Helmut-Schmidt-Universität
Universität der Bundeswehr Hamburg
University of the Federal Armed Forces Hamburg
Fächergruppe Volkswirtschaftslehre
Department of Economics

Discussion Paper No. 47
February 2006

Sustainability gaps in municipal solid waste management: The case of landfills

Stefan Bayer
and
Jacques Méry

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE February 2006	3. REPORT TYPE AND DATES COVERED Discussion Paper

4. TITLE AND SUBTITLE Sustainability gaps in municipal solid waste management: The case of landfills	5. FUNDING NUMBERS
6. AUTHOR(S) Dr. Stefan Bayer and Dr. Jacques Méry	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) UNIBW	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES Universitaet fuer der Bundeswehr Hamburg	10. SPONSORING/MONITORING AGENCY REPORT NUMBER Discussion Paper No. 47, February 2006

11. SUPPLEMENTARY NOTES

Text in English, 24 pages.

12a. DISTRIBUTION/AVAILABILITY STATEMENT Public release. Copyrighted. (1 and 21)	12b. DISTRIBUTION CODE

ABSTRACT (Maximum 200 words)

Our paper compares external effects of two municipal solid waste disposal technologies, bioreactor and dry tomb landfills, in a 600-year time-horizon using two different discounting techniques: Constant conventional discounting and Generation Adjusted Discounting (GAD). The paper starts with a short description of the basic characteristics of the two landfill-types. To demonstrate the sustainability deficiencies of constant discounting sustainability gaps are defined and calculated. Reference case for these calculations is the GAD which takes into account the basic requirements of sustainable development, namely intergenerational equity. Our calculations show that constant discounting usually uses too high discount rates to be in accordance with fundamental sustainability criteria leading to biased political suggestions. However, our approach is not solely restricted to landfills. It could be used as a guide to quickly check whether the results of social cost-benefit analyses of long-term public projects are in accordance with fundamental sustainability criteria.

14. SUBJECT TERMS FIZBW, German, Generation Adjusted Discounting (GAD), constant discounting, sustainability gap, external costs, bioreactor landfill, dry tomb landfill	15. NUMBER OF PAGES
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

Sustainability gaps in municipal solid waste management: The case of landfills

Dr. Stefan Bayer
Staff and Command College of the German Armed Forces
Department of Social Sciences
D-22585 Hamburg, Germany
e-mail: stefanbayer@bundeswehr.org

Dr. Jacques Méry
Hydrosystems and bioprocesses research unit
French institute of agricultural and environmental engineering research (Cemagref)
B.P. 44
F-92163 Antony, France
e-mail: jacques.mery@cemagref.fr

Abstract:

Our paper compares external effects of two municipal solid waste disposal technologies, bioreactor and dry tomb landfills, in a 600-year time-horizon using two different discounting techniques: Constant conventional discounting and Generation Adjusted Discounting (GAD). The paper starts with a short description of the basic characteristics of the two landfill-types. To demonstrate the sustainability deficiencies of constant discounting sustainability gaps are defined and calculated. Reference case for these calculations is the GAD which takes into account the basic requirements of sustainable development, namely intergenerational equity. Our calculations show that constant discounting usually uses too high discount rates to be in accordance with fundamental sustainability criteria leading to biased political suggestions. However, our approach is not solely restricted to landfills. It could be used as a guide to quickly check whether the results of social cost-benefit analyses of long-term public projects are in accordance with fundamental sustainability criteria.

Keywords: Generation Adjusted Discounting (GAD), constant discounting, sustainability gap, external costs, bioreactor landfill, dry tomb landfill.

AQ F07-01-0194

1 Introduction: Discounting and Sustainability in municipal solid waste landfills

Discounting is necessary to compare future and current monetary effects. One Euro today is – in general – worth more than the same Euro next year. Different reasons are given in the literature for positive discount rates (Ott, 2003, Bayer, 2003, Bayer, 2000). The usage of positive discount rates, however, diminishes present values of future effects which is especially the case for effects which take place in the very far future. One standard criticism against discounting is that it biases economic decisions in favour of current living generations and to the expense of future living ones which can be interpreted as an unfair and, therefore, unsustainable treatment of future generations. Discounting then even contradicts with the criterion of responsibility according to Hans Jonas (1979, see Ferrari, 2002, for a link of discounting, sustainability and the principle of responsibility) because unreflected positive discount rates almost fully "shrinks the future" (already, e.g., Pigou, 1912). Neoclassical theory favours current living generations via "high" discounting, e.g. using positive constant utility discount rates infinitely long, which – exogenously – places lower weights to effects which happen in the future. In fact, neoclassical theory imposes a moral judgement at the expense of future living generations (Ramsey, 1928). Thus, one could argue that constant discounting in neoclassical theory prevents sustainable development in general. Some philosophers demand, therefore, to refrain from discounting at all. Only in this case sustainable paths could be reached. For example, the responsibility criterion according to Jonas could be applied by setting the discount rate to zero. However, whenever there is positive growth, future living generations would be favoured at the expense of current living ones in cost-benefit analyses which is unsustainable as well. Sustainability demands that all current as well as future living generations have to be treated equally. One has to keep in mind the rationale of discounting in the very long-term: Discounting establishes a theoretical normative reference case where all affected people are ranked equally (Bayer, 2000). Both "pure strategies" – constant discounting as well as not discounting at all – neglect this criterion of equal treatment.

Economic cost-benefit analyses are generally based upon the utilitarian requirement for equal treatment of all affected individuals. Thus, the underlying assumed discounting technique must fulfil this requirement as well which can be done by employing a specific discounting procedure, the Generation Adjusted Discounting – GAD (Bayer, 2003, Rackwitz et al., 2005). In contrast to the most commonly used exponential discounting – i.e. constant discounting – technique (Koopmans, 1960, and almost all modern growth theory textbooks, e.g., Barro/Sala-I-Martin, 2004) GAD enables us to find sustainable outcomes.

Besides the intra- as well as intertemporal aspect of sustainable development, sustainable landfill management concentrates on three different general types of external costs: From the environmental side, one has to take into account the negative effects of the world-wide waste production, i.e. environmental external costs. Waste which is a by-product of any material economic activity is unavoidable due to thermodynamic reasons (Ayres and Martinas, 1995, O'Connor, 1996). There is always a residual pollution, sometimes by means of spatial or temporal transfers. For instance, ash residues of incinerators are a dangerous waste which must be landfilled perhaps infinitely-long (Hellweg et al., 2000). The external costs may occur in the remote future (e.g., greenhouse effect of methane emissions for anaerobic processes, leakage of leachate in the soil and the groundwater) which has to be considered in a social cost-benefit analysis. Managing waste is also a very difficult task because everybody is producing waste and nobody wants to have it in his backyard. Disamenity costs have also to be taken into account as external costs for a comprehensive analysis allowing for a socially accepted management of waste.

The paper is organized as follows: We start with assigning external effects of two different types of landfills, i.e., the dry tomb technology and the bioreactor type for municipal solid waste disposal (section 2). This is followed by considering the intertemporal aspect via discounting external effects to the planning horizon according to Generation Adjusted Discounting (GAD) and a comparison with outcomes using constant discounting (section 3). In section 4 we define a "sustainability gap", calculate some examples, and demonstrate that constant discounting could have a significant unsustainable character. Some political suggestions as well as a general outlook are given at the end.

2 The specific case of landfills

Most of waste treatment activities have to deal only with flows of materials. In contrast, landfills have also to cope with stocks of materials which are infinitely-long in direct physical contact with the soil and possibly water. These peculiarities lead to fears of human-beings with respect to the ability of the landfills – independent of the state of technological progress (complementary or even redundant mineral and man made synthetic barriers) – to protect the whole environment from (potential) damages caused by any pollutant flow at all points in time. These potential flows are due to the high chemical gradient between their internal content and the environment (Ayres and Martinas, 1995). This is the reason why landfills are one of the most important problems in waste management with respect to the implementation of sustainability criteria, which has already been addressed by Page (1988). Moreover, many studies show that – for example – solely the disamenity costs at stake are quite high (Faber, 1998, COWI, 2000, DEFRA, 2003, MEDD, 2005). There are intratemporal locational choice problems, too, possibly leading to rivalries in the usage of soil. In many developed countries newly planned as well as established municipal solid waste landfills lead to possibly costly conflicts in some regions (Barbier and Waechter, 2001).

Landfills can be distinguished in sanitary landfills (municipal solid waste), hazardous waste landfills and nuclear waste landfills. We concentrate – exemplary – on the first type of landfills in this paper. It is the most common in the world. Most of all countries use sanitary landfills for more than fifty percent of their municipal solid waste (ISWA, 2006). The potential damage of the waste mass will strongly decrease in less than one century if enough water is filled into the landfill to enhance the anaerobic degradation of the waste. But an enormous time lag has to be taken into account as well due to the time transfer of pollutants into the soil and the ground water which may last many centuries (Méry, 2005).

There are two main technologies in sanitary landfilling: The dry tomb technology (or passive landfill) where the waste mass degrades anaerobically in about half a century. It contains a risk of pollution which may occur during many decades while the protective barriers may fully or partly degrade. The bioreactor technology (or active landfill) aims at accelerating the anaerobic process to reduce potential pollution more rapidly by an active management of the liquid content of the waste mass (Vigneron, 2005). When the bioreactor technology is implemented, the external costs are more concentrated in the present compared to the dry tomb technology. Thus, the bioreactor technology has not the same potential to affect future generations with high long-term external costs as it is the case in the dry tomb technology.

Besides the efficiency aspect an argument of justice is relevant as well: When the bioreactor technology is implemented each generation would be able to cope with their own external costs instead of producing intertemporal external costs for future living individuals. Méry and Bayer (2005) show that the bioreactor-type landfills are more sustainable – i.e. efficient as well as fair – compared to the dry tomb-type especially when there are very low growth rates in the economy in a 600-year context (up to 1% p.a. real consumption growth). Additionally, although several studies with respect to external costs of landfills emphasize that long-term effects have to be taken into account, there is a danger that current environmental laws in different world regions underestimate the real damages by demanding only a thirty years post-closure survey which is the case in the European Union and the U.S.A (European Commission, 1999, U.S. EPA, 1991).

All these considerations show that the length of the time horizon has to be carefully chosen in order to capture all external effects caused by the emissions of landfills. The current state of knowledge requires an extension of the horizon for our analysis as long as physical effects could occur which automatically leads us to an intergenerational setting of many centuries (see Méry and Bayer, 2005). Thus, the question of discounting becomes of highest relevance.

