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The consequences of environmental policy for economic growth: A numerical simulation of the transition path

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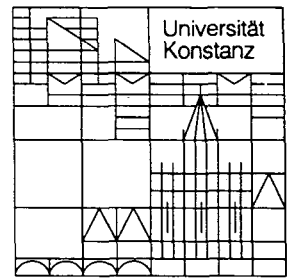
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Sonderforschungsbereich 178
„Internationalisierung der Wirtschaft“

Diskussionsbeiträge



Juristische
Fakultät

Fakultät für Wirtschafts-
wissenschaften und Statistik

Frank Hettich

**The Consequences
of Environmental Policy
for Economic Growth:
A Numerical Simulation
of the Transition Path**

24. JAN. 1996 Weltwirtschaft

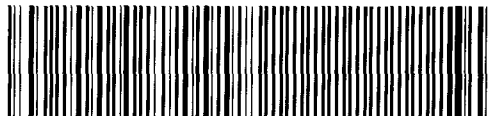
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**The Consequences of Environmental Policy
for Economic Growth:
A Numerical Simulation of the Transition Path***

Frank Hettich*

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The Consequences of Environmental Policy for Economic Growth: A Numerical Simulation of the Transition Path*

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Abstract

This paper analyses the consequences of tightening environmental policy for economic growth. To find out how the new balanced growth path is reached in the long run, we simulate numerically for the short and medium term the transition path of a change in environmental policy within an endogenous growth model. This enables us to analyse welfare effects also dynamically. Additionally, it is possible to compare accumulated levels of abatement, consumption, and output after the transition process with the business as usual scenario. Whereas long run growth rates are not affected by any environmental measure, there are non-monotonous adjustments during the transition. For environmental policy being suboptimal in the initial equilibrium, welfare in every period is higher compared to the business as usual scenario.

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1. Introduction

Deterioration of the natural environment is an issue of growing concern in policy debates these days. According to a public opinion survey in 1992, more than 55% of the EUROPEAN COMMUNITY's population is very concerned about national and international environmental problems.¹ In economic theory an overuse of the environment is explained by the existence of market failures. Firms and households – if they act individually rational – pollute too much, since they do not pay the price for social damages they cause. Governments can in principle correct these market failures by raising private costs up to the level of the social costs by means of efficient instruments such as PIGOUVIAN taxes or auctioned permits.

22% of the EUROPEAN COMMUNITY's population believe that concerns about the environment should get higher valued than economic development. 4% have the opposite opinion, 5% do not know, and 69% are of the opinion that economic development must be ensured but the environment protected at the same time.² The effects of environmental policy on economic growth are uncertain. Some people fear that tightening environmental policy causes a drop of GDP growth rates, others have the opposite opinion. No matter what is true it would be beneficial for economic agents – at least in the long run – if external costs were internalized. However, growth rates, especially that of GDP, is regarded at least as one of the main indicators of prosperity and performance of an economy, and it is certainly an important figure from a political economy point of view.

Economic research has recently begun to analyse the effects of environmental measures on economic growth in endogenous growth models. Neoclassical growth models are not suited to analyse these effects, because they rather assume than explain growth.³ Hence, in this paper, the effects of environmental care on economic growth and optimal technology choice are explained in a model with endogenous technical progress and perfect foresight. Pollution is modelled as a side product of the physical capital stock used in production, and it is assumed to affect only individuals' utility. Of course it is quite conceivable that pollution also affects production, an aspect not being analysed in this paper.

Whereas almost the whole literature examines the long run effects of environmental policy,⁴ little has been done so far to analyse the short and medium term effects.⁵ In order to address these aspects, we simulate

¹ See OECD (1992), table 14.1C and 14.1D, pp. 289-290. The percentage EUROPEAN COMMUNITY's citizens being highly concerned about national and international environmental problems are given in brackets:

National environmental problems: Water pollution (57%), and air pollution (59%).

International environmental problems: Extinction of some plants or animal species in the world (59%), depletion of the world forest and natural resources (57%), global warming (63%), and destruction of the ozone layer (70%).

² Figures are from OECD (1993), table 14.1A, p. 287.

³ In neoclassical growth models growth is exogenously given in the long run. See Gradus/Smulders (1993), section 2.1, for a formal analysis of the influence of environmental policy on economic growth in the neoclassical Cass-Koopmans growth model.

⁴ The following papers analyse long term effects: Baranzini/Bourguignon (1995), Bovenberg/Smulders (1993), Bovenberg/Mooij (1994), Gradus/Smulders (1993), Ligthart/van der Ploeg (1994), Marrewijk et al. (1993), Nielsen et al. (1995), Smulders/Gradus (1993), and Smulders (1995).

⁵ Exceptions are Bovenberg/Smulders (1994) and Perroni (1995).

numerically the adaptation of the economy to a change in environmental policy. The results lay the ground for a dynamic welfare analysis. Starting from a point where pollution is excessive from a welfare point of view, it is obvious that welfare increases in the long run if environmental policy is tightened. But there may be hard times during the transition. However, in this paper we find welfare to be higher in *every* period after the policy measure compared to the *business as usual* case where environmental policy is unchanged. Whereas growth rates in our model are not affected by environmental measures in the long run, they behave non monotonous during the adaptation process for plausible parameter values. We compute how accumulated levels of abatement, consumption, and output are affected in the long run due to the transition process, compared to business as usual. Additionally, we examine how results change if environmental policy measures are announced. This paper only deals with first best policies, i.e. there exists no other distortion apart from the negative environmental externality.

The paper proceeds as follows. Section 2 is restricted to long term effects and describes the analytical framework of the model: In subsection 2.1 we first lay out the model, in subsections 2.2 and 2.3 we then analyse the effects of environmental care on growth and on the ratios of variables, respectively. Short and medium term results are derived in section 3. Subsection 3.1 shows how the model is calibrated, and subsection 3.2 outlines the results of the numerical simulation. Section 4 concludes.

2. The analytical framework

The model of a closed economy used in this paper is a discrete version⁶ of Gradus/Smulders (1993). It is a simplified Lucas (1988)⁷ endogenous growth model, extended by a technological externality. All markets are assumed to be perfectly competitive, i.e. there is no unemployment of factors. All variables are denoted in per capita values. Therefore a change in the labour growth rate does not affect the equilibrium growth rates of the variables. Subscript t indicates the period for a variable that changes over time. In the following we lay out the model.

2.1. The model⁸

We assume individuals to be identical and to have perfect foresight over an infinite time horizon. The instantaneous utility function is additive separable and depends on consumption C and net pollution P in every period t (gross pollution minus abatement activities):

$$U_t = \ln C_t - \frac{\phi}{1+\psi} P_t^{1+\psi}, \quad (1)$$

⁶ For the purpose of simulation with GAMS (General Algebraic Modeling System) we reformulate the model in a discrete version. GAMS is a special software for solving e.g. multisectoral economy wide models or large simulation and optimisation models. For a description of GAMS see Brooke et al. (1992).

⁷ Unlike the original model, there is no externality in human capital to reflect the fact that people are more productive when they are around clever people as in the original Lucas version, where the production function is $Y = \alpha \cdot K^\beta (u \cdot h \cdot L)^{1-\beta} \cdot h_a^\omega$. Where h_a^ω represents the externality from average human capital.

⁸ In the appendix the model is summarised in mathematical form.

with $\phi \geq 0$, $\psi > 0$, and thus $U_C > 0$, $U_{CC} < 0$, $U_P < 0$, $U_{PP} < 0$.⁹ ϕ and ψ both are exogenous parameters, the first one representing the sensitivity of pollution on utility, the latter the elasticity of marginal utility of environment. Individuals' welfare at time zero is the discounted sum of utility [equation (1)] in every period:

$$U_0 = \sum_{t=0}^T \left[\left(\ln C_t - \frac{\phi}{1+\psi} \cdot P_t^{1+\psi} \right) \cdot (1+\sigma)^{-t} \right],$$

where σ is the exogenous rate of time preference, i.e. the subjective discount rate. It is assumed to be constant over time.

In our two sector model, the first sector produces an output good which provides consumption goods C , investment goods I ,¹⁰ and abatement activities A . The second sector is the research and education sector where skills and knowledge are generated endogenously.

The production function is of the COBB-DOUGLAS type. There are constant returns to scale with respect to physical and human capital but diminishing returns to factors separately. Economic agents divide their non-leisure time between producing and human capital accumulation. u is the fraction of non-leisure time devoted to production (producing output Y), and h is a measure for the average qualification, for simplicity called human capital stock. β and $(1-\beta)$ are the shares of physical and human capital in the production function, respectively. Both inputs, physical capital K and total effective labour ($u \cdot h$), are reproducible and thus can be accumulated. Falling marginal returns to one factor can be avoided. Therefore there are no limits for the growth of per capita output:

$$Y_t = K_t^\beta \cdot (u_t \cdot h_t)^{1-\beta}, \quad (2)$$

where $0 < \beta < 1$. Productivity growth is modelled as labour augmenting technical progress. The resource constraint is given by:

$$Y_t = C_t + I_t + A_t, \quad (3)$$

That means homogenous output Y is either consumed, or invested to increase the physical capital stock K , or used for abatement activities. The transformation of output into any of the three applications is cost-free.

