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DIPLOMOVÁ PRÁCE

Environmental Cost-Benefit Analysis: Social Time Discount Rate (or "Pure" Rate of Time Preference) Determination in Social Discounting of Public Projects/Policies in the Czech Republic

Vypracoval: Bc. Šárka Štěpaníková
Vedoucí: Mgr. Milan Ščasný PhD.
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Prohlášení

Prohlašuji, že jsem diplomovou práci vypracoval samostatně a použil pouze uvedené prameny a literaturu

V Praze, 20. května 2009:

Šárka Štěpaníková

ABSTRAKT

V důsledku degradace životního prostředí a nejistoty, do jaké míry je možné nahradit přírodní kapitál, vyvstala potřeba rozhodovacího nástroje, který by ohodnotil veřejný projekt či politiku jak z privátního, tak ze společenského úhlu pohledu (který zahrnuje i pohled environmentální). V této diplomové práci představujeme environmentální analýzu nákladů a přínosů (CBA) jako ideální teoretický prostředek k dosažení takového cíle, avšak ještě jako nedokonalý nástroj k jeho dosažení v praxi.

Diskuze o CBA je plná sporů, v této práci se však zaměřujeme pouze na jeden – volbu společenské diskontní míry (SDR), konkrétně na společenskou časovou diskontní míru (neboli „čistou“ míru časové preference) pro veřejné environmentální projekty či politiky v České republice. Tato otázka je v důsledku velké nejistoty budoucnosti a mezigenerační spravedlnosti jedním z nejkontroverznějších kroků v CBA. Hledáme proto nejvhodnější způsob určení SDR, hodnotu, kterou by společenská časová diskontní míra a SDR obecně měla mít ve veřejných environmentálních projektech nebo politikách v České republice a zda jsou tyto výsledky v souladu s doporučeními Evropské komise.

ABSTRACT

Due to the increasing environmental degradation and high uncertainty of the degree of the natural capital substitutability, a necessity for a decision tool, that would assess a public project/policy, apart from the private, also from the social (so also environmental) point of view, has arisen. We present the environmental cost-benefit analysis (CBA) as an ideal aid to accomplish such an objective in theory, however, as a still imperfect tool to achieve it in practice.

As the CBA is full of controversies, we address only one - the choice of the social discount rate (SDR), in particular the social time discount rate (or “pure” rate of time preference) for the public environmental projects/policies in the Czech Republic – that, due to a great uncertainty about the future and intergenerational justice, is one of the most controversial steps in the CBA. We search for the most appropriate way of the SDR determination, value the social time discount rate and the SDR in general should take in the public environmental projects/policies in the Czech Republic and whether these outcomes are in compliance with the recommendations of the European Commission.

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PROJECT OF MASTER THESIS

Author: Bc. Šárka Štěpaníková
Term of master examinations: February 2009
Leader of the master thesis: Mgr. Milan Ščasný PhD.

Preliminary title:

Cost-Benefit Analysis: Sensitivity Analysis of the Impact of Climate Change in the Czech Republic

Characteristic of the theme:

The objective of my thesis is to present cost-benefit analysis (CBA) as a practical aid in the context of environmental decision-making and at the same time, however, to explain complexity of its practical execution and to provide a detailed analysis of its most controversial parameters. The methodological approaches of the project are theoretical as well as practical. In the theoretical part we would make a comparison of CBA with alternative decision-making methods, analyze individual stages in practical execution of CBA and determine parameters about that there might exist uncertainty. Then we would proceed to the first practical section of the project where we would provide a critical assessment of collected CBAs that have been executed, across various fields, in the Czech Republic and we would determine the most controversial parameters. The detailed discussion of these parameters and demonstration of their different values' impact on the external cost of, most likely, carbon emissions would follow. In the second practical section, preferences on these parameters in the Czech Republic would be found out. In the final section, results of our findings would be discussed with their practical use in decision-making process in the Czech Republic.

Research questions:

- Does it depend on subject of CBA to determine parameters about which there is uncertainty?
- Can the CBA executor and his/her assumptions about the values of the parameters have a significant impact on outcome of the CBA?
- Has been CBAs well executed in the Czech Republic, i.e. in line with a state-of-the-art guidelines and methods?
- Is it important to get to know experts' preferences upon the values of the controversial parameters in the Czech Republic?
- Are the forms and values of the founded parameters for the Czech Republic compatible with experts' recommendations worldwide?
- How our findings can be used in practical decision-making process in the Czech Republic?