3 Generation Adjusted Discounting

Discounting has major impacts on the results and, of course, on the political suggestions of cost-benefit analyses. Constant exponential discounting with one single constant rate factually defines the above worked-out landfill-problems away in present value terms. Long-term impacts would not play any role in this discounting regime. We, therefore, apply another discounting technique, the GAD, which allows more sustainable statements even in these long time horizons which are of relevance for the landfill case.

3.1 General Framework

The innovation of GAD is to differentiate between intra- and intergenerational discounting with two different discount rates. For calculating intragenerational, generation-specific present values, all effects during the respective individuals' lifetimes have to be discounted to the beginning of the lives of these individuals by applying their respective individual time preference rate. Intragenerational present values can be easily interpreted as generational accounts. The intragenerational discount is given as the sum of the pure time preference rate (pure time preference rate PTPR) and the growth time preference rate (growth time preference rate GTPR): $\delta = \rho + \varepsilon \cdot g$, which is exactly the well-known Euler-equation. As is common, ρ represents the individual discount rate which depicts individual myopia and/or impatience. Due to ethical reasons, it can only be relevant for calculating individual (or in our case generation-specific) present values (Ramsey, 1928, Bayer, 2000, 2003). The product of the real growth rate g (per capita and per generation) and the elasticity of marginal utility with respect to consumption ε equals the growth-time preference rate. We want to assume – in accordance with most of the economic models using CRRA-utility functions – that ε is unity.

To calculate intergenerational present values, all intragenerational present values have to be once again discounted to the beginning of the planning time t_0 of the whole project. However, to treat all generations equally, intergenerational discounting from the beginning of the lifetime of each generation to t_0 need not consider aspects of myopia and/or impatience. From a social point of view, they differ only in their respective level of consumption which has to be taken into account by growth discounting according to decreasing marginal utility ("intergenerational discounting"). In table 1, the dark shaded area shows these time periods, where intergenerational discounting has to take place to determine a social present value at the beginning of our plans of action. Therefore, only the intergenerational discount rate – the real growth rate – can be used for equity reasons.

Generation	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}	t_{11}	t_{12}	t_{13}	$\ldots t_n$
A	c_0														
B	c_0	$c_1\cdot\theta^{-1}$													
C	c_0	$c_1\cdot\theta^{-1}$	$c_2\cdot\theta^{-2}$												
D	c_0	$c_1\cdot\theta^{-1}$	$c_2\cdot\theta^{-2}$	$c_3\cdot\theta^{-3}$											
E	c_0	$c_1\cdot\theta^{-1}$	$c_2\cdot\theta^{-2}$	$c_3\cdot\theta^{-3}$	$c_4\cdot\theta^{-4}$										
F	c_0	$c_1\cdot\theta^{-1}$	$c_2\cdot\theta^{-2}$	$c_3\cdot\theta^{-3}$	$c_4\cdot\theta^{-4}$	$c_5\cdot\theta^{-5}$									
G	c_0	$c_1\cdot\theta^{-1}$	$c_2\cdot\theta^{-2}$	$c_3\cdot\theta^{-3}$	$c_4\cdot\theta^{-4}$	$c_5\cdot\theta^{-5}$	$c_6\cdot\theta^{-6}$								
H	c_0	$c_1\cdot\theta^{-1}$	$c_2\cdot\theta^{-2}$	$c_3\cdot\theta^{-3}$	$c_4\cdot\theta^{-4}$	$c_5\cdot\theta^{-5}$	$c_6\cdot\theta^{-6}$	$c_7\cdot\theta^{-7}$							
I		c_1	$c_2\cdot\theta^{-1}$	$c_3\cdot\theta^{-2}$	$c_4\cdot\theta^{-3}$	$c_5\cdot\theta^{-4}$	$c_6\cdot\theta^{-5}$	$c_7\cdot\theta^{-6}$	$c_8\cdot\theta^{-7}$						
J			c_2	$c_3\cdot\theta^{-1}$	$c_4\cdot\theta^{-2}$	$c_5\cdot\theta^{-3}$	$c_6\cdot\theta^{-4}$	$c_7\cdot\theta^{-5}$	$c_8\cdot\theta^{-6}$	$c_9\cdot\theta^{-7}$					
K				c_3	$c_4\cdot\theta^{-1}$	$c_5\cdot\theta^{-2}$	$c_6\cdot\theta^{-3}$	$c_7\cdot\theta^{-4}$	$c_8\cdot\theta^{-5}$	$c_9\cdot\theta^{-6}$	$c_{10}\cdot\theta^{-7}$				
L					c_4	$c_5\cdot\theta^{-1}$	$c_6\cdot\theta^{-2}$	$c_7\cdot\theta^{-3}$	$c_8\cdot\theta^{-4}$	$c_9\cdot\theta^{-5}$	$c_{10}\cdot\theta^{-6}$	$c_{11}\cdot\theta^{-7}$			
M						c_5	$c_6\cdot\theta^{-1}$	$c_7\cdot\theta^{-2}$	$c_8\cdot\theta^{-3}$	$c_9\cdot\theta^{-4}$	$c_{10}\cdot\theta^{-5}$	$c_{11}\cdot\theta^{-6}$	$c_{12}\cdot\theta^{-7}$		
N							c_6	$c_7\cdot\theta^{-1}$	$c_8\cdot\theta^{-2}$	$c_9\cdot\theta^{-3}$	$c_{10}\cdot\theta^{-4}$	$c_{11}\cdot\theta^{-5}$	$c_{12}\cdot\theta^{-6}$	$c_{13}\cdot\theta^{-7}$	
⋮								⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋱

Table 1: Intragenerational effects in an 8-Generation-Model, $\theta \equiv (1+\delta)$.

The application of GAD requires some simplifying assumptions. These assumptions are one possible application of GAD. All effects which take place in a specific time period are equally divided between all the then living generations. Additionally, all external effects influence all individuals' consumption. Whenever the external effects would influence investment units, we have to calculate consumption equivalents to deal with that problem (Bayer, 2003, 2004). We calculate present values in decadal steps assuming that all generations live exactly for 8 decades. This sufficiently represents the average life expectancy in the industrialized countries, which is our assumed framework. Thus, at each point in time, 8 simultaneously living generations of different age exist. At the end of each decade, the oldest generation dies and a new generation is born. At the beginning of our planning horizon, t_0, eight generations exist which are affected by equally distributed external effects. At the end of time period t_0, the oldest generation A dies and a new generation I is born, which lives up to time period t_8. The rest proceeds analogously.

GAD works as follows: Up to generation H the discounting process is in exact accordance with the Euler-equation ($\delta = \rho + \varepsilon g$). Thus, the generation-specific intragenerational present values can be added up to determine a social present value for all generations living in the time period when the analysis begins (t_0). Beginning with time period t_1 up to the end of the planning horizon the discounting process has to be adjusted due to the utilitarian requirement of equal treatment of all affected generations: Firstly, intragenerational present values have to be calculated which refer to the beginning of the lifetimes of all the then living generations. Afterwards, these generational accounts have to be discounted to the planning time t_0 solely using the growth rate (intergenerational discounting). Thus, whenever a positive myopic discount rate (ρ) is used, GAD uses lower intergenerational discount rates compared to intragenerational ones and the difference between the two rates is exactly the myopic discount rate.

Mathematically, the formula for calculating present values according to GAD is given as follows:

$$(1)\qquad PV_{GAD}=\sum_{j=0}^{L-1}(L-j)\cdot\frac{c_j/G_j}{\left(1+\rho_j+\varepsilon_j\cdot g_j\right)^j}+\sum_{\ell=1}^{PH}\frac{\sum_{i=\ell}^{\ell+(L-1)}\frac{c_i/G_i}{\left(1+\rho_i+\varepsilon_i\cdot g_i\right)^{i-\ell}}}{\left(1+\varepsilon_\ell\cdot g_\ell\right)^\ell},$$
$$\text{mit}\quad c_i,c_j=0\quad\text{für alle}\quad i,j>PH.$$

PH symbolizes the planning horizon of the analyzed project and *L* represents the life expectancy of each generation (8 decades). *G* is the number of generations living at the same time (8 generations are living simultaneously). All periodical project-induced consumption effects (c_i, c_j, c_ℓ) are assumed to be equally distributed between all then living generations. The variables j, i, and ℓ are used as time indices.

The first summand describes all intragenerational consumption effects which appear in the planning period for all presently-living generations. The longer the planning horizon is extended, the less important becomes this term. The fracture in the numerator (right summand in equation (1)) expresses all intragenerational consumption effects of all generations born after the planning period t_0. These intragenerational effects are discounted to the beginning of the lives of each respective generation only. All generations are allowed to employ the sum of the PTPR and the GTPR as their relevant discount rates. However, intragenerational present values have to be once again discounted with the term in the denominator of the fraction on the right-hand side of equation (1): $(1+\varepsilon_\ell \cdot g_\ell)^\ell$. The relevant discount rate is the GTPR (intergenerational discounting). At last, we have to consider that intragenerational as well as intergenerational effects possibly occurring after the end of the planning horizon cannot be taken into account in our calculations. Therefore, consumption effects c_i and c_j with $i, j > PH$ have to be set to zero.

Equation (1) shows that GAD does not require constant intra- as well as intergenerational discount rates. Whenever it would be necessary, these rates can vary for each time-period i, j, and ℓ. Thus, behavioral considerations with respect to hyperbolic discounting could easily be adopted into the GAD which is interesting especially for intragenerational discounting (Frederick et al., 2002).

The most important GAD-effect is the convergence of the long-term discount rate towards the growth time preference rate. Thus, the factual periodical discount rate decreases from the sum of the myopic and the growth time preference rate to the growth time preference rate which causes significant effects with respect to present value calculations. The pure time preference rate is not that significant as it is in the constant discounting regime because its impact almost fully disappears (Rackwitz et al., 2005).

One criticism against the usage of GAD is that it leads to intertemporal inconsistencies – like all discounting procedures which are not exponential (Strotz, 1955/56). This refers mainly to first-best-models. However, in a first best world all external costs have been internalized to the polluters. No biasing effects on prices, and, of course, on demand and supply do exist at all. Whenever we analyze external effects which are not internalized to the polluters, we automatically argue in a second-best world (Faucheux et al., 1998, Asheim, 1994) where prices are biased and do not show the market-shortages correctly. Goods and services which are produced or consumed with high external costs are oversupplied whereas goods and services which have external benefits are not sufficiently supplied compared to the optimal, i.e. first-best, market volume. And, of course, in second best worlds the argument of time-consistency according to Strotz does not play any role because the assumed "rational" way of planning cannot be realized due to the non-constant set of choices. Additionally, from a practical perspective in democracies, time consistency cannot play any decisive role because of the possibility of governmental changes after elections and, possibly, a radical change in the political direction. It is obvious that these effects can only be accidentally time-consistent and usually these types of political changes are highly time-inconsistent (Bayer, 2000, pp. 154-157, Méry, 2005, pp. 88-94).