The education sector where individuals accumulate knowledge is given by:

$$h_{t+1} - h_t = h_t \cdot \varepsilon \cdot (1 - u_t). \quad (4)$$

The change in the human capital stock depends on the time spent on studying $(1-u)$, the exogenous studying productivity parameter ε ($\varepsilon > 0$) and the current stock of physical capital h . This functional form possesses constant returns to scale in the production of human capital, i.e. the growth rate \hat{h} is proportional to the time spent on studying. Because of non-decreasing returns individuals always have

⁹ The differentiation of X with respect to Y is written as: $X_Y \equiv \partial X / \partial Y$

¹⁰ For simplicity it is assumed that there is no depreciation of the physical capital stock. There is also no depreciation of the human capital stock, as we will see later on.

the incentive to invest in human capital. As we will see later, human capital accumulation is the engine of growth in this model.

The capital stock K used in production causes a negative environmental externality as a side product. It is a production-consumption externality, which falls on private consumption but does not harm production. The amount of pollution is a public good, that can be reduced by means of abatement activities A , which consume a part of output (as equation (3) shows). A is modelled as a flow quantity. If A increases, the whole physical capital stock pollutes less, no matter if old or new. One can imagine some kind of end of pipe technology, e.g. filters, being used up within one period. Therefore, abatement activities have to be launched in period again. The net pollution function P has the form:

$$P_t = \left(\frac{K_t}{A_t} \right)^\gamma, \quad (5)$$

where $\gamma (>0)$ is the exogenous elasticity of the ratio K/A and $P_K > 0$ and $P_A < 0$.

The equilibrium in a the decentralized economy is not PARETO optimal. Because of the pure public good character of pollution, producers ignore the negative environmental effects arising from the use of physical capital in production: Private marginal return of physical capital is higher than its social return. No economic agent has the power to influence the level of pollution, moreover it is individually rational not to take the negative side effects, i.e. the externality, into account. The government can in principle correct the market failure, i.e. internalizing the externality, by raising private costs up to the level of social costs by means of efficient instruments such as PIGOUVIAN taxes or auctioned permits.¹¹ In contrast to a decentralized optimization, a central planner who maximises the utility of the representative economic agent takes the negative side effects of production into account.

In our paper we assume a central planer who maximises the utility of the representative economic agent. But she has no perfect information concerning the value of the sensitivity parameter ϕ of pollution on utility. We assume in the initial equilibrium too excessive pollution, therefore her presumed value for ϕ is below the real one.

We now derive the first order conditions of the maximization problem are derived. The society's or central planner's optimization problem is:

$$\max_{A_t, C_t, u_t} \sum_{t=0}^T \left\{ \left[\ln C_t - \frac{\phi}{1+\psi} \cdot \left(\frac{K_t}{A_t} \right)^{\gamma \cdot (1+\psi)} \right] \cdot (1+\sigma)^{-t} \right\}. \quad (6)$$

subject to the :

physical capital accumulation constraint:

$$K_{t+1} - K_t = K_t^\beta \cdot (u_t \cdot h_t)^{1-\beta} - C_t - A_t$$

and the human capital accumulation constraint:

$$h_{t+1} - h_t = h_t \cdot \varepsilon \cdot (1 - u_t),$$

where

$$0 \leq u_t \leq 1.$$

¹¹ Both instruments are appropriate to reach a first best solution. See for example Baumol/Oates (1988), part I.

Control variables for the maximization problem are abatement activities A , consumption C , and the fraction of non-leisure time devoted to production u in each period t . Human capital h and physical capital K are state variables.

The first order conditions are:¹²

$$\phi \cdot \gamma \cdot \frac{C_t}{K_t} = \left(\frac{A_t}{K_t} \right)^\mu \quad (7)$$

$$\frac{C_{t+1}}{C_t} = \left[1 + \beta \cdot \left(\frac{K_{t+1}}{u_{t+1} \cdot h_{t+1}} \right)^{\beta-1} \right] \cdot \frac{1}{1+\sigma} - \frac{\phi \cdot \gamma}{1+\sigma} \cdot \frac{C_{t+1}}{K_{t+1}} \cdot \left(\frac{A_{t+1}}{K_{t+1}} \right)^{1-\mu} \quad (8)$$

$$\frac{h_{t+1}}{h_t} = 1 + \varepsilon \cdot (1 - u_t) \quad (9)$$

$$\frac{K_{t+1}}{K_t} = \left(\frac{K_t}{u_t \cdot h_t} \right)^{\beta-1} - \frac{C_t}{K_t} - \frac{A_t}{K_t} + 1 \quad (10)$$

$$\left(\frac{K_{t+1}}{K_t} \right)^\beta \cdot \frac{1+\varepsilon}{1+\sigma} = \frac{C_{t+1}}{C_t} \cdot \left(\frac{h_{t+1}}{h_t} \right)^\beta \cdot \left(\frac{u_{t+1}}{u_t} \right)^\beta \quad (11)$$

Equation (8) is the EULER-equation for this model. If we substitute (7) and replace the term $[K/(u \cdot h)]^{\beta-1}$ by Y/K , equation (8) reduces to:

$$\frac{C_{t+1}}{C_t} = \frac{1 + (\beta \cdot Y_t - A_t) \cdot K_t}{1 + \sigma} \quad (12)$$

This condition is also known as the KEYNES-RAMSEY-RULE that describes the optimal consumption path over time. The ratio of future to present consumption is determined by unity plus private marginal product of physical capital, corrected by the term $(-A/K)$, and discounted with the rate of time preference. The rule differs from the market solution without internalization by the term $(-A/K)$ due to the fact that the use of physical capital causes an externality which affects the individuals utility. There is a wedge between private and social return to physical capital. $(\beta \cdot Y/K - A/K)$ can be seen as the social interest rate for physical capital. In the case of negative externalities, the marginal product of physical capital must be higher in order to attain the same optimal growth rate of consumption than without one. Consumption grows, remains constant or declines if the social interest rate is larger, equal or smaller than the rate of time preference σ .

2.2. Long term growth rates

In this subsection we show first that in the long run all endogenous variables grow along a balanced growth path (BGP) and then we discuss the effects of environmental care on the long term growth rates.

¹² Defining μ as $(1 + \gamma + \gamma\psi)$.

2.2.1. Derivation of the growth rates

Long run growth rates are endogenous in our model. A growth path is called balanced if all variables (A , C , h , K , Y , u) grow at a constant rate. In the following, we determine analytically the long run growth rates of various variables.¹³

Rearranging equation (9) leads to:

$$u_t = 1 - \frac{\hat{h}}{\varepsilon}. \quad (13)$$

From equation (13) we see that u does not change over time, it \hat{h} is constant.

Taking logs of both sides of equation (7) and differentiating it with respect to time we get:

$$\hat{C} = \mu \cdot \hat{A} + (1 - \mu) \cdot \hat{K}. \quad (14)$$

Inserting A/K from equation (7) into (8) and replacing the term $[K/(u \cdot h)]^{\beta-1}$ by Y/K leads to:

$$\hat{C} = \left(\beta \cdot \frac{Y}{K} - \sigma \right) \cdot \frac{1}{1 + \sigma} - \frac{(\phi \cdot \gamma)^{\frac{1}{\mu}}}{1 + \sigma} \cdot \left(\frac{C}{K} \right)^{\frac{1}{\mu}} \quad (15)$$

Inserting A/K from equation (7) into (10) and replacing the term $[K/(u \cdot h)]^{\beta-1}$ by Y/K leads to:

$$\hat{K} = \frac{Y}{K} - \frac{C}{K} - (\phi \cdot \gamma)^{\frac{1}{\mu}} \cdot \left(\frac{C}{K} \right)^{\frac{1}{\mu}} \quad (16)$$

Inserting Y/K from equation (15) into (16), and differentiating it with respect to time, we see that:

$$\hat{C} = \hat{K}. \quad (17)$$

Inserting C/K from equation (15) into (16), and differentiating it with respect to time, we find that:

$$\hat{K} = \hat{Y}. \quad (18)$$

Taking logs of both sides of the production function (2), differentiating the production function with respect to time, and taking equation (18) into consideration we get:

$$\hat{h} = \hat{Y}. \quad (19)$$

Inserting equation (17) into (14) leads to:

$$\hat{A} = \hat{C}. \quad (20)$$

Equations (17) - (20) show that variables A , C , h , K and Y grow at the same constant rate along a BGP.

Using this result, we get from equation (11) that the growth rate g for those variables is given by:

$$\hat{A} = \hat{C} = \hat{h} = \hat{K} = \hat{Y} \equiv g = \frac{1 + \varepsilon}{1 + \sigma} - 1 \quad (21)$$

We see from equation (21) that long run growth depends on preferences and technology and is thus endogenous. The larger is the exogenous studying parameter ε and the smaller is the rate of time preference σ , the higher is the rate of growth. Marginal productivity in education rises if ε rises or if u declines. If ε rises, it is more attractive for the individuals to spend more time in the education sector. Human capital grows faster raising marginal productivity of physical capital up to the point where both marginal productivities are equal. This also leads to a higher accumulation of physical capital and

¹³ A variable with a hat stands for growth rate, e.g. $\frac{X_t}{X_{t-1}} - 1 \equiv \hat{X}_t$.

results in a higher growth rate g . If the rate of time preference declines, i.e. future consumption is higher valued, individuals spend more time in education which raises the marginal productivity in education. Again, human and physical capital grows faster which results in a higher growth rate g .