Hypotheses:

- The most controversial parameters in conducting CBA are discount rate and equity weighting.
- Stakeholders' preferences differ according to their profession.

Method of verification:

- Critical assessment of collected CBA executed in the Czech Republic
- Sensitivity analysis
- Analysis of stakeholder preferences by Delphi method

Preliminary outline:

1) ***Introduction***
   - Policy decisions in the world of scarce resources → make a choice among the alternative → how to choose the best one? (The two fundamental theorems of welfare economics, effects of environmental regulation, cost-benefit analysis)

2) ***Comparison of CBA with alternative decision-making methods***
   - Discussion of the other decision-making aids, advantages of CBA (i.e. multi-criteria tool, cash-flow analysis of private project contra CBA that covers impacts on whole society)

3) ***Steps of well executed CBA***
   - Discussion of a list of logical steps and questions that need to be addressed, determination of parameters about which there might exist uncertainty

4) ***Critical assessment of CBAs executed in the Czech Republic***
   - Collection of the CBA (across various fields) and addressing the issues:
     A) Has been each step followed?
     B) What is the scope of the impacts covered?
     C) How are the benefits monetized?
     D) What are the values of key parameters such as discount rate, price prediction/escalation contra trends in BAU?
     E) How are the benefits aggregated?
   - Identification of the main conceptual problems in real applications of CBA

5) ***Sensitivity analysis – Case study***

   A) <u>Discussion of controversial parameters</u>
   - Theoretical background and practical demonstration of their different values' impact on the external cost of environmental burden, most likely of carbon emissions

   B) <u>Method</u>
   - Elicitation of stakeholders' preferences to derive social preference for weighting policy outcomes appearing in future and/or other regions; motivation by Weitzman's work *Gamma Discounting*; literature review on

the subject will follow; discussion of possible methods; pros and cons for Delphi method

C) Field experiment

- Delphi method use: Identification of stakeholders, problem presentation, invitation of the experts to participate in the experiment, conduct of the experiment, analysis of the results

D) Results discussion

- Reasoning upon the degree of the findings' use in the practical decision-making process in the Czech Republic on the basis of the collected CBA

6) Conclusion

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Signature of the consultant: Signature of the author:

CONTENTS:

1. Introduction

First theorem of welfare economics states that under the conditions of perfect competition[1] a Pareto-efficient (optimal) equilibrium[2] is always achieved without any government intervention (Just, Hueth, Schmitz, 2004). The overall social welfare is maximized there. However, the perfect competition does not exist in the most of the real life situations and thus Pareto-efficient outcome is not achieved. Speaking about the environmental issues, the market does not reflect total economic value of the environmental goods and services and therefore the market failure of externalities[3] arises which results in the fact that the conventional (neoclassical) economics does not manage to allocate natural resources in en efficient manner[4] (social costs are high) and the social welfare thus reduces. Second theorem of welfare economics links up to the first theorem and states that out of the infinity of all possible Pareto-efficient outcomes, the central planner can achieve any particular desired one by enacting a lump-sum wealth redistribution and then letting the market takes over (Just, Hueth, Schmitz, 2004). This theorem gives legitimacy to state interventions. The two theorems thus open a space for environmental economics[5] and its environmental regulation whose importance has increased since the 1970's due to the more visible and serious environmental degradation.

[1] The conditions of perfect competitive market are the following: There are so many buyers and sellers in each market that no one can individually affect prices, that buyers and sellers can easily enter and exit from each market, that the goods sold in each market are homogenous (i.e. identical), that there is an absence of transaction costs in buying and selling in each market, that information is perfect, and that private costs and benefits are identical to social costs and benefits (i.e. there are no externalities) (Boardman, 2006).

[2] Pareto-efficient equilibrium is an equilibrium in which by a change of allocation of resources you cannot make someone better off without making someone else worse off (Samuelson, 1992).

[3] Externalities are activities that affect others for better (positive externalities) or worse (negative externality), without those others paying (negative externalities) or being compensated (positive externalities) for the activity (Samuelson, 1992). Externalities exist when private costs or benefits do not equal social costs or benefits.