Besides efficiency and equity, the necessity of intertemporal consistency is an additional topic which might be in conflict with the two former arguments. Efficient solutions need neither to be time consistent nor fair and the opposite is also valid: fair solutions need neither to be efficient nor time-consistent and so on. One may consider that the deficiency of time-inconsistency of the GAD is (at least) qualitatively compensated by the fulfilment of equal treatment of all affected generations. Thus GAD produces efficient and fair results with the lack of time-consistency. Especially in second-best models the overall net gain of offering fair and efficient results at the expense of time-consistency is quite close to a Pareto-improvement.

3.2 Present Value Calculations – Results

GAD is applied to a data set which is in more detail explained and derived in Méry and Bayer (2005). The exact external costs of a typical bioreactor- and a dry-tomb-landfill are given in Annexes A1 and A2. To capture uncertainties with respect to the intragenerational as well as the intergenerational discount rate we assume a range of possible rates according to major publications on these figures. The individual discount rate (PTPR) is strictly assumed to be positive, which is in accordance with general findings (for some exemptions see, e.g., Loewenstein and Prelec, 1992, Price, 1993): $0.5\% \leq \text{PTPR} \leq 4.5\%$. The intergenerational discount rate (GTPR) is assumed to range from $-1\% \leq \text{GTPR} \leq 3\%$. These figures can be observed in European history and, more general, could be legitimated when concentrating on effects which completely take place in industrialized countries. But GAD does not require the application of these assumptions. It can be used in developing countries as well, where we have to increase both rates. Thus, the application of GAD is not limited to our specific examples.

We assume a time horizon of 600 years. At the one hand, we have to consider at least half a millennium to integrate all plausible environmental impacts in the analysis (INVS, 2004, Méry and Bayer, 2005). On the other hand, the time horizon should not predetermine the results of our comparison of the external costs of bioreactor and dry tomb landfills. Sensitivity calculations with shorter time horizons show that up to 400 years planning horizon, some of our results in the 600 year context could not be confirmed. Starting with 500 years time horizon, the results are not time sensitive any more. Arguing conservatively, we extend the assumed time horizon to 600 years to be sure that the time-sensitivity of our results does not bias them towards the one (bioreactor) or the other direction (dry tomb). Extending the time horizon beyond 600 years does not make any sense for our comparison since the general trend of the efficiency of dry-tomb- and bioreactor-landfills is not reversed.

We exemplary concentrate on the best guess case. The results of the two others cases (best case, worst case) are given in the Annexes B1 and B2. For simplifying our analysis, we calculated all present values in decadal steps, and, of course, the yearly discount rates given in table 2 have been adjusted to that procedure. Table 2 is organized as follows. In the left column different constant discount rates (δ) are listed ranging from 7.5% to –0.5%. To calculate the present values conventionally, these constant rates are used to discount all external effects E_t according to the exponential formulation (in discrete time-steps):

$$(2) \qquad PV_0 = \sum_{t=0}^{600} \frac{E_t}{(1+\delta_t)^t}$$

Present value calculations in the GAD-regime have been done according to equation (1) (see above).

Best Guess			**GAD**		**Constant Discounting**	
Discount Rate	intra	inter	Bioreactor	Dry Tomb	Bioreactor	Dry Tomb
7.5%	4.5%	3.0%	15.76	***9.77***	14.93	***8.68***
6.5%	4.5%	2.0%	18.59	***12.33***	17.15	***10.17***
6.0%	3.0%	3.0%	19.25	***12.24***	18.42	***11.07***
5.5%	4.5%	1.0%	23.30	***18.09***	19.82	***12.09***
5.5%	2.5%	3.0%	20.63	***13.26***	19.82	***12.09***
4.5%	4.5%	0.0%	***46.88***	60.16	23.14	***14.66***
4.0%	2.0%	2.0%	26.69	***18.97***	25.12	***16.32***
4.0%	3.0%	1.0%	29.43	***24.10***	25.12	***16.32***
4.0%	3.5%	0.5%	34.00	***32.93***	25.12	***16.32***
4.0%	4.0%	0.0%	***51.81***	67.64	25.12	***16.32***
4.0%	4.5%	-0.5%	***158.95***	276.83	25.12	***16.32***
3.5%	0.5%	3.0%	27.74	***18.94***	27.39	***18.36***
3.5%	4.5%	-1.0%	***1185.17***	2278.33	27.39	***18.36***
3.0%	1.0%	2.0%	31.36	***23.24***	30.05	***20.93***
3.0%	2.0%	1.0%	34.94	***30.01***	30.05	***20.93***
3.0%	3.0%	0.0%	***64.51***	87.58	30.05	***20.93***
3.0%	4.0%	-1.0%	***1367.27***	2631.39	30.05	***20.93***
2.0%	0.5%	1.5%	39.01	***32.35***	37.34	***29.21***
2.0%	1.0%	1.0%	42.23	***38.51***	37.34	***29.21***
2.0%	1.5%	0.5%	***50.51***	54.58	37.34	***29.21***
2.0%	2.0%	0.0%	***82.91***	117.80	37.34	***29.21***
2.0%	2.5%	-0.5%	***278.08***	498.94	37.34	***29.21***
2.0%	3.0%	-1.0%	***1877.80***	3622.62	37.34	***29.21***
1.5%	0.5%	1.0%	46.82	***44.23***	43.00	***36.88***
1.5%	1.0%	0.5%	***56.70***	63.42	43.00	***36.88***
1.5%	1.5%	0.0%	***95.39***	138.94	43.00	***36.88***
1.5%	2.0%	-0.5%	***328.52***	594.23	43.00	***36.88***
1.5%	2.5%	-1.0%	***2239.51***	4325.71	43.00	***36.88***
0.5%	0.5%	0.0%	***130.84***	200.83	***73.90***	89.62
-0.5%	0.5%	-1.0%	***5176.63***	10046.72	***867.03***	1629.97

Table 2: Present value calculations of net external costs, dry tomb and bioreactor landfills, best guess, €/t.

In table 2, bold italic figures in the columns indicate lower present values of net external costs in our two different discounting regimes. Constant discounting mainly shows the dry tomb technology as the efficient one producing lower present values of external costs. Only in two very extreme cases with very low constant discount rates (0.5% and –0.5%) the bioreactor type landfill is more efficient than the dry-tomb one. However, using GAD the bioreactor landfill has lower present values of external costs compared to the dry tomb case in 14 more cases. Altogether, the bioreactor landfill is more efficient than the dry tomb one in 16 cases in our best guess scenario (19 times in the best case scenario, 16 times in the worst case scenario, see Annexes B1 and B2). The efficiency of our two different landfill types significantly depend on the assumed discounting regime even for identical initial discount rates. Thus, our small example shows clearly that the choice of the discounting regime is a strategic decision to calculate present values of external costs.

The efficiency judgements mainly depend on the size of the growth rate (intergenerational discount rate). The lower it is, the more favourable the bioreactor type becomes. When there is high growth, the dry tomb landfill is the better solution. In the assumed 600-year context, a real growth rate even for industralized countries of 1% p.a. is a quite meaningful assumption (Maddison, 2001). Higher annual growth rates have never been observed in comparable time horizons. Thus, all cases where growth rates up to 1% are used seem to be realistic, and, this leads to the conclusion that the bioreactor-type landfill is the more suitable with respect to sustainability compared to the dry-tomb technology.

Another finding is that GAD allows for a more detailed analysis: While constant discounting always leads to the same present values and, therefore, the same efficiency result using one specific discount rate (e.g., 3%), this is not the case applying GAD: Generally, a switch in efficiency is observable whenever the growth discount rate is lowered. In the 3%-case, GAD shows that the bioreactor- as well as the dry tomb-landfill is favourable in two cases each. Thus, the two different discounting techniques would generate very different suggestions with respect to technological choice in municipal solid waste management.

It can be stated that the above criticized moral judgement of neoclassical theory – an inherent bias at the expense of future living generations and favouring current living ones – applying the constant discounting regime becomes relevant and predetermines the efficiency of our two landfill technologies. This is obviously in sharp contradiction to the normative requirement of equal treatment of all affected generations. Therefore, we want to demonstrate the "unsustainability" of constant discounting by calculating "sustainability gaps" which become relevant whenever one decides to use the constant discounting regime in social cost-benefit analyses.

4 Sustainability gaps (with respect to intergenerational fairness)

4.1 General concept

GAD is explicitly based upon the basic utilitarian requirement of equal treatment of all affected generations. Thus, it can be interpreted as a reference discounting technique which allows for sustainable decision-making and is very easily applicable in cost-benefit analyses. The present values calculated using GAD must be produced whenever alternative techniques would be applied to identify whether they are in accordance with the sustainability criteria of intertemporal fairness.

Given the GAD present value, one is able to solve equation (2) – constant discounting – with respect to the now endogenous discount rate d to calculate which equivalent constant discount rate d generates exactly the GAD present value. The difference in constant discount rates between the original and the modified calculation can be interpreted as a "sustainability gap" of constant discounting compared to sustainable discounting, in fact GAD. Thus, we ask which constant discount rate is able to calculate the same present value as is computed by the GAD. For example, we assume an original discount rate of 4.5% – which is split up into 4.5% intragenerational discount rate and 0% intergenerational discount rate. The GAD present value in the bioreactor best guess case is given with 46.88 €/t (see table 2). To calculate the sustainability gap of constant discounting in that specific case, we need to know, which constant discount rate exactly produces the sustainable present value of 46.88. This means we have to solve the following equation (3) for d_t which is done numerically.

$$(3) \qquad 46.88\,€/\mathrm{t} = \sum_{t=0}^{600} \frac{E_t}{(1+d_t)^t} \quad \Leftrightarrow \quad d_t = 1.25\%.$$

A constant discount rate of 1.25% leads to a present value of external costs of 46.88 €/t. Compared to the original discount rate of 4.5% this figure is significantly lower. In this special case, a sustainability gap of the constant discounting regime can be quantified with 3.25% per year (4.5%-1.25%). In other words: A social cost-benefit analysis in the constant discounting regime uses a discount rate which is 3.25% p.a. higher (in absolute terms) as it should be the case in the sustainable discounting regime. Thus, in each year a bias of 3.25% (in absolute terms) at the expense of future living generations exists. The exponential development of this large difference need not be emphasized.