2.2.2. Effects of environmental care on growth rates

As a general rule it can be stated that the internalization of external effects has an impact on the endogenous growth rate if it affects the incentive to invest in the engine of growth. The engine of growth is also called the core of the model.

*The core can be defined as the set of reproducible production factors that can be produced according to technologies that feature (taken together) constant returns with respect to the same set of production factors.*¹⁴

Equation (21) on page 8 shows that the endogenous growth rate is solely determined by the discount rate σ and the studying productivity parameter ϵ , but not by abatement activities of pollution. Therefore in the long run the growth rates of the variables are not affected by environmental policy.

In this model the core is human capital accumulation. Human capital accumulates at a constant rate on the BGP. The dirty factor of production is physical capital. Internalization equalises private and social marginal productivity of physical capital, but it does not affect the marginal productivity of human capital accumulation. Due to arbitrage between human and physical capital accumulation, the long run growth rates are not affected by environmental policy. On the BGP marginal productivity of human and physical capital is equal.

It is important to distinguish between optimal and feasible growth. Optimal growth is determined by preferences. Growth is optimal when it is welfare maximising, no matter if the growth rate is higher or lower after the internalization. Feasible growth on the other hand is determined by technology.¹⁵ If human capital was the dirty input, there would be a trade off between environmental care and economic growth. In this case the optimal growth rate would be lower than the feasible growth rate.

If the technological externality caused by physical capital does not only harm utility but also the profitability of human capital investment, optimal growth rates can even be higher than those achieved in a market economy where pollution is not internalized.¹⁶

2.3. Long term ratios of variables

In the last subsection we have seen that the model grows along a balanced growth path in the long run. All variables, apart from u , grow with the same constant rate g which is not affected by environmental policy.

The ratios of the variables in the long run are needed in order to make comparative statics. Then we are able to analyse how the ratios A/K , C/K and K/h change, when we vary ϕ . Additionally we need good

¹⁴ Smulders (1994), p. 15.

¹⁵ See Smulders 1994, p. 5, for further discussion.

¹⁶ Gradus/Smulders (1993) section 4, pp. 38-43.

start values for the simulation.

We derive first the ratios of the variables and then we discuss how environmental care affects the ratios.

2.3.1. Derivation of the ratios of variables

For the derivation of the ratios, the relevant first order conditions difference equations (7) - (10) can be rewritten to:

$$\phi \cdot \gamma \cdot \frac{C_t}{K_t} = \left(\frac{A_t}{K_t} \right)^\mu \quad (22)$$

$$g = \left[\beta \cdot \left(\frac{K_t}{u_t \cdot h_t} \right)^{\beta-1} - \sigma \right] \cdot \frac{1}{1+\sigma} - \frac{\phi \cdot \gamma}{1+\sigma} \cdot \frac{C_t}{K_t} \left(\frac{A_t}{K_t} \right)^{1-\mu} \quad (23)$$

$$g = \varepsilon \cdot (1 - u_t) \quad (24)$$

$$g = \left(\frac{K_t}{u_t \cdot h_t} \right)^{\beta-1} - \frac{C_t}{K_t} - \frac{A_t}{K_t} \quad (25)$$

Inserting equation (21) into (24) we yield the fraction of non-leisure time devoted to production on the BGP.¹⁷

$$u_{BGP} = \frac{\sigma \cdot (1 + \varepsilon)}{\varepsilon \cdot (1 + \sigma)}, \quad (26)$$

Inserting C/K from equation (22) into (23) and (25), and then substituting the factor ratio $(\dots)^{\beta-1}$ of one equation into the other yields the ratio of A and K :

$$0 = \frac{\varepsilon \cdot (\sigma + 1 - \beta) + \beta \cdot \sigma}{1 + \sigma} + (1 - \beta) \cdot \left(\frac{A}{K} \right)_{BGP} - \left[\left(\frac{A}{K} \right)_{BGP} \right]^\mu \cdot \frac{\beta}{\phi \cdot \gamma}. \quad (27)$$

In the same fashion we get an equation for the ratio of C and K by inserting A/K of equation (22) into (23) and (25):

$$0 = \frac{\varepsilon \cdot (\sigma + 1 - \beta) + \beta \cdot \sigma}{1 + \sigma} - \beta \cdot \left(\frac{C}{K} \right)_{BGP} + (1 - \beta) \cdot \left[\left(\frac{C}{K} \right)_{BGP} \right]^\mu \cdot (\phi \cdot \gamma)^{\frac{1}{\mu}}. \quad (28)$$

And by inserting C/K of equation (22) into (23) and (25), and then substituting A/K of one equation into the other yields the ratio of K and h by :

$$0 = \frac{\sigma \cdot (1 + \varepsilon)}{1 + \sigma} + (1 - \beta) \cdot \left[\frac{1}{u_{BGP}} \cdot \left(\frac{K}{h} \right)_{BGP} \right]^{\beta-1} - \frac{1}{\phi \cdot \gamma} \cdot \left\{ \beta \cdot \left[\frac{1}{u_{BGP}} \cdot \left(\frac{K}{h} \right)_{BGP} \right]^{\beta-1} - \varepsilon \right\}^\mu. \quad (29)$$

¹⁷ All relations of the variables on the BGP are marked with the subscript *BGP*.

Along the BGP the ratios of all variables are constant over time. Equations (27), (28), and (29) cannot be solved analytically for A/K , C/K , and K/h , respectively. Also net pollution P is constant on the BGP, because both variables A and K grow at the same constant rate.

2.3.2. Effects of environmental care on ratios

From subsection 2.2.2. we know that in the long run endogenous technical progress is not affected by environmental policy (here modelled as a change in ϕ). But of course it affects the ratio of the variables on the BGP. Equation (27), (28), and (29) describe how the ratios A/K , C/K , and K/h change, if we modify ϕ , given all other parameters. For reasonable parameters, ratios A/K and C/K are increasing and K/h is a decreasing function of ϕ .

The fraction of time devoted to production [equation (26)] is independent of any environmental policy measure. It is an increasing function of σ and a decreasing function of ε as we can see by the following differentiations:

$$\frac{\partial u_{BGP}}{\partial \varepsilon} < 0 \quad \text{and} \quad \frac{\partial u_{BGP}}{\partial \sigma} > 0.$$

3. The Simulation of the transition path

So far we investigated the effects of environmental care on growth as well as on the ratios of the variables in the long run i.e. on the balanced growth path. Now we come to the analysis of the transition path of the system after an exogenous shock to a new BGP. In our analysis we focus on a shock caused by increased environmental protection. From subsection 2.2.2. we know that growth rates on the new BGP are not affected by environmental policies (modelled as a change in ϕ). But due to the structural break, we can expect lower growth rates along the transition to the new BGP, i.e. in the short and medium term. Levels of consumption or output in the scenario of increased environmental care (IEC) are therefore expected to be lower in the new equilibrium compared to business as usual (BAU) where pollution control is unchanged. In the following qualitative and quantitative aspects of the shock are analysed. Moreover, in this chapter we try to answer the following questions:

- How large are the differences of abatement activities, consumption, and output levels during and after the policy change, compared with BAU?
- How big are the losses or gains of growth in consumption and output during the shock? This question becomes particularly relevant if we assume that the government is confronted with political restrictions concerning growth losses.
- How long takes the transition process? If the adaptation takes a long time being accompanied by welfare losses, we are facing intergenerational problems.
- What are the effects on welfare if we assume that environmental protection alters from a sub optimal to an optimal level (or rather in direction to the optimal level)? It is obvious that in the long run individuals are better off, but how are the effects during the adaptation process? For example how is welfare in year 1 or 2 after the shock compared to BAU? Are there hard times?
- Do the results change if policy measures are announced, i.e. if individuals know in advance that the price for pollution will be higher in the future?

To answer the questions above we need to know how welfare and levels of the key variables develop during the transition. To figure out how the adaptation process looks like and what the path determines, we simulate the transition process of the model with GAMS, using plausible parameter values.

In subsection 3.1. the determination of reasonable parameter values and the calibration of the model is described. Subsection 3.2. summarises the simulation results and is structured as follows. First, the increased environmental care scenario is illustrated graphically, and the transition process is explained (subsection 3.2.1.). Then the results will be confronted with the scenarios where environmental policy measures are announced (subsection 3.2.2.). Third, the main results of the different scenarios are discussed (subsection 3.2.3.). Subsection 3.2.4. finishes with a sensitivity analysis.

3.1. Determination of reasonable parameter values

The results of the numerical simulation depends on the choice of the exogenous parameter values. We can calibrate the parameters so as to capture a number of empirical stylised facts of the FEDERAL REPUBLIC OF GERMANY.

