount of investment activities that would be needed to lower emissions to the committed target.

The policy package focuses on the following activities:

Thermal services for the residential sector

> Case studies indicate that the switch from conventional standards to low energy standards is cost-neutral for new buildings. For existing buildings these low energy standards are profitable in the context of a general renovation activity.

Cogeneration technologies

> International comparisons reveal that Austria widely lacks the application of cogeneration technologies in the non-industrial sector. Together with heat pumps these technologies offer a substantial increase of the efficiency of the energy transformation system.

Transport and mobility

Road transport in Austria is hitting limits in particular in urban areas. A major redesign is needed for preventing a breakdown of road transport in the agglomeration areas that involves the design of an integrated mobility system.

Innovative biomass technologies

Austria has not only plenty of biomass that could be used sustainably but has also the prototypes of advanced biomass technologies that could prove very competitive and profitable on international markets.

Conventional and advanced solar technologies

Per capita indicators reveal Austria as a leader in thermal solar technologies. Advanced solar such as photovoltaics could be considered as part of a promising research and development program.

Materials and waste management

Rather underestimated so far was the potential for reducing methane emissions stemming from land fills. Both the reduction of material flows and thermal waste technologies emerge as attractive policy options.

Table 1: Key numbers of the Austrian Kyoto Policy Package

Each year over 10 years	
Technology investments related to climate change policies	12.55 Bill ATS
Incentive financing	1.44 Bill ATS
Reduction of GHG in target period	16.11 Mill tonsCO_2-equivalent
Net-*effect* on public budgets	+8 to +12 Bill ATS
Employment	+12,000 to +16,000 Persons

Table 2: Summary of the policies and measures of the Austrian Kyoto Policy Package

	Emissions reductions in 2010 Mio tons CO_2-equivalent	Incentive financing per year 2000-2010 Bill ATS	Investments related to climate policy per year 2000-2010 Bill ATS
Energy	6.61	1.38	6.74
Waste management	2.20	0.00	0.00
Industry	0.60	0.06	0.21
Residential sector	4.40	0.00	5.60
Transport	2.10	0.00	0.00
Agriculture and forestry	0.20	0.00	0.00
Total	**16.11**	**1.44**	**12.55**

6. Conclusions

The overall picture of the economic analysis of the Austrian Kyoto Policy Package is rather surprising since it reveals that carefully designed climate change policies are rather an opportunity than a burden. The driving forces for this result are both the deliberate choice of technologies and the corresponding institutional reforms.

From a microeconomic perspective the range of policy options has to be evaluated according to their rate of returns. In the case of Austria about 40 percent of the investments needed to achieve a reduction of GHG emissions of about 16 mill tons CO_2-equivalent per year in the Kyoto target period 2008 to 2010 yield a rate of return that should be sufficient to trigger actions by companies and households if current market barriers are eliminated. The next 40 percent of the investments in the proposed climate policy package need cooperation with the financial sector in order to make them viable.

Only the remaining share of about 20 percent requires incentive financing by the public sector in order to raise their returns.

From a macroeconomic perspective this temporary support by public funds is highly attractive. It stimulates not only technologies that contribute to the competitiveness of the economy but also increases economic activity, creates jobs and lowers unemployment. The net incomes of public budgets is a multiple of the initial outlays for incentive financing.

Why do these results differ from those that consider climate policy rather a burden in the sense of a loss of economic welfare? It is mainly three ingredients in our modeling approach that generate our positive evaluation of the proposed climate policy package. First we emphasize the potential for induced technological change and the resulting impacts on economic growth and competitiveness. Second we allow for underutilized factors of production, in particular labor and capital, at least for the time span until the Kyoto target period, thus lowering crowding-out effects and generating multiplier effects. Thirdly we implicitly assume that a number of policy measures that benefit GHG emissions serve also other policy targets, as improving the quality of houses or redesigning the transport system. It is this joint production character of policies that questions also the concept of a unique abatement cost curve.

Some recommendations that are based on these arguments may very well change current mainstream opinions about the economic evaluation of Kyoto strategies.

Early action may be supported on the grounds of the amount of technical progress that is induced and the resulting benefits which may even create funds for temporary compensation to those that may experience disadvantages from emissions reduction policies.

The share of domestic actions may evolve to be much higher than a naïve comparison of marginal abatement costs may suggest because of the incentives for technological progress and the stimulating multiplier effects on other sectors of an economy.

Finally, the Kyoto mechanisms will have to be judged also with respect to their implicit impacts on induced technological change. For the Clean Development Mechanism, for example, it will be crucial if only surplus technologies are traded or if appropriate technologies for developing countries are provided.