[4] An efficient allocation is such in which the costs of a policy/project are minimized (Markandya, Perelet, Mason, Taylor, 2001).

[5] The environmental economics follows the conventional neoclassical economics in the sense of having as its central concern the efficient allocation of scarce resources among competing uses (Markandya, Perelet, Mason, Taylor, 2001). This branch, in contrast to the neoclassical economics, however, brings the scarce natural resources into mainstream economic analysis framework. Thus it deals with issues such as pollution control, the efficient setting of emission standards, the conservation of natural capital etc. The overall objective is to identify policies (government's intervention is desired here in contrast to the neoclassical economics) which would move the economic system towards an efficient allocation of natural capital (policies which would internalize environmental externalities). This branch differs from the ecological economics in the sense of reaching environmental objectives by using market mechanisms. These two branches, however, overlap, into certain extend.

Since Pareto-efficient equilibrium cannot be achieved in practice, environmental regulation should seek a Pareto improvement which is "a reallocation of assets that makes at least one person better off (increase his or her utility) without making anyone else worse off" (Markandya, Perelet, Mason, Taylor, 2001). And since the compensation of losers does not take place in reality, the environmental regulation should seek the so called Kaldor-Hicks improvement. It is in fact a Pareto improvement with the distinction of the loosing party(ies) being compensated only hypothetically by the beneficiaries.

As the first-best policy of lump-sum wealth redistribution is difficult to enforce and thus practically not used, the so called second-best policies/projects (e.g. the EU Emission Trading Scheme), due to which a decision-maker conducts welfare redistribution in order to correct the market failure (e.g. externalities), are implemented. These policies/projects, however, do not necessarily lead to the Kaldor-Hicks improvement. There can be present an efficiency problem into certain extent (e.g. private cost increase), an effectiveness problem (e.g. a desired level of pollution is not reached) or redistribution effects (e.g. a disadvantage of lower income groups or future generations). For this reason there is a need for a comprehensive evaluation procedure that would accomplish the following objective: It would be able to take into account, apart from the private, also social (including environmental) impacts of the public policies/projects and decide whether the policy/project leads to the Kaldor-Hicks improvement (in case of one option considered) or which option leads to the biggest Kaldor-Hicks improvement (in case of more options considered) and thus whether or which option should be undertaken. The environmental cost-benefit analysis (CBA) is considered to be such a procedure.

The goal of this thesis is, despite of the theoretical fundamentals' criticism (which is not part of the thesis), to present the environmental CBA as an ideal aid to accomplish the objective of a proper assessment of public projects/policies due to inclusion of even social (including environmental) impacts in theory, however, as a still imperfect tool to achieve the objective in practice. As the CBA is full of controversies, we further address only one, one of the most controversial steps - the choice of the social discount rate (SDR). In particular, we discuss the role of the social time discount rate (or "pure" rate of time preference) in the social discounting of the public environmental projects/policies in the Czech Republic. The central questions addressed are: What way (positive or normative) of the SDR determination is a more appropriate

one, what value(s) the social time discount rate and the SDR in general should take in the public environmental projects/policies in the Czech Republic and whether the outcomes are in compliance with the recommendations of the European Commission. The thesis is structured as follows:

The first part of the diploma thesis (chapter 2) briefly introduces theoretical foundations of the environmental CBA.

The second part of the diploma thesis (chapter 3) then analyzes, in a greater detail, individual stages of the environmental CBA – their theoretical instructions and practical (intended and unintended) difficulties.

The third part of the diploma thesis (chapter 4) devotes to the problems of social discounting. In the first section of the chapter we will present types of SDR and their advocates. In the second section of the chapter, we will, firstly be looking for the most appropriate model for the Czech Republic within the market way of the SDR determination that is preferred by some economists because of having some characteristics of positive economy. Secondly, we will subject this way of the SDR determination to criticism, discuss the assumptions under which such a SDR might be applied and the role the social time discount rate (or "pure" rate of time preference) plays in this way of SDR determination. Thirdly, we will suggest an alternative way of the SDR determination - intergenerational approach to social discounting. We will discuss values of its parameters and, due to the complexity of the issue, our attention will be concentrated on the social time discount rate, its different role in this model, the necessity of being derived in a different way and argumentation for a specific value of the parameter. And, finally, the most appropriate value(s) of the SDR for the public environmental policies/projects are discussed and compared to the European Commission's (EC's) recommendations.