As an approximation for the long term growth rate g , we compute the per capita growth rate of the average real gross domestic product between 1971 and 1991. The rate of time preference is approximated by the average deflated mortgage bond yield between 1971 and 1991.¹⁸ Therefore, we set g equal to 1.969% and σ equal 3.784%. Using equation (21) we calibrate the studying productivity parameter $\varepsilon = 5.827\%$.

We then fix the share of physical capital in the production function $\beta = 0.25$,¹⁹ the elasticity of the ratio K/A of the pollution function $\gamma = 1$, and the elasticity of marginal utility of environment $\psi = 0.1$.²⁰ For $\gamma = 1$, gross pollution is a linear function of the physical capital stock. For $\psi > 0$, utility is decreasing in pollution.

In Western Germany pollution abatement and control expenditures as a percentage of GDP were 1.6% in the years 1987-1990.²¹ Therefore, we calibrate ϕ (sensitivity towards pollution in the utility function) such that abatement expenditures in our model satisfy this share with respect to GDP. This is fulfilled for ϕ being set equal to 0.0004055 in the IEC scenarios. The share of physical capital in the production function β , the rate of time preference σ , ψ and γ are varied in a sensitivity analysis at the end of this chapter. In all scenarios, parameter values are chosen such that the growth rate remains at 1.97% and pollution abatement at 1.6% of output on the initial balanced growth path. We presume that environmental care is below the optimal policy level on the initial balanced growth path. After the policy change the share of abatement activities as a percentage of GDP is 4%. Optimal environmental policy

¹⁸ For the computation we use the annual statistics of the OECD main economic indicators 13100310 (FDR GDP, current prices, million DM, Western Germany), 13102512 (FDR GDP implicit price level, I/90, Western Germany), IMF International Finance Statistics of the industrialised countries 134 61A (mortgage bond yield, Germany per annum, Z A51) and EUROSTAT 123000000 (total working population /male and women, Western Germany, 1000 Source).

¹⁹ Following Lucas (1988), p. 26.

²⁰ Gradus/Smulders (1993), p. 42.

²¹ OECD (1993), table 14.2A, p. 294.

requires that this share rises to 8%. This value is chosen arbitrarily. For a qualitative analysis of the adaptation process this level is not substantial but it is needed to make the different scenarios comparable. Therefore, due to this assumption increased environmental efforts enhance welfare in the long run.

Although this is the usual approach for a calibration, it is objectionable. If the model is calibrated as described above, we implicitly assume that it is at least a good approximation of the real world. Furthermore, we suppose the real world to be on a balanced growth path. We should be aware of the underlying assumptions but nevertheless, we gain some interesting insights in how increased environmental care influences growth rates and welfare during the adaptation process.

3.2. Simulation results

Our simulation covers 60 periods. For all scenarios the economy reaches its new BGP within this period of time. The resource constraint has to be fulfilled exactly in every period. The accumulated computing error of the resource constraint over all periods in all scenarios is at least smaller than $1 \cdot \exp(-15)$. In year 1 the government increases the costs of physical capital. In the long run pollution abatement, as a percentage of domestic product, increases from 1.6% to 4%.

3.2.1. Increased environmental care scenario

Figure 1 traces the growth rates of output and consumption during the transition after an unanticipated environmental policy change. The horizontal axis is the time axis, measured in years, the vertical axis represents the growth rates of both variables.

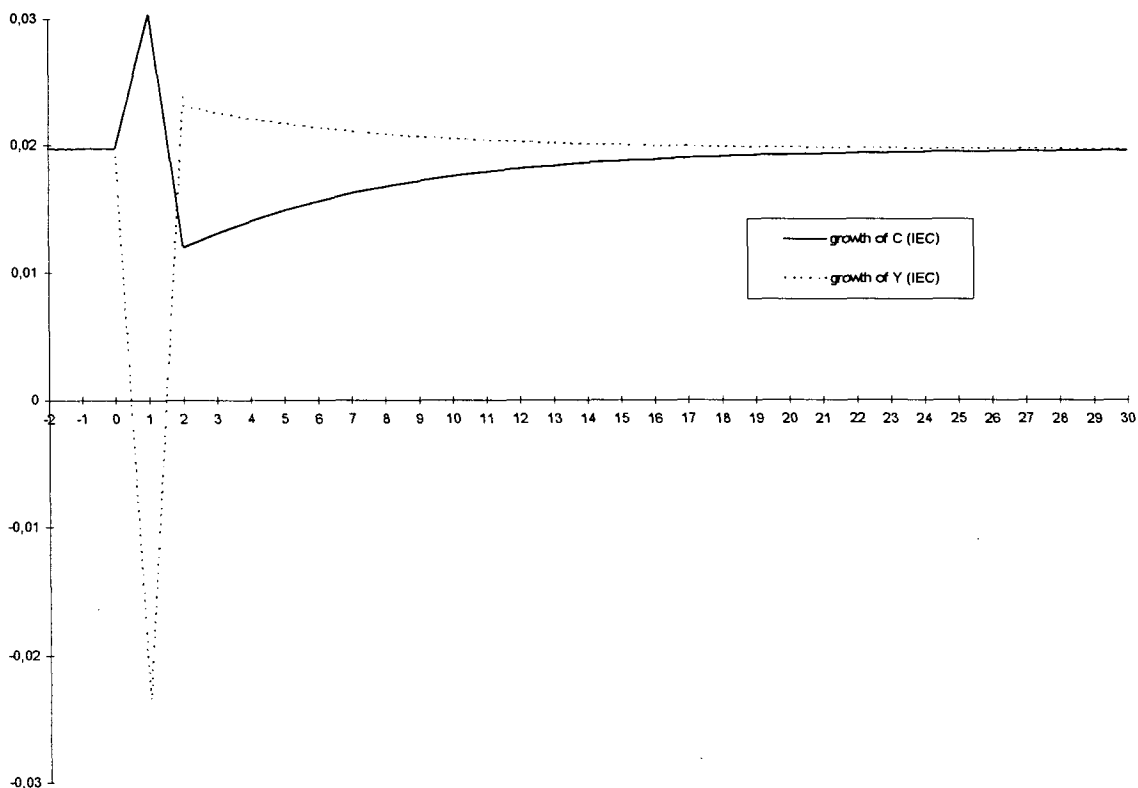


Figure 1: Growth rates of output and consumption.

In the years before the shock ($t = -2$ to 0) both growth rates are on the BGP equilibrium levels of 1.97%. They converge to this value again in the long run. In year 1 when the government changes its environmental policy, output growth declines to minus 2.34%, but already in year 2 it is positive again and with 2.31% over its equilibrium rate. During the following years output growth converges to its steady state value. Between year 1 and 45 output growth is above the equilibrium rate. However, the *level* of output in all years is below the BAU levels. Therefore growth rates above 1.97% are due to the negative growth rate in year 1.

Growth of consumption is almost mirror-inverted to output growth. In year 1 consumption growth increases above its long term growth rate at 3.04%. Although the price for pollution is increased, it is optimal to enlarge consumption. This can be interpreted as a kind of overshooting: In year 1 firms realise that marginal productivity of human capital compared to physical capital is too low. Therefore investment in physical capital is almost zero, but at the same time abatement activities are increased. Economic agents increase education efforts and the fraction of time devoted to production decreases. Increased abatement activities and the decline of output do not offset reduced investments, hence consumption is above its BAU level. But already in year 2 the growth rate of consumption declines to 1.19%.

We observe the same kind of path for the abatement growth rates. In year 1 the growth rate increases up to 173.43%, in year 2 it is 0.57%, then it converges to its steady state growth rate. (See figure A1 in the appendix on page 24 for a graphical illustration.)

In the long run the share of physical to human capital in the input mix must decrease because physical capital is the dirty factor. Due to decreased marginal productivity of physical capital resulting from increased costs of pollution, marginal productivity of human capital is relatively higher. Investment in physical capital declines in year 1 and demand for human capital is increased. The fraction of time devoted in education increases and yields a higher human capital accumulation. After year 1 the growth rates of investment and the fraction of time converge back to their steady state values. Growth rates of physical and human capital stock therefore possess the following paths:

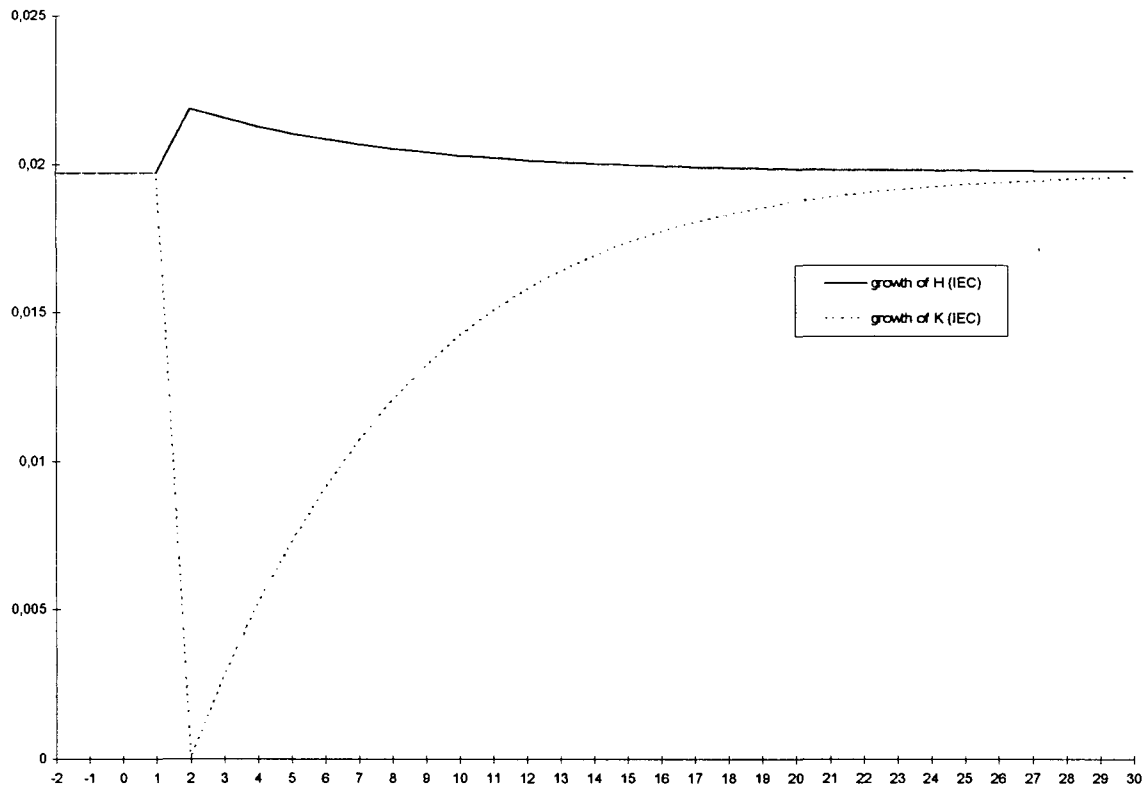


Figure 2: Growth rates of physical and human capital stock.

Due to tightening of environmental care, there is a sudden and significant decline of output growth, even down to a negative level. However this decline is very limited in time (only period 1). In contrast, consumption growth increases in period 1 on a level above its equilibrium rate but, in period 2 it is below the equilibrium value.

3.2.2. Announcement effects

In subsection 3.2.1. we analysed an unanticipated change in environmental policy. We now assume that the economic agents know in advance of the policy change. Furthermore, we assume that all individuals believe in the announced policy changes. In this subsection we first compare both announced scenarios that describe announcement effects of 5 and 10 years, respectively (in the figures indicated with IEC_a5 and IEC_a10, respectively), with the already known unanticipated increase of pollution costs (the IEC scenario, described in subsection 3.2.1.). Second we describe a further scenario, the IEC_grad scenario, where the government gradually increases costs of pollution within the first 10 years. Every increase of pollution is known in year 1.

In the following three figures (figures 3 to 5) growth rates of the IEC scenario are compared with the growth rates of the IEC_a5 and IEC_a10 scenarios. For a better comparability of the different scenarios growth rates of abatement, consumption, and output are depicted in different figures. In figure 3 growth rates of consumption, in figure 4 growth rates of output and in figure 5 growth rates of abatement activities are traced. The announcement of the policy measure produce an effect already in the year of announcement. After the year where the policy action takes place (year 5 or 10) we observe the same kind of path like in the scenario without announcement. However, the deflections are smaller.

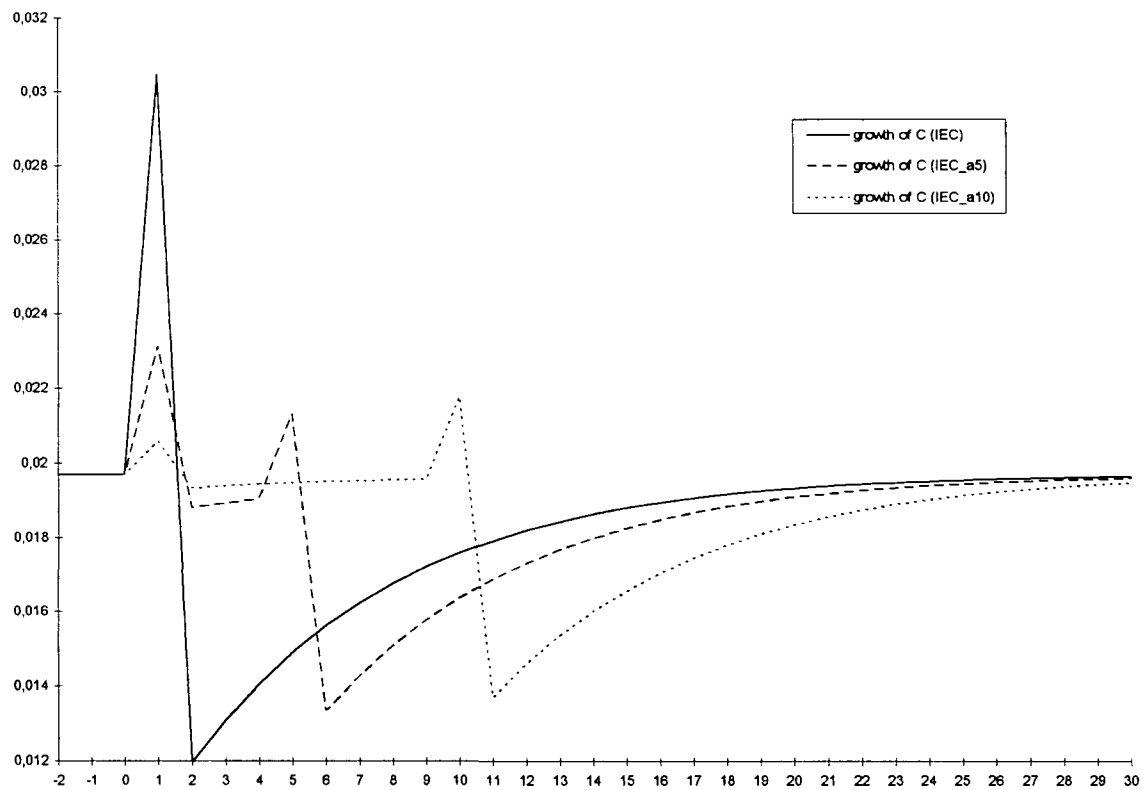


Figure 3: Growth of consumption in the three scenarios.

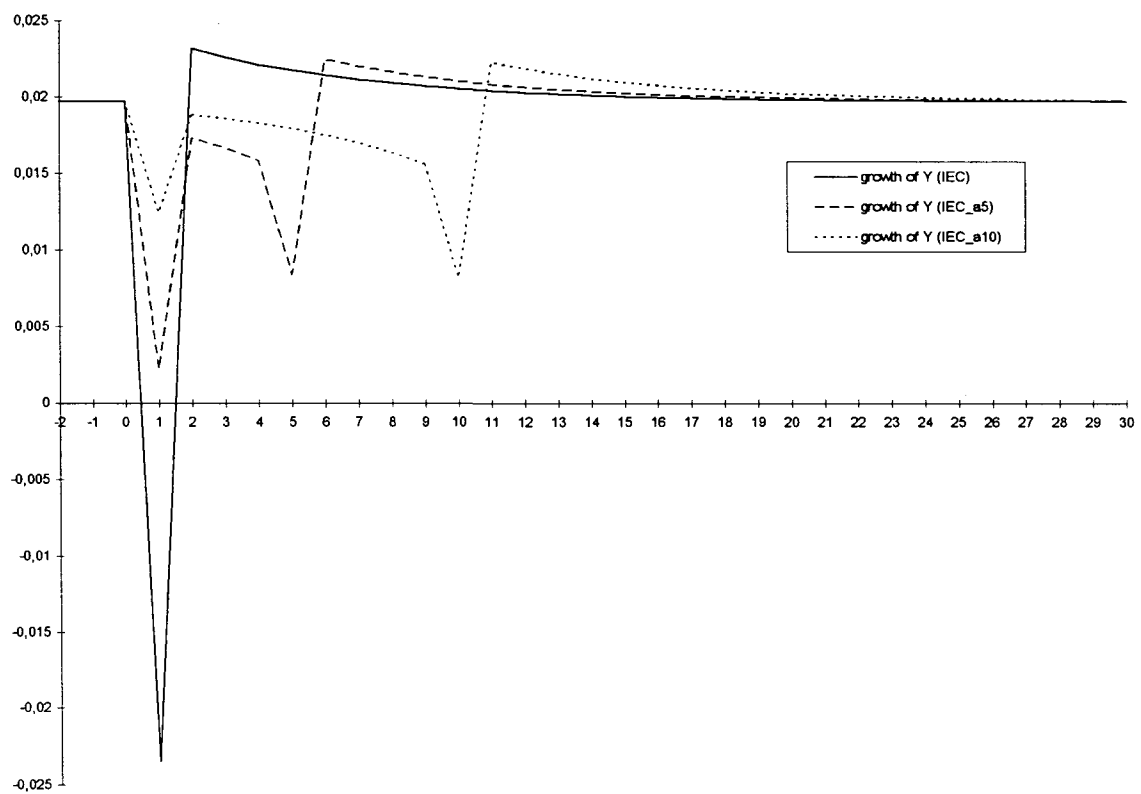


Figure 4: Growth of output in the three scenarios.