The sustainability gap can alternatively be illustrated in a relative way by calculating the ratio of the absolute difference of the original discount rate (4.5% in our example) and the GAD-equivalent constant discount rate (1.25% in our example, leading to 3.25% in the numerator) divided by the GAD-equivalent constant discount rate of 1.25%. In our example a ratio of 2.6 (or 260%) results which means that the yearly constant discount rate is by the factor 2.6 too high in sustainability terms.

4.2 Sustainability gaps in waste management: Definition and Results

After having shown how to calculate GAD-equivalent constant discount rates we want to define the sustainability gap as the difference between the original constant discount rate and the GAD-equivalent ones:

(4) absolute sustainability gap
= original constant discount rate – GAD-equivalent constant discount rate.

We prefer to calculate absolute differences compared to relative ones because it more illustrative and easier to interpret compared to the relative notation. Whenever calculating relative sustainability gaps, the ethical reference is taken into account twofold which complicates its understanding without having additional information. Table 3 gives the absolute sustainability gaps in the best guess scenario. Tables C1 and C2 in the Annex depict the respective figures in the best case and the worst case scenarios.

Best Guess			**GAD equivalent constant discount rate**		**Sustainability Gap (in absolute percentages)**	
Discount Rate	intra	inter	Bioreactor	Dry Tomb	Bioreactor	Dry Tomb
7.5%	4.5%	3.0%	7.103%	6.750%	0.3973%	0.7498%
6.5%	4.5%	2.0%	5.936%	5.391%	0.5639%	1.1095%
6.0%	3.0%	3.0%	5.699%	5.433%	0.3008%	0.5665%
5.5%	4.5%	1.0%	4.456%	3.559%	1.0439%	1.9407%
5.5%	2.5%	3.0%	5.236%	5.005%	0.2645%	0.4955%
4.5%	4.5%	0.0%	1.253%	0.826%	3.2467%	3.6743%
4.0%	2.0%	2.0%	3.646%	3.369%	0.3536%	0.6315%
4.0%	3.0%	1.0%	3.109%	2.532%	0.8906%	1.4679%
4.0%	3.5%	0.5%	2.315%	1.725%	1.6848%	2.2751%
4.0%	4.0%	0.0%	1.020%	0.715%	2.9804%	3.2847%
4.0%	4.5%	-0.5%	0.012%	-0.020%	3.9876%	4.0204%
3.5%	0.5%	3.0%	3.429%	3.376%	0.0712%	0.1241%
3.5%	4.5%	-1.0%	-0.573%	-0.576%	4.0729%	4.0756%
3.0%	1.0%	2.0%	2.784%	2.646%	0.2157%	0.3543%
3.0%	2.0%	1.0%	2.278%	1.935%	0.7224%	1.0654%
3.0%	3.0%	0.0%	0.656%	0.515%	2.3441%	2.4849%
3.0%	4.0%	-1.0%	-0.605%	-0.607%	3.6053%	3.6074%
2.0%	0.5%	1.5%	1.831%	1.763%	0.1685%	0.2368%
2.0%	1.0%	1.0%	1.557%	1.422%	0.4430%	0.5778%
2.0%	1.5%	0.5%	1.074%	0.930%	0.9256%	1.0705%
2.0%	2.0%	0.0%	0.393%	0.337%	1.6065%	1.6633%
2.0%	2.5%	-0.5%	-0.192%	-0.202%	2.1921%	2.2016%
2.0%	3.0%	-1.0%	-0.675%	-0.676%	2.6752%	2.6764%
1.5%	0.5%	1.0%	1.257%	1.200%	0.2434%	0.2997%
1.5%	1.0%	0.5%	0.849%	0.774%	0.6510%	0.7258%
1.5%	1.5%	0.0%	0.287%	0.254%	1.2135%	1.2465%
1.5%	2.0%	-0.5%	-0.244%	-0.250%	1.7436%	1.7499%
1.5%	2.5%	-1.0%	-0.713%	-0.714%	2.2131%	2.2140%
0.5%	0.5%	0.0%	0.102%	0.096%	0.3979%	0.4044%
-0.5%	0.5%	-1.0%	-0.887%	-0.887%	0.3867%	0.3868%

Table 3: GAD-equivalent discount rates and sustainability gaps in the best guess scenario.

It can be seen in table 3 that all GAD-equivalent constant discount rates are absolutely lower compared to the original ones. From the perspective of sustainability constant discounting always uses too high values to calculate present values and the requirement of equal treatment is not taken seriously. Ramseys (1928) critical statement using positive utility discount rates can, therefore, be fully confirmed using table 3 as well as tables C1 as well as C2 in the Annex.

The first interesting finding of our calculations is that there are – in some cases – enormous differences in yearly discount rates. The maximum in a – not very realistic case – is approximately 4% which factually describes the difference of yearly discount rates. Obviously, this has significant impacts on the present value calculations and the conclusions which can be drawn applying social cost-benefit analyses. In all other cases the sustainability gap is not negligible especially when one is beware of the fact that this gap measures yearly discount rates which are applied in a 600-year time horizon. The lowest sustainability gap in the best guess scenario is given with 0.07% (in absolute terms). The isolated compound interest effect of this very low figure in a 600-years calculation is still quite high: The overall return is about 52% in a 600 year planning horizon. Obviously, whenever the sustainability gaps become larger, the overall return will be much higher as well and the differences in present values become much more distinct.

Table 3 works out, that the sustainability gap becomes larger when there is negative growth in the future compared to these cases where there is positive growth. Here, future generations would be worse off compared to current living ones. Thus, additional consumption units tomorrow are of higher social value than consumption units today. This must be taken into account by discounting negatively, which is usually not done in the constant discounting regime. This clearly demonstrates the unsustainable character of constant discounting once again.

It has to be emphasized that the GAD-equivalent discount rate could also be negative which only happens when there is a negative growth rate, of course. Theoretically, the Euler equation could become negative as well whenever the negative growth rate ($\varepsilon \cdot g$) overcompensates the positive myopic discount rate (ρ). However, this is usually not assumed in theoretical as well as in empirical economic studies. Some authors assume negative growth rates, but still use positive discount rates because the myopic discount rate is set higher (in absolute terms) compared to the growth rate. In these cases constant discounting implicitly assumes that future generations are wealthier than current living ones which – in this specific framework – is not true at all. Using GAD instead, the wealth implications are taken into account by using only the growth rate for intergenerational discounting and refuse discounting with the myopic rate whenever intergenerational comparisons have to be carried out.

The most important application of the sustainability gap which has been defined above is to use it as a measure to check the sustainability of projects which are calculated using a constant discount rate – or any other discounting technique which is inherently “unsustainable”. The higher the sustainability gap becomes the more “unsustainable” the decision has been and vice versa. Additionally, one is able to work out an indicator for sustainable or unsustainable decision-making of governments or other project managers.

To summarize, the application of the constant discounting regime inherently lacks in fulfilling fundamental sustainability criteria. Thus, using GAD in long-term cost-benefit analyses enables a non-distorting decision where all affected generations are of equal value to the beginning of the lifetime of a specific project.

5 Conclusions

It has been shown how ethical aspects can be implemented in decision-support tools like cost-benefit analyses via discounting in the framework of a GAD-regime. The application of the sustainable discounting procedure GAD for the judgement of the efficiency of two landfill technologies (dry tomb and bioreactor) produces results which are in sharp contrast to the results of constant unsustainable discounting. Not-surprisingly, long-term effects do not play a decisive role in the constant discounting regime whereas they are taken more into account in the GAD-regime. Our analysis leads us to two different findings: With respect to the landfill example we are able to show that the bioreactor-type is generally more efficient than its alternative, the dry tomb-type, especially when relatively low long-term growth rates exist, i.e., up to 1% p.a. Secondly, we introduce a measure to check the sustainability of long-term public projects, a “sustainability gap”: Having a look at the project-specific discount rate and calculating a sustainability gap, we are able to judge to what extent sustainability criteria have been considered in the planning process of these projects. High sustainability gaps indicate that the project planner does not take the requirement of intergenerational fairness into account whereas low ones show the opposite.

Moreover, the sustainable discounting technique GAD can be applied to many other public projects where long-term effects have to be dealt with: hazardous and nuclear waste landfills, energy supply and demand, global warming, pension systems, etc. GAD may suggest – possibly radical – policy modifications and a sounder judgement of their sustainable character in comparison to the constant discounting regime.

Acknowledgements

The authors would like to thank the DAAD (PKZ D/0333552) and EGIDE (No. 07657 NH) who provided welcome financial support. The views expressed in this paper are the author's and not necessarily those of the organizations they are affiliated with.

References

Ayres, R., and Martinas, K., 1995. Waste potential entropy: the ultimate ecotoxic? Economie appliquée, XLVIII: 95-120.

Barbier, R., and V. Waechter 2001. Débats autour d'une décharge. Annales des Ponts et Chaussées, 97: 48-53

Barro, R. J. and X. Sala-i-Martin, 2004. Economic Growth, 2nd Edition. MIT Press, Cambridge, Mass., XVI, 654 pp.

Bayer, S., 2000. Intergenerationelle Diskontierung am Beispiel des Klimaschutzes. Metropolis, Marburg, 255 pp.

Bayer, S., 2003. Generation Adjusted Discounting in long-term Decision-Making. International Journal of Sustainable Development, 6: 133-149.

Bayer, S., 2004. Nachhaltigkeitskonforme Diskontierung – Das Konzept des "Generation Adjusted Discounting", Vierteljahreshefte zur Wirtschaftsforschung, 73: 142-157.

COWI, 2000. Economic valuation of environmental externalities from landfill disposal and incineration of waste. Report funded by the European Commission (http://www.europa.eu.int/comm/environment/enveco/waste/cowi_ext_from_landfill.pdf, 15th Feb. 2006).

DEFRA (Department for Environment, Food and Rural Affairs.), 2003. A study to estimate the disamenity costs of landfill in Great Britain (http://www.defra.gov.uk/environment/waste/landfill/pdf/landfill_disamenity.pdf, 15th Feb. 2006).

European Commission, 1999: Council directive 1999/31/EC of April 1999 on the landfill of waste, Brussels.

Faber, S., 1998. Undesirable facilities and properties values: a summary of empirical studies. Ecological Economics, 24: 1-14.