2. Fundamentals of the Environmental CBA

The cost-benefit analysis (CBA) was originally designed to evaluate the net financial benefits (benefits minus costs) (Markandya, Perelet, Mason, Taylor, 2001). Such a CBA is called financial analysis (European Commission, Directorate General Regional Policy, 2008). The costs are defined here as private (or individual) expenses and benefits as private (or individual) revenues.

However, due to the market failure existence, the need to appraise projects/policies using the prices that would prevail in competitive markets ("shadow prices") has arisen (Pearce, 2006). The CBA that takes into consideration, apart from the private benefits and costs (impacts), also social impacts (impacts not reflected by the market) of projects/policies is called economic analysis, extended, or social CBA (European Commission, Directorate General Regional Policy, 2008). In this case a benefit/cost may be defined in a more general way as an increase/decrease in an individual well-being, utility or welfare.

These analyses started to be applied to the developing world due to its great market distortions. In the developed world they rather focused on shadow prices in contexts where markets did not exist at all (e.g. accident risks and time savings being notable early examples) (Pearce, 2006). Since the 1970's, due to the more visible and serious environmental degradation, the CBA has started to intend taking into account the environmental type of the social impacts as well. The economic analysis therefore intends to evaluate the overall impacts of a policy/project and thus can make a judgement upon the degree if the possible Kaldor-Hicks improvement. However, the environmental CBA is nowadays still rarely used in the Czech public decision-making and, instead, less comprehensive but less controversial decision instruments (e.g. Environmental Impact Assessment[6]) are applied (Czech Ministry of the Environment, 2009).

In short[7], to be able to include the social impacts into the analysis, these impacts need to be determined and quantified in physical units (along the whole time horizon of the project/policy) and, in order them to be comparable to the private ones, need to be

[6] Environmental Impact Assessment (EIA) is a systematic procedure for collecting information about the environmental impacts of a project/policy (Pearce, 2006). It is not a comprehensive evaluation procedure since it ignores non-environmental impacts and it ignores costs. It also may not account in a detailed way for the ways in which impacts vary with time.

[7] Stages of the environmental CBA will be discussed in greater detail in the next chapter.

expressed in uniform units – the monetary units – the units that the elaborate apparatus of business finances uses to make final conclusions about the alternatives (Sieber, 2004). And then to compare the policy/project's impacts that arise in different time periods across the time horizon, we might use net present value analysis (or net benefit criterion) which implies social discounting – essentially, the further in the future the impact arises the lower weight it is assigned to it – and the impacts are thus turned into present values (PV) (Boardman, 2006). The net benefit criterion is a decision rule according to which any single policy/project alternative (relative to status quo) with a positive NPV (net present value) should be adopted (Boardman, 2006). Thus the necessary condition for adoption of a policy/project is: PV(B) > PV(C) or alternatively NPV > 0. In case of more alternatives that are all mutually exclusive (one policy/project can only be undertaken to the exclusion of another policy/project since these are, for example, two different ways of achieving the same objective), the policies/projects should be ranked by their NPVs and the one with the highest positive NPV should be adopted (Pearce, 2006).

In order the process of such CBA to be accomplished, there need to be theoretical foundations (that are criticized by some but we will not devote to this criticism in this thesis) that can be summarized as follows:

First, the preferences of individuals are to be taken as the source of value (Pearce, 2006). To say that an individual's well-being, welfare or utility is higher in state X than in state Y is to say that he/she prefers X to Y.

Second, preferences are measured by a willingness to pay (WTP) and willingness to accept compensation[8] (Pearce, 2006).

Third, it is assumed that the individuals' preferences can be aggregated so that social cost is simply the sum of all individuals' costs and the social benefit is the sum of all individuals' benefits (Pearce, 2006).

And fourth, if beneficiaries from a change can hypothetically compensate the losers from a change, and have some net gains left over, then the basic test that benefits exceed costs is met (and the Kaldor-Hicks improvement is achieved) (Pearce, 2006).

[8] For more details, please, refer to the next chapter.

3. Stages of the Environmental CBA

In this chapter let's analyze individual stages in practical execution of CBA in a greater detail, individual stages of the environmental CBA – their theoretical instructions and practical (intended and unintended) difficulties. What are the steps and questions that a CBA executor has to address? Theoretical procedure is quite straightforward. However, how close is this ideal stage to practical performance?