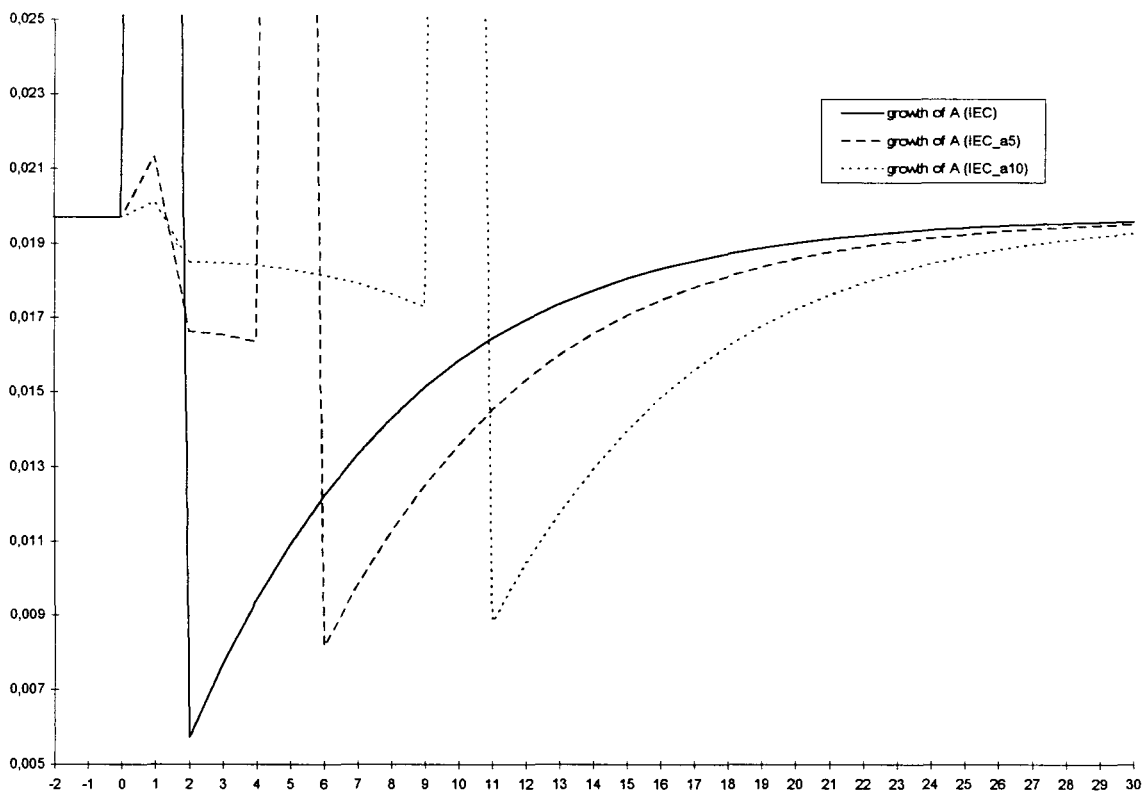


Figure 5: Growth of abatement activities in the three scenarios.²²

With announcement of the environmental policy there is no negative output growth rate at any point of time.

In an further scenario, called the IEC_grad scenario, the government *gradually* increases the costs of pollution in the first 10 years. The time path of the policy action is known by the individuals in year 1. Figure 6 describes the growth rates of output, consumption, and abatement activities. The paths of the growth rates are quite similar to that of the IEC scenario, however the deflections of the growth rates to the equilibrium growth rates are smaller but stretched over 10 years reflecting the gradual increase of environmental costs between year 1 and 10. In this scenario output growth rates are below their equilibrium values not only in the first period (like in the IEC scenario), but also within the first 10 years where the policy measures take place – without being negative.

²² Growth rates of A in year 1, A_a5 in year 5, and A_a10 in year 10 are 173.43%, 171.36%, and 171.58% respectively. For reasons of scaling they are not depicted in the figure.

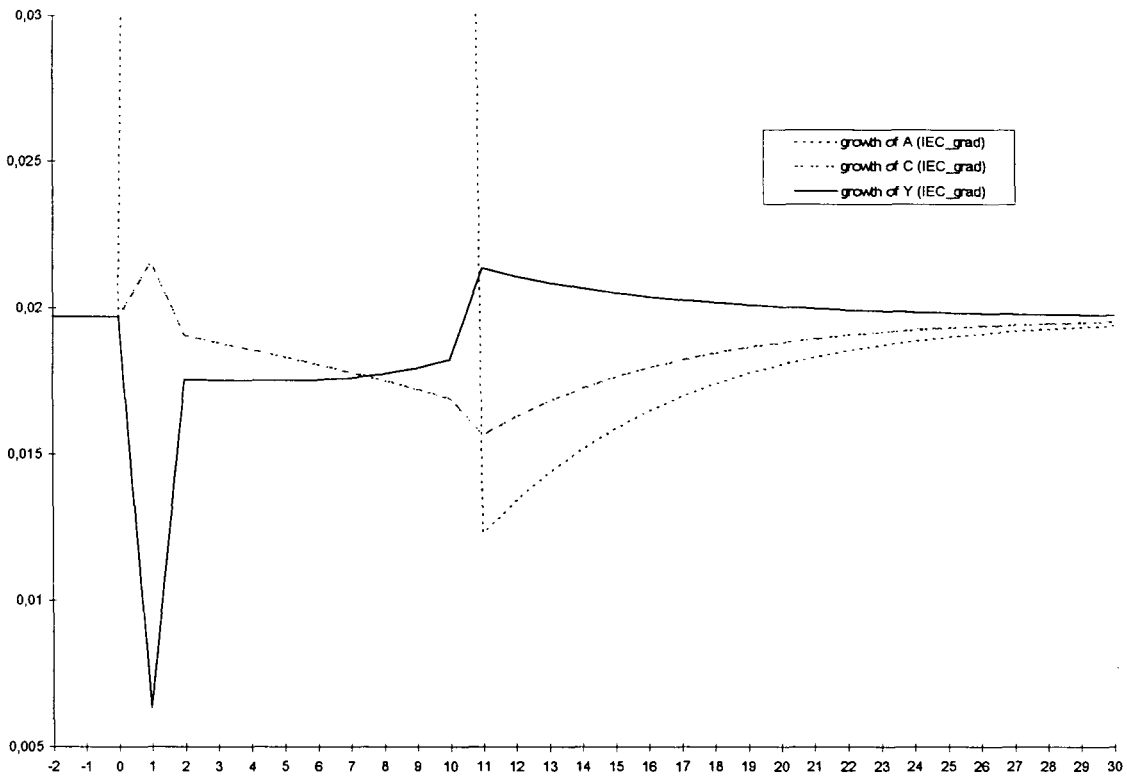


Figure 6: Growth of abatement, consumption and output in the IEC_grad scenario.²³

3.2.3. Comparison of the main results of the different scenarios

Table 1 represents the main results of the different scenarios analysed in subsection 3.2.1. and 3.2.2. It is structured as follows: transitional implications are split into effects on levels, effects on welfare and into political indicators. The BAU scenario in column 2 serves as a benchmark case for the different IEC scenarios. Effects on levels and welfare are computed as a percentage deviation from the BAU scenario. Exogenous parameters for the BAU and all IEC scenarios are determined to be $\beta = 0.25$, $\gamma = 1$, $\psi = 0.1$, $\sigma = 0.0378446$, and $\varepsilon = 0.05828794$. The only exogenous parameter being different is ϕ . In the BAU scenario ϕ is set equal to 0,000040555, but equal to 0.000318496 in the IEC scenarios which reflects the fact that pollution abatement as a percentage of domestic product increases from 1.6% to 4% in the long run. In the long run investment as a percentage of domestic product and the ratios of physical and human capital decreases from 7.91% and 4.22 in the BAU scenario to 7.1% and 3.65 in the IEC scenarios, respectively. In all scenarios the long term growth rate g is equal to 1.97%.

²³ In the years 1 to 10 abatement growth decreases from 12.59% (year 1) to 11.71% (year 10).

scenario		BAU	IEC	IEC_a5	IEC_a10	IEC_grad
announced span of time		0	0	5	10	*
effects on levels						
abatement consumption output	levels in the shock year as a % of BAU	100	268.16	264.05	263.08	*
		100	101.05	100.27	100.1	*
		100	95.76	96.31	96.5	*
abatement consumption output	sum of the levels over all years as a % of BAU	100	245.97	240.86	233.85	239.08
		100	96.39	96.64	96.91	96.7
		100	97.67	97.83	97.87	97.85
effects on welfare						
shock period period after the shock	welfare as a % of BAU	100	127.73	126.19	111.83	*
		100	127.06	125.63	111.5	*
sum of welfare over all years ²⁴ as a % of BAU		100	119.19	117.96	107.58	118.11
political indicators						
consumption output	highest growth rate (with year of appearance)		3.04 (1) 2.31 (2)	2.31 (1) 2.25 (6)	2.18 (10) 2.23 (11)	2.16 (1) 2.13 (11)
consumption output	lowest growth rate (with year of appearance)	- -	1.2 (2) -2.35 (1)	1.33 (6) 0.22 (1)	1.37 (11) 0.82 (10)	1.56 (11) 0.63 (1)
duration of transition (in years) ²⁵		0	45	48	53	50

Table 1: Results of the IEC scenarios.