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Appendix A

Classification of sectors

The 32 industries classification of the E3ME model is defined by NACE-CLIO and comprises the following sectors:

	Sector
1	Agriculture etc.
2	Coal and coke
3	Oil and gas extraction
4	Gas Distribution
5	Refined oil
6	Electricity etc.
7	Water supply
8	Ferrous and non-ferrous metals
9	Non-metallic mineral products
10	Chemicals
11	Metal products
12	Agricultural and industrial machines
13	Office machines
14	Electrical goods
15	Transport equipment
16	Food, drink and tobacco
17	Textiles, clothing and footwear
18	Paper and printing products
19	Rubber and plastic products
20	Recycling, emission abatement
21	Other manufactures
22	Construction
23	Distribution
24	Lodging and catering
25	Inland transport
26	Sea and air transport
27	Other transport
28	Communications
29	Bank. finance and insurance
30	Other market services
31	Non-market services
32	Unallocated

The 12 industries plus households of the energy submodel presented can be viewed as an aggregated version of the 17 industries of the energy submodel in E3ME. This is the correspondence between these 17 industries (17-E3ME) and the 32 industries (32-E3ME):

		17-E3ME	**32-E3ME**
1	Iron and steel, non-ferrous metals	2+3	8
2	Chemicals	4	10
3	Mineral products	5 + 6	9
4	Food, drink and tobacco	7	16
5	Textiles, clothing and footwear	8	17
6	Paper and printing	9	18
7	Engineering etc.	10	12 to 15
8	Other Industry	11	11, 19 to 21
9	Inland Transport	12+13	25
10	Air transport	14	26
11	Inland navigation	15	27
12	Other final use	17	1,7,22 to 24
13	Households	16	28 to 32

Appendix B

The Austrian Kyoto-Policy Package

	Emissions reductions in 2010 Mio tons CO_2-equivalent	Incentive financing per year 2000-2010 Bill ATS	Investments related to climate policy per year 2000-2010 Bill ATS
Energy	**6.61**	**1.38**	**6.74**
District heating systems	1.06	0.29	1.68
Cogeneration	0.60	0.00	0.90
Heat pumps	1.10	0.33	1.10
Biomass	1.69	0.25	0.83
Biogas	0.79	0.14	0.34
Small scale hydro	0.49	0.08	0.31
Wind power	0.14	0.07	0.14
Thermal solar	0.74	0.22	1.44
Photovoltaics	(0.03)	(0.41)	(0.45)
Information activities	n.q.	n.q.	n.q.
Research & development	n.q.	n.q.	n.q.
Renewables in heating systems	n.q.	n.q.	n.q.
Tax policy	n.q.	n.q.	n.q.
Regional energy plans	n.q.	n.q.	n.q.

	Emissions reductions in 2010 Mio tons CO_2-equivalent	Incentive financing per year 2000-2010 Bill ATS	Investments related to climate policy per year 2000-2010 Bill ATS
Waste management	**2.20**	**0.00**	**0.00**
Landfills	0.20	0.00	0.00
Thermal units	2.00	0.00	0.00
Industry	**0.60**	**0.06**	**0.21**
Fuel substitution	0.30	0.06	0.21
Efficiency of mechanical systems	0.30	0.00	0.00

	Emissions reductions in 2010 Mio tons CO_2-equivalent	Incentive financing per year 2000-2010 Bill ATS	Investments related to climate policy per year 2000-2010 Bill ATS
Residential sector	**4.40**	**0.00**	**5.60**
Building codes for thermal efficiency	2.40	(1.51)	5.04
Efficiency of electric appliances	0.60	0.00	0.00
Efficiency of heating systems	1.40	0.00	0.56

	Emissions reductions in 2010 Mio tons CO_2-equivalent	Incentive financing per year 2000-2010 Bill ATS	Investments related to climate policy per year 2000-2010 Bill ATS
Transport and mobility	**2.10**	**0.00**	**0.00**
Zoning regulations	0.10	0.00	0.00
Incentives for switching transport from road to railway	0.20	0.00	0.00
Local transport management	0.30	0.00	0.00
Investments in local transport systems	0.30	0.00	0.00
Reduction of fleet fuel consumption	0.30	0.00	0.00
Off-road vehicles	0.10	0.00	0.00
Market instruments (taxes and road pricing)	0.50	0.00	n.q.
Public awareness programs	0.10	0.00	0.00
Research and technology programs	0.10	0.00	0.00
Biofuels in specific applications	0.10	0.00	0.00

	Emissions reductions in 2010 Mio tons CO_2-equivalent	Incentive financing per year 2000-2010 Bill ATS	Investments related to climate policy per year 2000-2010 Bill ATS
Agriculture and forestry	**0.20**	**0.00**	**0.00**
Ecological agricultural production	0.05	0.00	0.00
Propagation of wood products	0.15	0.00	0.00

TOTAL	16.11	1.44	12.55