3.1. "Ex ante" or "Ex post" CBA

Firstly, it has to be decided what type of CBA is going to be performed. There are two main types of CBA - "ex ante" and "ex post" CBA (Boardman 2006). "Ex ante" CBA is the most frequent and useful from all types of CBAs as it serves to decide whether a policy or project (investment) that has not yet been done is worth to carry out from the overall social well-being perspective. It is worth to carry out if the present value of expected benefits of the policy/project exceeds the preset value of expected costs (Pearce, 2006). When we speak about CBA, in this work, we usually refer to "ex ante" CBA. "Ex post" CBA, on the other side, informs us whether a policy/project, that has entirely been done, has been carried out to really contribute to the overall social well-being, whether, in general, particular classes of policies/projects are worthwhile to perform from the social point of view. We can learn from such analysis whether the "ex ante" analysis was accurately performed and if it was not, what justifications were used to perform the policy/project. In this way we can avoid the mistakes (e.g. exaggeration or underestimation of costs/benefits, wrong assumptions) in future similar analyses. In case of a policy/project decision where no CBA aid was used, the "ex post" CBA can show the extent to which the decision-making procedure used imposed an efficiency cost on society if the "ex post" analysis reveals higher actual costs than benefits of the policy/project already carried out.

There are also two minor types of CBA – "in medias res" and "ex ante/ex post or ex ante/in medias res comparison"– that are a mixture of the two main CBA types mentioned above (Boardman 2006). "In medias res" CBAs are used for policies/projects that have already been started but have not been ended yet. Actual values of benefits and costs of a policy/project are known ("ex post" characteristic). This reduced uncertainty can help to better estimate the values of future benefits and costs and thus

decisions upon continuation or termination of a policy/project (or similar policies/projects) can be made ("ex ante" characteristic). If, for example, a policy/project is estimated to have higher costs and lower benefits in the future, it is usually terminated if the actual costs given up to the policy/project are still low and it is usually recommended for continuation if these costs are already high. The "ex ante/ex post or ex ante/in medias res comparison" compares the CBAs of the same policy/project. It serves for learning about efficacy of CBA as a decision-making and evaluative tool for similar policies/projects because omission, forecasting, measurement or evaluation errors can be found due to such comparisons. These analyses are not, however, performed frequently.

3.2. Choice of policy/project options

Secondly, a CBA executor must decide which policy/project options CBA will be executed on (Pearce, 2006). Every policy/project has a goal to be reached and there are different ways to achieve it. For example, a goal of a policy is to improve air quality. There may be different ways to reach that goal - environmental taxes, command-and-control regulation, tradable property rights etc. These types of regulation themselves might be the policy options. However, the policy options also may be different settings under particular type of regulation (e.g. free allocation of allowances to emit CO2 or their allocation through sale in auction under the tradable property rights). And also, the options might be different scales of the policy. For example, the decision-maker might have already decided that he/she would only consider the tradable property rights regulation and the setting of allowance allocation through sale in auction. Therefore, his/her policy options might be now inclusion of different groups of polluters (sectors) in the scheme. Also, in case of an investment projects, one project can be compared to completely different alternative project(s) or to hypothetical project - the situation when no resources are invested, the status quo. Or the analyst might decide for only one policy option to undertake CBA on.

We can see that the list of policy/project alternatives can be quite large. In practice, however, analysts usually analyze only a few alternatives (less than six) (Boardman 2006). There are the following reasons for this. First, there is a cognitive constraint. It means that there might be so many alternatives that we do not have to be capable to list all of them. Second, there often exists resource constraint. The CBAs are

costly in terms of time, skills and money. For example, the Environmental Protection Agency (EPA) spent approximately 700,000 dollars for major CBA projects in 1980's. And third, there are often political, ethical and other factors present which predetermine the exact reduced list of options. Because of, especially, the third reason, very often not the best option(s) is/are chosen for the analysis. Since not always decisions upon the choice of option(s) are made on the basis of efficiency and/or effectiveness but are influenced by the mentioned factors, the option that passes a cost-benefit test (benefits exceed costs) (in case of one option being presented) or the one that reaches the highest net benefit (in case of more options being presented) is not always the best thing to do (Pearce, 2006). Other options that are not presented might yield higher net benefits for the same cost outlay.