* Cost of pollution increase gradually within the first 10 years. The time path of the policy action is known by the individuals in year 1.

Column 3 representing the IEC scenario, shows an unanticipated policy change. Pollution abatement and control expenditures as a percentage of domestic product increase from 1.6% (BAU scenario) to 4%. Already in year 1 welfare increases by 27,73%. There are no hard times for individuals from a welfare point of view. This is true for *all* years and *all* scenarios. During the transition process people do not suffer from the structural change because the utility losses arising from the decline in consumption and output are more than offset by the utility gains from decreased pollution.

Comparing the IEC scenario with scenario IEC_a5 and IEC_a10 where the policy change is announced 5 and 10 years in advance, respectively, we observe that the deflections of the output and consumption growth rates become smaller the longer is the announced span of time. However, the overall gains of welfare decrease,²⁶ and the duration of the transition process increases with the announced span of time. An unanticipated change hence yields the highest welfare gains.

In scenario IEC_grad environmental costs are increased gradually. Compared with IEC_a5 and IEC_a10 it yields a higher overall welfare, with growth deflections being somewhere in-between of both scenarios.

²⁴ The simulation covers 60 years.

²⁵ The actual growth rate converges to the steady state value. Rounding error is 1/1000.

²⁶ This is the case, since during the announcement lag the environmental policy action is unchanged. Whereas in the IEC scenario during this period of time costs of pollution have already increased.

3.2.4. Sensitivity analysis

A sensitivity analysis enables us to test to which extent the results in subsection 3.2.3. depend on the chosen parameter values and if results change dramatically by slightly modifying one parameter value. Since the determination of parameter values is somehow arbitrary a sensitivity analysis is necessary. Table 2 shows the results of the sensitivity analysis, where first exogenous parameter values, second ratios of variables on the new BGP and finally transitional implications are listed. The sensitivity scenarios 1-6 cannot be compared to the BAU scenario: due to differing parameter values they have their *own* BAU scenario which is not listed. Therefore the percentage deviation of levels and welfare relate to their corresponding BAU scenario. In the following we compare the sensitivity scenarios with the IEC scenario. Deviations from the IEC parameter values are indicated with shade.

sensitivity scenario	1	2	3	4	5	6
exogenous parameter						
β	0.2	0.4	0.25	0.25	0.25	0.25
γ	1	1	1	1	0.8	1.2
ψ	0.1	0.1	0.1	0.1	0.1	0.1
ϕ	0.000421	0.000186	0.000274	0.000359	0.001016	0.000098
σ	0.037844	0.037844	0.3	0.45	0.037844	0.037844
ε	0.058287	0.058287	0.050280	0.065584	0.058287	0.058287
announced span of time	0	0	0	0	0	0

ratios of the variables on the new BGP (in the long run)						
long term growth rate g	1.97	1.97	1.97	1.97	1.97	1.97
pollution abatement as a % of domestic product	4	4	4	4	4	4
consumption as a % of domestic product	90.59	83.83	87.78	89.69	88.9	88.9
investment as a % of domestic product	5.4	12.17	8.22	6.3	7.1	7.1
ratios of physical and human capital	2.34	13.76	4.09	3.3	3.66	3.66

effects on levels						
abatement consumption output	levels in the shock year as a % of BAU	272.74	261.8	268.13	268.16	266.96
		101.17	100.71	101.16	100.97	101.05
		94.10	98.23	95.57	95.92	95.78
abatement consumption output	sum of the levels over all years as a % of BAU	245.27	245.4	246	245.96	245.91
		96.31	96.07	96.48	96.33	96.4
		97.85	97.29	97.57	97.74	97.67

effects on welfare							
shock period	welfare period after the shock } as a % of BAU	127.9	134.81	127.6	125.51	118.6	143.54
period after the shock		127.25	133.95	126.92	124.98	118.07	142.6
sum of welfare over all years as a % of BAU		117.33	121.47	118.63	117.96	112.64	129.93

political indicators							
consumption	highest growth rate (with year of appearance)	3.16 (1)	2.69 (1)	3.14 (1)	2.96 (1)	3.04 (1)	3.05 (1)
output		2.81 (2)	1.97 (52)	2.29 (2)	2.33 (2)	2.31 (2)	2.31 (2)
consumption	lowest growth rate (with year of appearance)	0.9 (2)	1.52 (2)	1.27 (2)	1.12 (2)	1.2 (2)	1.19 (2)
output		-4.04 (1)	0.16 (1)	-2.54 (1)	-2.19 (1)	-2.33 (1)	-2.36 (1)
duration of transition (in years)		38	52	40	41	45	46

Table 2: Results of the sensitivity analysis.

In the sensitivity scenario 1 and 2, the share of physical capital in the production function is varied. With $\beta = 0.2$ the economy is less and with $\beta = 0.4$ it is more physical capital intensive. The proportion

to output of abatement activities and investment is higher and of consumption is lower for the capital intensive economy, compared with the IEC scenario. The capital intensive economy is also more pollution intensive. Therefore a tighter environmental policy induces a stronger welfare increase and the deflection of the growth rates are smoother than in the IEC scenario. The opposite applies to the less physical capital intensive economy. The sensitivity scenario has one special feature. During the transition we do not observe output growth rates above its equilibrium rate, as it is the case for all others scenarios. Moreover the output growth rates during the whole adaptation process are below this equilibrium value.

In the sensitivity scenario 3 and 4 the rate of time preference is varied. Individuals value the future higher in the sensitivity scenario 3 and lower in 4. Given the growth rate g being equal to 1.97% we must calibrate the studying productivity parameter ε in those scenarios again. The percentage of investment in sensitivity scenario 4 (higher rate of time preference) is lower as in the IEC scenario, because individual value the future less than the presence compared to the IEC scenario. Therefore the ratio of physical to human capital is lower. The opposite is true for the sensitivity scenario 3. The other results are quite similar to the IEC scenario.

The elasticity γ of the ratio K/A of the pollution function is modified in the sensitivity scenario 5 and 6. $\gamma > 1$ implies that the economy becomes *ceteris paribus* more pollution intensive for every unit of physical capital over time.²⁷ The increase of welfare is higher than in the IEC scenario (vice versa for $\gamma < 1$). Certainly $\gamma > 1$ does not seem to be realistic. One would rather assume that the economy becomes less pollution intensive for every unit of physical capital over time due to technical progress. However, the results are in both cases more or less the same.

Summarising the results gained from the sensitivity analysis we see that the qualitative properties of the adaptation process remain unchanged in all scenarios. This does not apply for the sensitivity scenario 2, where output growth rates during the whole adaptation process lie below their equilibrium values. Moreover, quantitative differences are of minor importance.

4. Conclusion

In all scenarios (including the IEC and the sensitivity scenarios) the sum of abatement activities over a range of 60 years increases at least by 133%, whereas the sum of losses in consumption and output in the worst case equals 4% and 2.5%, respectively. The aggregated material losses are small compared to the aggregated increase of the abatement activities.

The sooner policy actions are announced, the smaller are the deviations of growth rates compared to the equilibrium values, and the smaller are the aggregated welfare gains. The starting point for the welfare analysis here is not where the policy action takes place, but where it is announced. Therefore, the welfare gains are the smaller the larger the announcement period is.

The adaptation of the growth rates to the new BGP are non-monotonous: Apart from a sharp decline in

²⁷ $\hat{p} = \gamma \cdot (\hat{K} - \hat{A})$; on the BGP is $\hat{K} - \hat{A} = 0$.

the period where the policy action takes place, growth rates of the national product are above their equilibrium value during the whole adaptation process. The course of the consumption growth rates is almost mirror inverted. After an increase in period one above its equilibrium value, the consumption growth rate sharply declines and finally slowly converges back.

In terms of welfare there are no hard times at all. Already in year 1 welfare *in all scenarios* increases by at least 10%, which means there are no intergenerational problems. From a welfare point of view, not only in the long run but also in the short run there is no reason to refrain from environmental policy.

However, from a political economy point of view it may be interesting how growth rates of the national product behave after tightening environmental policy. 69% of the EUROPEAN COMMUNITY'S population believe that economic growth must be ensured but the environment protected at the same time. 4% believe that economic development should get higher concern than economic development.²⁸ According to this figures the majority would like to have increased environmental care without growth losses. With regard to the public opinion survey the government could assume that its capability is solely valued in terms of GDP growth rates. Therefore it will be very reluctant to tighten environmental policy if this is accompanied with growth losses, since then the re-election probabilities solely depend on the growth rate of the national product. This assumption concerning government behaviour is extreme, but it is certainly an important factor of influence.²⁹ It would be somehow more realistic to assume that the re-election probability additionally depends on success in reducing pollution. The government faces a trade-off between reducing pollution and the growth rate of the national product. But this trade-off only exists in the first period, because after year 1 growth rates of output lie above the long term growth rate. Whether and how long the government announces the tighter environmental policy to avoid large output growth losses depends on the weight of the two factors of influence.