Faucheux, S., and O'Connor, M., 1998. Valuation for sustainable development: methods and policy indicators. Edward Elgar, Cheltenham et al., 326 pp.

Ferrari, S., 2002. Equité intergénérationelle et environnement naturel: quelle place pour l'actualisation? CERESUR, Université de la Réunion.

Frederick, S., Loewenstein, G., and O'Donoghue, T., 2002. Time Discounting and Time Preference: A Critical Review. Journal of Economic Literature, 40: 351-401.

Hellweg, S., Hofstetter, T., and Hungerbühler, K., 2003. Discounting and the environment – Should current impacts be weighed differently than impacts harming future generations? International Journal of Life cycle analysis, 8: 8-18.

INVS, 2005. Stockage des déchets et santé publique. Institut National de Veille Sanitaire, Saint Maurice (http://www.invs.sante.fr/publications/2005/dechets/pdf/synthese.pdf, 15th Feb. 2006).

ISWA, 2006. International Waste Information. International Solid Waste Association (ISWA), Copenhagen, Denmark. (http://www.iswa.org/index.php?option=com_weblinks&Itemid=50&catid=54, 15th Feb. 2006).

Jonas, H., 1979. Das Prinzip Verantwortung. Insel Verlag, Frankfurt a.M., 423 pp.

Koopmans, T.C., 1960. Stationary Ordinal Utility and Impatience. Econometrica, 28: 287-309.

Loewenstein, G., and Prelec, D., 1992. Anomalies in Intertemporal Choice: Evidence and an Interpretation. The Quarterly Journal of Economics, 107: 573-597.

Maddison, A., 2001. The world economy. A millenial perspective. OECD, Paris, 384 pp.

MEDD, 2004. Consentement local à payer et localisation d'une décharge. Ministère de l'Environnement et du Développement Durable, Paris (http://www.ecologie.gouv.fr/IMG/pdf/Etude_CET_rapport_final.pdf, 15th Feb. 2006).

Méry, J., 2005. Contribution a une gestion durable du risque environnemental du stockage des déchets ménagers et assimilés: l'évaluation des coûts externes des fuites de lixiviat des décharges. PhD-thesis, University of Versailles Saint Quentin en Yvelines, Versailles, 203 pp., available on request by the author.

Méry, J. and Bayer, S., 2005. Comparison of external costs between dry tomb and bioreactor landfills: Taking intergenerational effects seriously. Waste Management & Research, 23: 514-526.

O'Connor, M., 1994. Entropy, liberty and catastrophe: the physics and metaphysics of waste disposal. In: Burley P., and Foster, J. (Editors), Economics and thermodynamics: New perspectives on economic analysis. Kluwer, Dordrecht, pp. 119-182.

Ott, K., 2003. Reflections on discounting: Some philosophical remarks. International Journal of Sustainable Development, 6: 7-24.

Page, T., 1988. Intergenerational Equity and the Social Rate of Discount. In: Smith, V.K. (Editor), Environmental Resources and Applied Welfare Economics. Essays in Honor of John V. Krutilla. Resources for the Future, Washington D. C., pp. 71-89.

Pearce, D.W., and Ulph, D., 1995. A Social Discount Rate for the United Kingdom. Working Paper GEC 95-01, Centre for Social and Economic Research on the Global Environment (CSERGE), London.

Pigou, A.C., 1912. Wealth and Welfare. MacMillan, London, XXXI, 493 pp.

Price, C., 1993. Time, Discounting & Value. Blackwell, Oxford and Cambridge, Mass., XVIII, 393 pp.

Rackwitz, R., Lentz, A., and Faber, M., 2005. Socio-economically sustainable civil engineering infrastructures by optimization. Structural safety, 27: 187-229.

Ramsey, F.P., 1928. A mathematical theory of saving. The Economic Journal. 28: 543-559.

Strotz, R.H., 1955/56. Myopia and Inconsistency in Dynamic Utility Maximization. Review of Economic Studies, 23: 165-180.

US EPA, 1991. Resource Conservation and Recovery Act, subtitle D – Solid Waste (Non Hazardous), Environment Protection Agency, Washington, D.C.

Vigneron, V., 2005. Voies de réduction des oxydes d'azote lors de leur injection dans un massif de déchets ménagers et assimilés. Contribution à l'étude de la recirculation de lixiviat nitrifié dans une installation de stockage de déchets ménagers et assimilés bioactive. PhD-thesis, University of Paris XII-Val de Marne, 336 pp., available on request by the author.

Annexes A, B, and C

Annex A1: Temporal distribution of dry-tomb landfill externalities

Temporal distribution of externalities in dry tomb-type-landfills (Euros per tonne and decade)

Physical non perceived costs (3 levels of leachate emissions and natural time lags 1, 10, 50 decades)			Disamenities (induced traffic, animals, dust, odours)			Global warming costs (due to methane leakage) Damage costs			Avoided pollution benefits from energy plants (due to methane energy use)			Sum of all external costs		
Best case	Best guess	Worst case	Best case	Best guess	Worst case	Best case	Best guess	Worst case	Best case	Best guess	Worst case	Best case	Best guess	Worst case
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	2.5	10	25	0.253	0.7	3.5	1	0.5	0.1	1.753	10.2	28.4
0	0	0.1	2.5	10	25	0.4	2.15	5.715	1	0.5	0.1	1.9	11.65	30.715
0	0	0.1	1	4	10	0.22	1.25	3.5	1	0.5	0.1	0.22	4.75	13.5
0	0	0.1	1	4	10	0.115	0.75	2	1	0.5	0.1	0.115	4.25	12
0	0	0.1	1	4	10	0.078	0.42	1.2	0.8	0.5	0.1	0.278	3.92	11.2
0	0	0.1	1	4	10	0.047	0.23	0.6	0.6	0	0	0.447	4.23	10.7
0	0	0.2	1	4	10	0.02	0.14	0.34	0.4	0	0	0.62	4.14	10.54
0	0	0.4	1	4	10	0.005	0.08	0.2	0.2	0	0	0.805	4.08	10.6
0	0	0.6	1	4	10	0.001	0.05	0.1	0	0	0	1.001	4.05	10.7
0	0	0.8	1	4	10	0.0004	0.02	0.05	0	0	0	1.0004	4.02	10.85
0	0.1	1	1	4	10	0	0	0	0	0	0	1	4.1	11
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.2	0.5	1	4	10	0	0	0	0	0	0	1	4.2	10.5
0	0.2	0.5	1	4	10	0	0	0	0	0	0	1	4.2	10.5
0	0.2	0.5	1	4	10	0	0	0	0	0	0	1	4.2	10.5
0	0.2	0.5	1	4	10	0	0	0	0	0	0	1	4.2	10.5
0	0.2	0.5	1	4	10	0	0	0	0	0	0	1	4.2	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0.1	0.1	0.5	1	4	10	0	0	0	0	0	0	1.1	4.1	10.5
0.1	0.1	0.5	1	4	10	0	0	0	0	0	0	1.1	4.1	10.5
0.1	0.1	0.5	1	4	10	0	0	0	0	0	0	1.1	4.1	10.5
0.1	0.1	0.5	1	4	10	0	0	0	0	0	0	1.1	4.1	10.5
0.1	0.1	0.5	1	4	10	0	0	0	0	0	0	1.1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5
0	0.1	0.5	1	4	10	0	0	0	0	0	0	1	4.1	10.5

Annex A2: Temporal distribution of bioreactor landfill externalities

Temporal distribution of externalities in bioreactor-type-landfills (Euros per tonne and decade)

	Physical non perceived costs (3 levels of leachate emissions and natural time lags 1, 10, 50 decades)			Disamenities (induced traffic, animals, dust, odours)			Global warming costs (due to methane leakage) Damage Costs			Avoided pollution benefits from energy plants (due to methane energy use)			Sum of all external costs		
Decades	Best case	Best guess	Worst case	Best case	Best guess	Worst case	Best case	Best guess	Worst case	Best case	Best guess	Worst case	Best case	Best guess	Worst case
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	5	20	50	0.271	0.625	3.4489	3	1.5	0.3	2.271	19.125	53.1489
2	0	0	0.1	5	20	50	0.523	2.9	7.64	3	1.5	0.3	2.523	21.4	57.44
3	0	0	0.1	0.5	2	5	0.18	1.2	3.2	0	0	0	0.68	3.2	8.3
4	0	0	0.1	0.5	2	5	0.081	0.5	1.4	0	0	0	0.581	2.5	6.5
5	0	0	0.1	0.5	2	5	0.04	0.25	0.7	0	0	0	0.54	2.25	5.8
6	0	0	0.1	0.5	2	5	0.02	0.15	0.35	0	0	0	0.52	2.15	5.45
7	0	0	0.5	0.5	2	5	0.01	0.05	0.15	0	0	0	0.51	2.05	5.65
8	0	0	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2	5.5
9	0	0	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2	5.5
10	0	0	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2	5.5
11	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
12	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
13	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
14	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
15	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
16	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
17	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
18	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
19	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
20	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
21	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
22	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
23	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
24	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
25	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
26	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
27	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
28	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
29	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
30	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
31	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
32	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
33	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
34	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
35	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
36	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
37	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
38	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
39	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
40	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
41	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
42	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
43	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
44	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
45	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
46	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
47	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
48	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
49	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
50	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
51	0.1	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.6	2.1	5.5
52	0.1	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.6	2.1	5.5
53	0.1	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.6	2.1	5.5
54	0.1	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.6	2.1	5.5
55	0.1	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.6	2.1	5.5
56	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
57	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
58	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5
59	0	0.1	0.5	0.5	2	5	0	0	0	0	0	0	0.5	2.1	5.5

Annex B1: Present value calculations of net external costs, dry tomb and bioreactor landfills, best case, €/t.