It is obvious that the GDP is a unsatisfactory indicator for welfare. It is not able to reflect welfare properly nor is it a good approximation. Although consumption growth rates as well do not reflect welfare properly, they are still closer to the welfare criteria.

When analyzing the results we should be conscious of the rigid assumption underlying the analysis: For instance we assumed perfect competition in all markets, a closed economy, homogeneous individuals, inter- and intratemporal additive separable utility functions, perfect information over the whole time horizon, and non-existence of adaptation costs. For the calibration we supposed the real world to be on a balanced growth path. Future work will aim at dealing with these shortages. The introduction of adaptation costs certainly changes the results for the adaptation process: Welfare losses during the transition can be expected, and intergenerational problems may arise. If we allow for heterogeneous individuals there will be losers and winners of the policy change. Another major problem is the assumption of a closed economy, since the most severe environmental problems are international ones. For instance global warming or acid rain damage not only the country of origin but also cross borders.

²⁸ Figures are from OECD (1993), table 14.1A, p. 287.

²⁹ This fact is well known in the political business cycles literature and supported by many econometrically tests. For a listing of various econometric analyses see for example Mueller (1989), chapter 15, table 15.1 and 15.2.

If we open up the economy by considering international externalities and by allowing capital to be internationally mobile this deficiency can be avoided.

5. Appendix

Structure of the economy	
utility function	$U_t = \ln C_t - \frac{\phi}{1+\psi} P_t^{1+\psi}$ $\phi \geq 0, \psi > 0, \text{ and thus } U_C > 0, U_{CC} < 0, U_P < 0, U_{PP} < 0$
net pollution function	$P_t = \left(\frac{K_t}{A_t} \right)^\gamma$ $P_K > 0 \text{ and } P_A < 0$
resource constraint	$Y_t = C_t + I_t + A_t$
physical capital accumulation	$K_{t+1} - K_t = K_t^\beta \cdot (u_t \cdot h_t)^{1-\beta} - C_t - A_t$
production function	$Y_t = K_t^\beta \cdot (u_t \cdot h_t)^{1-\beta} \text{ with } 0 \leq u_t \leq 1$
human capital accumulation	$h_{t+1} - h_t = h_t \cdot \varepsilon \cdot (1 - u_t)$

Table A1: Model in mathematical form.

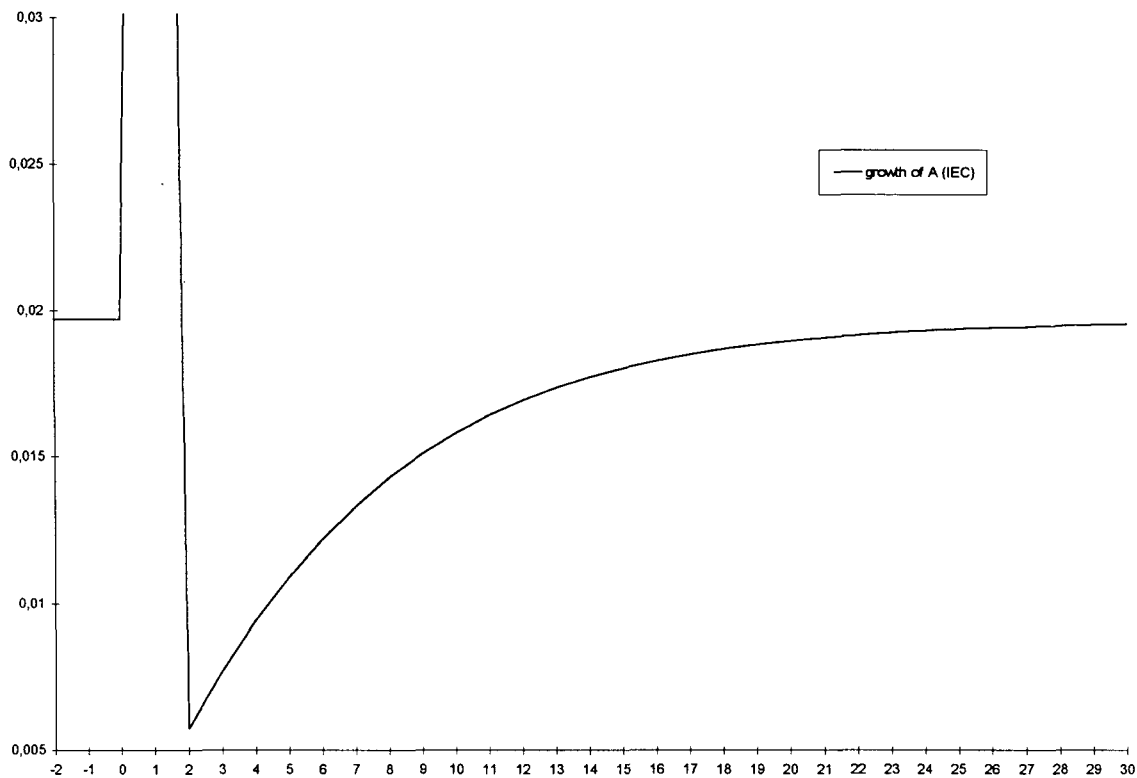


Figure A1: Growth rates of abatement activities.

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Workshop 1995

Environmental Policy in Open Economies

June 5-7, 1995
Waldhaus Jakob, Eichhornstrasse 84, D-78464 Konstanz

Monday, June 5, 1995

19.00 - 21.00 Welcome Reception.

Tuesday, June 6, 1995

Chairman: Heinrich Ursprung.

9.00 - 9.45 *Opening Address:* Hans-Jürgen Vosgerau (Speaker of the SFB 178, Konstanz).

Introduction: Bernd Genser (SFB 178, Konstanz).

9.45 - 10.30 Coffee Break.

10.30 - 12.00 James R. Markusen (University of Colorado, Boulder):
Costly Pollution Abatement, Competitiveness, and Plant Location Decisions.
Discussant: Ulrich Landwehr (University of Mannheim).

Gunter Stephan (University of Bern):
*Laissez-Faire, International Cooperation or National Greenhouse Policy:
A CGE Study.*

Discussant: Andreas Haufler (University of Konstanz).

12.00 - 14.00 Lunch Break.

14.00 - 15.30 Roger D. Congleton (George Mason University):
Return to Rio: On the Political Economy of Environmental Treaties.
Discussant: Hans Peter Grüner (University of Konstanz).

Rolf Bommmer (SFB 178, Konstanz):
*Endogenous Environmental Policy and Trade Liberalization - A Signaling
Approach.*

Discussant: Ronald Jones (University of Rochester).

15.30 - 16.00 Coffee Break.

- 16.00 - 17.30 Michael Rauscher (University of Kiel):
Protectionists, Environmentalists, and the Formation of Environmental Policy in an Open Economy.
 Discussant: John S. Chipman (University of Minnesota).
 Achim Körber (SFB 178, Konstanz):
Raising Rivals' Costs with Environmental Policy - A Lobbying Approach.
 Discussant: Hans Gersbach (University of Basel).

Wednesday, June 7, 1995

Chairman: Bernd Genser.

- 9.00 - 10.30 Ernst Mohr (University of Kiel, Hochschule St.Gallen):
Sustainable Development and International Distribution: Theory and Application to Rainforests as Carbon Sinks.
 Discussant: Carsten Schmidt (University of Konstanz).
 Sebastian Killinger (SFB 178, Konstanz):
Decentralized Internalization of International Externalities.
 Discussant: Lucas Bretschger (University of Zürich).
- 10.30 - 11.00 Coffee Break.
- 11.00 - 12.30 Ronnie Schöb (University of München):
Choosing the Right Instrument: Environmental Policy in the Presence of a Double Dividend.
 Discussant: Frank Hettich (SFB 178, Konstanz).
 Günther Schulze and Rolf Bommer (SFB 178, Konstanz):
 Economic Integration and Economic Policy. Does NAFTA Increase Pollution?
 Discussant: Sven Arndt (McKenna College).
- 12.30 - 14.30 Lunch Break.
- 14.30 - 16.00 Albert Schweinberger (SFB 178, Konstanz):
Environmental and Commercial Policies in More or Less Populous Open Economies.
 Discussant: James R. Markusen (University of Colorado, Boulder).
 Ruud de Mooij (Ministry of Economic Affairs, The Hague) and
 Lans A. Bovenberg (University of Tilburg):
Environmental Taxation and the Double Dividend: The Role of Factor Substitution and Capital Mobility.
 Discussant: Gebhard Kirchgässner (University of St. Gallen).
- 16.00 Closing Address: Heinrich Ursprung (SFB 178, Konstanz).