Best Case			**GAD**		**Constant Discounting**	
Discount Rate	intra	inter	Bioreactor	Dry Tomb	Bioreactor	Dry Tomb
7.5%	4.5%	3.0%	1.99	***1.50***	1.83	***1.35***
6.5%	4.5%	2.0%	2.42	***1.90***	2.12	***1.56***
6.0%	3.0%	3.0%	2.46	***1.85***	2.29	***1.68***
5.5%	4.5%	1.0%	3.26	***2.99***	2.49	***1.82***
5.5%	2.5%	3.0%	2.65	***1.99***	2.49	***1.82***
4.5%	4.5%	0.0%	***8.63***	12.86	2.95	***2.16***
4.0%	2.0%	2.0%	3.59	***2.87***	3.24	***2.39***
4.0%	3.0%	1.0%	4.22	***3.99***	3.24	***2.39***
4.0%	3.5%	0.5%	***5.31***	6.06	3.24	***2.39***
4.0%	4.0%	0.0%	***9.64***	14.51	3.24	***2.39***
4.0%	4.5%	-0.5%	***36.28***	66.50	3.24	***2.39***
3.5%	0.5%	3.0%	3.66	***2.78***	3.59	***2.67***
3.5%	4.5%	-1.0%	***296.61***	570.37	3.59	***2.67***
3.0%	1.0%	2.0%	4.30	***3.50***	4.00	***3.05***
3.0%	2.0%	1.0%	5.14	***4.99***	4.00	***3.05***
3.0%	3.0%	0.0%	***12.30***	18.92	4.00	***3.05***
3.0%	4.0%	-1.0%	***342.49***	658.92	4.00	***3.05***
2.0%	0.5%	1.5%	5.65	***5.06***	5.26	***4.39***
2.0%	1.0%	1.0%	***6.41***	6.46	5.26	***4.39***
2.0%	1.5%	0.5%	***8.39***	10.26	5.26	***4.39***
2.0%	2.0%	0.0%	***16.28***	25.70	5.26	***4.39***
2.0%	2.5%	-0.5%	***64.86***	120.54	5.26	***4.39***
2.0%	3.0%	-1.0%	***471.18***	907.51	5.26	***4.39***
1.5%	0.5%	1.0%	***7.24***	7.47	6.33	***5.80***
1.5%	1.0%	0.5%	***9.60***	12.03	6.33	***5.80***
1.5%	1.5%	0.0%	***19.03***	30.48	6.33	***5.80***
1.5%	2.0%	-0.5%	***77.08***	143.81	6.33	***5.80***
1.5%	2.5%	-1.0%	***562.35***	1083.82	6.33	***5.80***
0.5%	0.5%	0.0%	***27.01***	44.60	***13.12***	17.38
-0.5%	0.5%	-1.0%	***1302.33***	2518.27	***208.38***	397.92

Annex B2: Present value calculations of net external costs, dry tomb and bioreactor landfills, worst case, €/t.

Worst Case			**GAD**		**Constant Discounting**	
Discount Rate	intra	inter	Bioreactor	Dry Tomb	Bioreactor	Dry Tomb
7.5%	4.5%	3.0%	43.12	***26.70***	40.91	***23.79***
6.5%	4.5%	2.0%	50.74	***33.59***	46.91	***27.86***
6.0%	3.0%	3.0%	52.56	***33.42***	50.36	***30.29***
5.5%	4.5%	1.0%	63.37	***48.75***	54.16	***33.08***
5.5%	2.5%	3.0%	56.30	***36.20***	54.16	***33.08***
4.5%	4.5%	0.0%	***125.51***	156.97	63.12	***40.06***
4.0%	2.0%	2.0%	72.63	***51.54***	68.47	***44.56***
4.0%	3.0%	1.0%	79.86	***64.79***	68.47	***44.56***
4.0%	3.5%	0.5%	91.88	***87.46***	68.47	***44.56***
4.0%	4.0%	0.0%	***138.59***	176.37	68.47	***44.56***
4.0%	4.5%	-0.5%	***419.27***	711.96	68.47	***44.56***
3.5%	0.5%	3.0%	75.52	***51.59***	74.59	***50.06***
3.5%	4.5%	-1.0%	***3107.31***	5837.44	74.59	***50.06***
3.0%	1.0%	2.0%	85.20	***63.04***	81.74	***57.00***
3.0%	2.0%	1.0%	94.66	***80.51***	81.74	***57.00***
3.0%	3.0%	0.0%	***172.22***	228.01	81.74	***57.00***
3.0%	4.0%	-1.0%	***3584.46***	6741.82	81.74	***57.00***
2.0%	0.5%	1.5%	105.71	***87.19***	101.29	***79.06***
2.0%	1.0%	1.0%	114.19	***103.06***	101.29	***79.06***
2.0%	1.5%	0.5%	***135.94***	144.27	101.29	***79.06***
2.0%	2.0%	0.0%	***220.90***	306.18	101.29	***79.06***
2.0%	2.5%	-0.5%	***732.18***	1282.00	101.29	***79.06***
2.0%	3.0%	-1.0%	***4922.11***	9280.79	101.29	***79.06***
1.5%	0.5%	1.0%	126.48	***118.19***	116.39	***99.26***
1.5%	1.0%	0.5%	***152.42***	167.40	116.39	***99.26***
1.5%	1.5%	0.0%	***253.86***	360.77	116.39	***99.26***
1.5%	2.0%	-0.5%	***864.57***	1526.44	116.39	***99.26***
1.5%	2.5%	-1.0%	***5869.77***	11081.65	116.39	***99.26***
0.5%	0.5%	0.0%	***347.37***	520.42	***198.10***	235.71
-0.5%	0.5%	-1.0%	***13564.01***	25733.68	***2276.67***	4181.18

Annex C1: GAD-equivalent discount rates and sustainability gaps in the best case scenario.

Best Case			**GAD equivalent constant discount rate**		**Sustainability Gap (in absolute percentages)**	
Discount Rate	intra	inter	Bioreactor	Dry Tomb	Bioreactor	Dry Tomb
7.5%	4.5%	3.0%	6.9353%	6.7629%	0.5647%	0.7371%
6.5%	4.5%	2.0%	5.6683%	5.2443%	0.8317%	1.2557%
6.0%	3.0%	3.0%	5.5689%	5.3930%	0.4311%	0.6070%
5.5%	4.5%	1.0%	3.9738%	3.0648%	1.5262%	2.4352%
5.5%	2.5%	3.0%	5.1208%	4.9529%	0.3792%	0.5471%
4.5%	4.5%	0.0%	0.9357%	0.6864%	3.5643%	3.8136%
4.0%	2.0%	2.0%	3.4980%	3.2170%	0.5020%	0.7830%
4.0%	3.0%	1.0%	2.7770%	2.2147%	1.2230%	1.7853%
4.0%	3.5%	0.5%	1.9666%	1.4347%	2.0334%	2.5653%
4.0%	4.0%	0.0%	0.7935%	0.6071%	3.2065%	3.3929%
4.0%	4.5%	-0.5%	-0.0168%	-0.0393%	4.0168%	4.0393%
3.5%	0.5%	3.0%	3.4006%	3.3501%	0.0994%	0.1499%
3.5%	4.5%	-1.0%	-0.5799%	-0.5799%	4.0799%	4.0799%
3.0%	1.0%	2.0%	2.7070%	2.5624%	0.2930%	0.4376%
3.0%	2.0%	1.0%	2.0708%	1.7479%	0.9292%	1.2521%
3.0%	3.0%	0.0%	0.5513%	0.4536%	2.4487%	2.5464%
3.0%	4.0%	-1.0%	-0.6115%	-0.6112%	3.6115%	3.6112%
2.0%	0.5%	1.5%	1.7908%	1.7205%	0.2092%	0.2795%
2.0%	1.0%	1.0%	1.4730%	1.3197%	0.5270%	0.6803%
2.0%	1.5%	0.5%	0.9769%	0.8572%	1.0231%	1.1428%
2.0%	2.0%	0.0%	0.3508%	0.3067%	1.6492%	1.6933%
2.0%	2.5%	-0.5%	-0.2023%	-0.2091%	2.2023%	2.2091%
2.0%	3.0%	-1.0%	-0.6803%	-0.6795%	2.6803%	2.6795%
1.5%	0.5%	1.0%	1.2212%	1.1668%	0.2788%	0.3332%
1.5%	1.0%	0.5%	0.7985%	0.7343%	0.7015%	0.7657%
1.5%	1.5%	0.0%	0.2613%	0.2341%	1.2387%	1.2659%
1.5%	2.0%	-0.5%	-0.2511%	-0.2554%	1.7511%	1.7554%
1.5%	2.5%	-1.0%	-0.7177%	-0.7168%	2.2177%	2.2168%
0.5%	0.5%	0.0%	0.0968%	0.0910%	0.4032%	0.4090%
-0.5%	0.5%	-1.0%	-0.8896%	-0.8883%	0.3896%	0.3883%

Annex C2: GAD-equivalent discount rates and sustainability gaps in the worst case scenario.

Worst Case			**GAD equivalent constant discount rate**		**Sustainability Gap (in absolute percentages)**	
Discount Rate	intra	inter	Bioreactor	Dry Tomb	Bioreactor	Dry Tomb
7.5%	4.5%	3.0%	7.1114%	6.7618%	0.3886%	0.7382%
6.5%	4.5%	2.0%	5.9474%	5.4148%	0.5526%	1.0852%
6.0%	3.0%	3.0%	5.7051%	5.4431%	0.2949%	0.5569%
5.5%	4.5%	1.0%	4.4758%	3.6095%	1.0242%	1.8905%
5.5%	2.5%	3.0%	5.2404%	5.0135%	0.2596%	0.4865%
4.5%	4.5%	0.0%	1.2792%	0.8444%	3.2208%	3.6556%
4.0%	2.0%	2.0%	3.6518%	3.3827%	0.3482%	0.6173%
4.0%	3.0%	1.0%	3.1235%	2.5653%	0.8765%	1.4347%
4.0%	3.5%	0.5%	2.4225%	1.7605%	1.5775%	2.2395%
4.0%	4.0%	0.0%	1.0384%	0.7294%	2.9616%	3.2706%
4.0%	4.5%	-0.5%	0.0146%	-0.0186%	3.9854%	4.0186%
3.5%	0.5%	3.0%	3.4298%	3.3783%	0.0702%	0.1217%
3.5%	4.5%	-1.0%	-0.5727%	-0.5755%	4.0727%	4.0755%
3.0%	1.0%	2.0%	2.7871%	2.6534%	0.2129%	0.3466%
3.0%	2.0%	1.0%	2.2872%	1.9546%	0.7128%	1.0454%
3.0%	3.0%	0.0%	0.6647%	0.5226%	2.3353%	2.4774%
3.0%	4.0%	-1.0%	-0.6051%	-0.6073%	3.6051%	3.6073%
2.0%	0.5%	1.5%	1.8333%	1.7674%	0.1667%	0.2326%
2.0%	1.0%	1.0%	1.5615%	1.4307%	0.4385%	0.5693%
2.0%	1.5%	0.5%	1.0813%	0.9382%	0.9187%	1.0618%
2.0%	2.0%	0.0%	0.3970%	0.3401%	1.6030%	1.6599%
2.0%	2.5%	-0.5%	-0.1914%	-0.2009%	2.1914%	2.2009%
2.0%	3.0%	-1.0%	-0.6751%	-0.6764%	2.6751%	2.6764%
1.5%	0.5%	1.0%	1.2587%	1.2040%	0.2413%	0.2960%
1.5%	1.0%	0.5%	0.8527%	0.7790%	0.6473%	0.7210%
1.5%	1.5%	0.0%	0.2886%	0.2556%	1.2114%	1.2444%
1.5%	2.0%	-0.5%	-0.2431%	-0.2495%	1.7431%	1.7495%
1.5%	2.5%	-1.0%	-0.7131%	-0.7140%	2.2131%	2.2140%
0.5%	0.5%	0.0%	0.1025%	0.0961%	0.3975%	0.4039%
-0.5%	0.5%	-1.0%	-0.8867%	-0.8868%	0.3867%	0.3868%

Bisher erschienen:

Diskussionspapiere der Fächergruppe Volkswirtschaftslehre

- Bayer, Stefan & Jacques Méry, Sustainability Gaps in Municipal Solid Waste Management: The Case of Landfills, No. 47 (February 2006).
- Schäfer, Wolf, Schattenwirtschaft, Äquivalenzprinzip und Wirtschaftspolitik, Nr. 46 (Januar 2006).
- Sepp, Jüri & Diana Eerma, Developments of the Estonian Competition Policy in the Framework of Accession to the European Union, No. 45 (January 2006).
- Kruse, Jörn, Zugang zu Premium Content, Nr. 44 (Dezember 2005).
- Dewenter, Ralf & Jörn Kruse, Calling Party Pays or Receiving Party Pays? The Diffusion of Mobile Telephony with Endogenous Regulation, No. 43 (November 2005).
- Schulze, Sven, An Index of Generosity for the German UI-System. No. 42 (October 2005).
- Bühler, Stefan, Ralf Dewenter & Justus Haucap, Mobile Number Portability in Europe, No. 41. (August 2005).
- Meyer, Dirk, Manuskriptstaus behindern den Wissenschaftsbetrieb: Zur Möglichkeit von Einreichungsgebühren, Autorenhonoraren und Gutachterentgelten, Nr. 40 (Juni 2005).
- Carlberg, Michael, International Monetary Policy Coordination, No. 39 (March 2005).
- Zimmermann, Klaus W. & Reto Schemm-Gregory, Eine Welt voller Clubs, Nr. 38 (März 2005), erscheint in: *Zeitschrift für Wirtschaftspolitik.*
- Hackmann, Johannes, Die Bestimmung der optimalen Bevölkerungsgröße als (wirtschafts-) ethisches Problem, Nr. 37 (März 2005).
- Josten, Stefan Dietrich, Middle-Class Consensus, Social Capital and the Mechanics of Economic Development, No. 36 (January 2005).
- Dewenter, Ralf & Ulrich Kaiser, Anmerkungen zur ökonomischen Bewertung von Fusionen auf dem Printmedienmarkt, Nr. 35 (Januar 2005).
- Göbel, Markus & Tobias Thomas, Informal Institutions and the "Weaknesses" of Human Behavior, No. 34 (January 2005).
- Dewenter, Ralf & Justus Haucap, Estimating Demand Elasticities for Mobile Telecommunications in Austria, No. 33 (Dezember 2004).
- Meyer, Dirk, Die Entmachtung der Politik: Zur Frage der Überlebensfähigkeit demokratischer Nationalstaaten in einer globalisierten Weltwirtschaft, Nr. 32 (Dezember 2004).
- Josten, Stefan Dietrich & Klaus W. Zimmermann, Unanimous Constitutional Consent and the Immigration Problem, No. 31 (Dezember 2004), erscheint in: *Public Choice.*
- Bleich, Torsten, Importzoll, Beschäftigung und Leistungsbilanz: ein mikrofundierter Ansatz, Nr. 30 (September 2004).
- Dewenter, Ralf, Justus Haucap, Ricardo Luther & Peter Rötzel, Hedonic Prices in the German Market for Mobile Phones, No. 29 (August 2004).

- Carlberg, Michael, Monetary and Fiscal Policy Interactions in the Euro Area, No. 28 (März 2004).
- Dewenter, Ralf & Justus Haucap, Die Liberalisierung der Telekommunikationsbranche in Deutschland, Nr. 27 (März 2004), erschienen in: *Zeitschrift für Wirtschaftspolitik* 53, 2004, 374-393.
- Kruse, Jörn, Ökonomische Konsequenzen des Spitzensports im öffentlich-rechtlichen und im privaten Fernsehen, Nr. 26 (Januar 2004).
- Haucap, Justus & Jörn Kruse, Ex-Ante-Regulierung oder Ex-Post-Aufsicht für netzgebundene Industrien?, Nr. 25 (November 2003), erschienen in *Wirtschaft und Wettbewerb* 54, 2004, 266-275.
- Haucap, Justus & Tobias Just, Der Preis ist heiß. Aber warum? Zum Einfluss des Ökonomiestudiums auf die Einschätzung der Fairness des Preissystems, Nr. 24 (November 2003), erschienen in *Wirtschaftswissenschaftliches Studium* (*WiSt*) 33 (9), 2004, 520-524.
- Dewenter, Ralf & Justus Haucap, Mobile Termination with Asymmetric Networks, No. 23 (October 2003), erscheint in: *European Journal of Law and Economics* 20, 2005.
- Dewenter, Ralf, Raising the Scores? Empirical Evidence on the Introduction of the Three-Point Rule in Portugese Football, No. 22 (September 2003).
- Haucap, Justus & Christian Wey, Unionisation Structures and Innovation Incentives, No. 21 (September 2003), erschienen in: *The Economic Journal* 114, 2004, C145-C165.
- Quitzau, Jörn, Erfolgsfaktor Zufall im Profifußball: Quantifizierung mit Hilfe informationseffizienter Wettmärkte, Nr. 20 (September 2003).
- Reither, Franco, Grundzüge der Neuen Keynesianischen Makroökonomik, Nr. 19 (August 2003), erschienen in: *Jahrbuch für Wirtschaftswissenschaften* 54, 2003, 131-143.
- Kruse, Jörn & Jörn Quitzau, Fußball-Fernsehrechte: Aspekte der Zentralvermarktung, Nr. 18 (August 2003).
- Bühler, Stefan & Justus Haucap, Mobile Number Portability, No. 17 (August 2003), erschienen in: *Journal of Industry, Competition and Trade* 4, 2004, 223-238.
- Zimmermann, Klaus W. & Tobias Just, On the Relative Efficiency of Democratic Institutions, No. 16 (July 2003).
- Bühler, Stefan & Justus Haucap, Strategic Outsourcing Revisited, No. 15 (July 2003), erscheint in *Journal of Economic Behavior and Organization*, 2005.
- Meyer, Dirk, Die Energieeinsparverordnung (EnEV) - eine ordnungspolitische Analyse, Nr. 14 (Juli 2003).
- Zimmermann, Klaus W. & Tobias Thomas, Patek Philippe, or the Art to Tax Luxuries, No. 13 (June 2003).
- Dewenter, Ralf, Estimating the Valuation of Advertising, No. 12 (June 2003).
- Otto, Alkis, Foreign Direct Investment, Production, and Welfare, No. 11 (June 2003).
- Dewenter, Ralf, The Economics of Media Markets, No. 10 (June 2003).
- Josten, Stefan Dietrich, Dynamic Fiscal Policies, Unemployment, and Economic Growth, No. 9 (June 2003).

- Haucap, Justus & Tobias Just, Not Guilty? Another Look at the Nature and Nurture of Economics Students, No. 8 (June 2003).
- Dewenter, Ralf, Quality Provision in Interrelated Markets, No. 7 (June 2003).
- Bräuninger, Michael, A Note on Health Insurance and Growth, No. 6 (June 2003).
- Dewenter, Ralf, Media Markets with Habit Formation, No. 5 (June 2003).
- Haucap, Justus, The Economics of Mobile Telephone Regulation, No. 4 (June 2003).
- Josten, Stefan Dietrich & Achim Truger, Inequality, Politics, and Economic Growth. Three Critical Questions on Politico-Economic Models of Growth and Distribution, No. 3 (June 2003).
- Dewenter, Ralf, Rational Addiction to News?, No. 2 (June 2003).
- Kruse, Jörn, Regulierung der Terminierungsentgelte der deutschen Mobilfunknetze?, Nr. 1 (Juni 2003).

Frühere Diskussionsbeiträge zur Wirtschaftspolitik

- Bräuninger, Michael & Justus Haucap, Das Preis-Leistungs-Verhältnis ökonomischer Fachzeitschriften, Nr. 120 (2002), erschienen in: *Schmollers Jahrbuch* 123, 2003, S. 285-305.
- Kruse, Jörn, Competition in Mobile Communications and the Allocation of Scarce Resources: The Case of UMTS, Nr. 119 (2002), erschienen in: Pierrre Buigues & Patrick Rey (Hg.), *The Economics of Antitrust and Regulation in Telecommunications*, Edward Elgar: Cheltenham 2004.
- Haucap, Justus & Jörn Kruse, Predatory Pricing in Liberalised Telecommunications Markets, Nr. 118 (2002), erschienen in: Christian von Hirschhausen, Thorsten Beckers & Kay Mitusch (Hrsg.), *Trends in Infrastructure Regulation and Financing*, Edward Elgar: Cheltenham 2004, S. 43-68.
- Kruse, Jörn, Pay-TV versus Free-TV: Ein Regulierungsproblem?, Nr. 117 (2002), erscheint in: Mike Friedrichsen (Hg.), *Kommerz - Kommunikation - Konsum. Zur Zukunft des Fernsehens in konvergierenden Märkten*, 2003.
- Kruse, Jörn, Regulierung der Verbindungsnetzbetreiberauswahl im Mobilfunk, Nr. 116 (2002), als Kurzform erschienen in: *Multimedia und Recht*, Januar 2003, S. 29-35.
- Haucap, Justus & Jörn Kruse, Verdrängungspreise auf liberalisierten Telekommunikationsmärkten, Nr. 115 (2002), erschienen in: *Perspektiven der Wirtschaftspolitik* 5, 2004, 337-361.
- Haucap, Justus & Helmmar Schmidt, Kennzeichnungspflicht für genetisch veränderte Lebensmittel: Eine ökonomische Analyse, Nr. 114 (2002), erschienen in: *Zeitschrift für Wirtschaftspolitik* 53, 2002, S. 287-316.
- Kruse, Jörn & Jörn Quitzau, Zentralvermarktung der Fernsehrechte an der Fußball-Bundesliga, Nr. 113 (2002), erschienen in: *Zeitschrift für Betriebswirtschaft, Ergänzungsheft zur Sportökonomie*, 2002, S. 63-82.

- Kruse, Jörn & Justus Haucap, Zuviel Wettbewerb in der Telekommunikation? Anmerkungen zum zweiten Sondergutachten der Monopolkommission, Nr. 112 (2002), erschienen in: *Wirtschaftsdienst* 82, 2002, S. 92-98.
- Bräuninger, Michael & Justus Haucap, What Economists Think of Their Journals and How They Use Them: Reputation and Relevance of Economics Journals, Nr. 111 (2002), erschienen in *Kyklos* 56, 2003, S. 175-197.
- Haucap, Justus, Telephone Number Allocation: A Property Rights Approach, Nr 110 (2001), erschienen in: *European Journal of Law and Economics* 15, 2003, S. 91-109.
- Haucap, Justus & Roland Kirstein, Government Incentives when Pollution Permits are Durable Goods, Nr. 109 (2001), erschienen in: *Public Choice* 115, 2003, S. 163-183.
- Haucap, Justus, Konsum und soziale Beziehungen, Nr. 108 (2001), erschienen in: *Jahrbuch für Wirtschaftswissenschaften* 52, 2001, S. 243-263.
- Bräuninger, Michael & Justus Haucap, Was Ökonomen lesen und schätzen: Ergebnisse einer Umfrage, Nr. 107 (2000), erschienen in: *Perspektiven der Wirtschaftspolitik* 2, 2001, S.185-210.
- Haucap, Justus, Uwe Pauly & Christian Wey, Collective Wage Setting When Wages Are Generally Binding: An Antitrust Perspective, Nr. 106 (2000), erschienen in: *International Review of Law and Economics* 21, 2001, S. 287-307.
- Haucap, Justus, Selective Price Cuts and Uniform Pricing Rules in Network Industries, Nr. 105 (2000), erschienen in: *Journal of Industry, Competition and Trade* 3, 2003, 269-291.
- Bräuninger, Michael, Unemployment Insurance, Wage Differentials and Unemployment, Nr. 104 (2000) erschienen in: *Finanzarchiv* 75, 2000, S. 485-501.
- Kruse, Jörn, Universaldienstlast etablierter Postunternehmen, Nr. 103 (2000) erschienen in: *Zeitschrift für Betriebswirtschaft*, Ergänzungsheft 3, 2002, S. 99-117.
- Kruse, Jörn, Sportveranstaltungen als Fernsehware, Nr. 102 (2000) erschienen in: Schellhaaß, Horst-Manfred (Hg.), *Sportveranstaltungen zwischen Liga- und Medien-Interessen*, Hofmann: Schorndorf 2000, S. 15-39.

Frühere Diskussionsbeiträge aus dem Institut für Theoretische Volkswirtschaftslehre

- Bräuninger, Michael, Social Capital and Regional Mobility, Nr. 4/2002.
- Schäfer, Wolf, EU-Erweiterung: Anmerkungen zum Balassa-Samuelson-Effekt, Nr. 3/2002, erschienen in: Stefan Reitz (Hg.): *Theoretische und wirtschaftspolitische Aspekte der internationalen Integration*, Duncker & Humblot: Berlin 2003, S. 89-98.
- Bräuninger, Michael, The Budget Deficit, Public Debt and Endogenous Growth, Nr. 2/2002.
- Rösl, Gerhard, Die Umverteilung der Geldschöpfungsgewinne im Eurosystem: Das Earmarking-Verfahren seit dem 1.1.2002, Nr. 1/2002, als Kurzform erschienen in: *Wirtschaftsdienst* 82, 2002, S.352-356.
- Schniewindt, Sarah, Two-Way Competition in Local Telecommunication Networks, Nr. 2/2001.

- Reither, Franco, Optimal Monetary Policy when Output Persists: On the Equivalence of Optimal Control and Dynamic Programming, Nr. 1/2001.
- Schäfer, Wolf, MOEL-Wechselkursarrangements, Nr. 1/2000, erschienen in: Günther Engel & Peter Rühmann (Hg.): *Geldpolitik und Europäische Währungsunion*, Göttingen 2000, S. 217-228.
- Heppke, Kirsten, On the Existence of the Credit Channel in Poland, Nr. 8/1999.
- Bräuninger, Michael, Unemployment and International Lending and Borrowing in an Overlapping Generations Model, Nr. 8/1999.
- Henning, Andreas & Wolfgang Greiner, Organknappheit im Transplantationswesen - Lösungsansätze aus ökonomischer Sicht, Nr. 7/1999.
- Chung, Un-Chan, East Asian Economic Crisis - What is and What Ought to be Done: The Case of Korea, Nr. 6/1999, erschienen in: *Research in Asian Economic Studies* 10, 2002, S. 93-121.
- Carlberg, Michael, Europäische Währungsunion: Der neue Policy Mix, Nr. 5/1999, erschienen in *Wirtschaftswissenschaftliches Studium (WiSt)* 29(1), 2000, S. 8-13.
- Carlberg, Michael, European Monetary Union: The New Macroeconomics, Nr. 4/1999, erschienen in: Gerhard Rübel (Hg.), *Real and Monetary Issues of International Economic Integration*, Duncker & Humblot: Berlin 2000, S. 155-175.
- Bräuninger, Michael & J.-P. Vidal, Private versus Financing of Education and Endogenous Growth, Nr. 3/1999, erschienen in: *Journal of Population Economics* 13, 2000, S. 387-401.
- Reither, Franco, A Monetary Policy Strategy for the European Central Bank, Nr. 2/1999 erschienen in: Rolf Caesar & Hans-Eckart Scharrer (Hg.), *European Economic and Monetary Union: Regional and Global Challenges*, Nomos Verlag: Baden-Baden 2001, S. 213-226.
- Bräuninger, Michael, Wage Bargaining, Unemployment and Growth, Nr. 1/1999 erschienen in: *Journal of Institutional and Theoretical Economics* 156, 2000, S. 646-660.

Frühere Diskussionsbeiträge zur Finanzwissenschaft

- Josten, Stefan, Crime, Inequality, and Economic Growth. A Classical Argument for Distributional Equality, 2002, erschienen in: *International Tax and Public Finance* 10, 2003, S. 435-452.
- Zimmermann, Klaus W. & Tobias Thomas, Öffentliche Güter, natürliche Monopole und die Grenze marktlicher Versorgung, 2002, erschienen in: *Wirtschaftswissenschaftliches Studium (WiSt)* 32, 2003, S. 340-344.
- Holm-Müller, Karin & Klaus W. Zimmermann, Einige Anmerkungen zur Internalisierungsstrategie mit dem produktorientierten Konzept der Pigousteuer, 2002, erschienen in: *Zeitschrift für Umweltpolitik und Umweltrecht* 25, 2002, S. 415-420.
- Josten, Stefan, Nationale Schuldenpolitik in der EWU, 2002, erschienen in: *Wirtschaftsdienst* 82, 2002, S. 219-225.
- Hackmann, Johannes, Der Sonderabgabenbezug nach dem Lebenspartnerschaftsergänzungsgesetz, 2002, erschienen in: *Wirtschaftsdienst*, 82, 2002, S. 241-248.

- Josten, Stefan, Das Theorem der Staatsschuldneutralität. Eine kritisch-systematische Rekonstruktion, 2001, erschienen in: *Jahrbuch für Wirtschaftswissenschaften* 53, 2002, S. 180-209.
- Zimmermann, Klaus W., Komplikationen und Fallstricke in der Pigou-Analyse von Externalitäten, 2001, erschienen in: *Jahrbuch für Wirtschaftswissenschaften* 53, 2002, S. 245-267
- Josten, Stefan, National Debt in an Endogenous Growth Model, 2001, erschienen in: *Jahrbuch für Wirtschaftswissenschaften* 53, 2002, S. 107-123.
- Hackmann, Johannes, Vom Ehegattensplitting zum Partnerschaftssplitting?, 2001, erschienen in: Volker Arnold (Hg.), *Wirtschaftsethische Perspektiven VI*, Schriften des Vereins für Socialpolitik 228/VI, Ducker & Humblot: Berlin 2002, S. 189-222.
- Zimmermann, Klaus W. & Tobias Just, Politische Glaubwürdigkeit und der Euro: Eine verfassungsökonomische Perspektive, 2000, erschienen in: Fritz Söllner & Arno Wilfert (Hg.), *Die Zukunft des Steuer- und Sozialstaates*, Physica Verlag 2001, S. 373-397.
- Josten, Stefan, National Debt, Borrowing Constraints, and Human Capital Accumulation in an Endogenous Growth Model, 2000, erschienen in: *FinanzArchiv* 58, 2001, S. 317-338.
- Zimmermann, Klaus W. & Tobias Just, The Euro and Political Credibility in Germany, 2000, erschienen in: *Challenge* 44, 2001, S. 102-120
- Josten, Stefan, Public Debt Policy in an Endogenous Growth Model of Perpetual Youth, 1999, erschienen in *FinanzArchiv* 57, 2000, S. 197-215.
- Zimmermann, Klaus W., Internalisierung als Nirwana-Kriterium der Umweltpolitik, 1999, erschienen in: Kilian Bizer, Bodo Linscheidt & Achim Truger (Hg.), *Staatshandeln im Umweltschutz. Perspektiven einer institutionellen Umweltökonomik*, Duncker & Humblot: Berlin 2000.
- Hackmann, Johannes, Die unterlassene Besteuerung der Nutzungswerte selbstgenutzten Wohnungseigentums: Vergebene Reformpotentiale, 1999, erschienen in: R. Lüdeke, W. Scherf & W. Steden (Hg.), *Wirtschaftswissenschaft im Dienste der Verteilungs-, Geld- und Finanzpolitik*, Festschrift für A. Oberhauser, Berlin 2000, S. 387-412.
- Zimmermann, Klaus W. & Tobias Just, Interest Groups, Referenda, and the Political Process: On the Efficiency of Direct Democracy, 1999, erschienen in: *Constitutional Political Economy* 11, 2000, S. 147-163.
- Josten, Stefan, Staatsverschuldung und Wirtschaftswachstum in einem Diamond-OLG-Modell mit AK-Technologie, 1999, erschienen in: *Jahrbuch für Wirtschaftswissenschaften* 51, 2000, S. 237-254.