3.3. Issue of "Standing"

The third question the CBA executor must address is the one of whose benefits and costs will be included in the CBA (Pearce, 2006). The preferences of individuals are the source of value[9] in the CBA and, as we have stated in the preceding chapter, these preferences can be aggregated to obtain the so called "social" preference about the policy/project[10]. The "social" preference is the preference of the society, of the sum of all individuals. The first question that arises here, however, is what does it mean "all individuals"? The theory suggests that benefits and costs of those that have "standing" - are affected by the policy/project - should be included in the CBA. In practice, the CBA executers often include those individuals for whom the policy/project is designed. Thus the individuals "who count" for the policy/project on city level, are inhabitants of the city, for the policy/project on state level, the individuals "who count" are citizens of the state etc.

Such a rule is, however, too simplistic. The group of people affected by the policy/project is often larger than the group for which the policy/project is designed, especially in case of environmental issues. Traditionally, CBA was applied to human

[9] The value is measured in terms of willingness to pay (WTP) and/or willingness to accept compensation. We deal with this issue in the next section of this chapter.

[10] In case of "ex ante" CBA, it is expressed in terms of net present value (NPV) of expected benefit. If the NPV is a positive number, the preset value of the policy/project's expected benefits exceeds the present value of expected costs. If the NPV results in a negative number, then the present value of the policy/project's expected costs exceeds the preset value of expected benefits. In case of "ex post" CBA, the "social" preference is expressed in terms of net value (NV) of actual benefit. The reasoning of NV being positive or negative is analogous to the NPV.

systems only, in markets where there was some distortion (or in one that did not exist at all) and thus the need for appraisal of a policy/project using a price that would prevail in competitive market arose (Pearce, 2006). However, since the 1970's as the environmental harms of industrial production has begun more and more visible and inconvenient, CBA started to be applied, apart from human, also to environmental systems. In fact, all human actions affect the environment. Defining geographical boundary of the sum of individuals "who count" is much more complicating under such a view. That is to say that a state policy/project that affects the state's citizens for better and worse can also affect for better or worse citizens of another/other state(s) because environmental systems are highly interconnected. For example, a policy of prohibition of chemicals' release into rivers in one state can affect for better fishermen, farmers, water-tourists etc. not only in that state but in all states around where that state's rivers flow into. There are policies that have even global impacts such are the policies affecting emissions of greenhouse gases (GHGs). For example, a policy that leads to an increase in emissions of GHGs in one state affects for worse the Earth as a whole because the origin of emitting does not make any difference for the state of the atmosphere.

There are basically two main reasons for a CBA executor to include the non-state individuals into the CBA of the emitting country (Pearce, 2006). First, it is the ethical consideration that others should not suffer because of another person/other people acting. Second, it is a legal obligation (e.g. a transborder pollution agreement) that obligates the emitting country to take into account the costs of the other state citizens. The problem with the first reason, however, is that nowadays' economic interests still often gain victory over the ethical ones. And Klaus Töpfer, Executive Director of the United Nations Environment Programme, explains the problem with the second reason: 'We have over 500 international and regional agreements, treaties and deals covering everything from the protection of the ozone layer to the conservation of the oceans and seas. Almost all, if not all, countries have national environmental laws too. But unless these are complied with, unless they are enforced, then they are little more than symbols, tokens, paper tigers' (United Nations Environment Programme, 2002). Thus practical decision-making processes, due to the victory of economic interests over the ethics and the insufficiency of environmental agreements' enforcement, often lead to non-inclusion of "all individuals" into CBAs.

3.4. Proper Inclusion of Economic Impacts in CBA

In this stage, the CBA practitioner has to determine what economic impacts (benefits and costs) would be included in the CBA. The theory suggests that the economic impacts of the policy/project that affect individuals' well-being are proper impacts for inclusion in the CBA (Pearce, 2006). We need to add that the individuals at this stage are meant the individuals who have "standing" and that the impacts accrued to these individuals can arise in whatever stage of the life cycle[11] of the policy/project. We need to find the impacts of the policy/project life cycle that affect well-being of all the individuals who have "standing".

Thus, for example, a price increase of a rose as such would not be, surprisingly, identified as a proper impact for the inclusion because, if nothing else change (e.g. people buy the same amount), then the only effect of this price increase, from the perspective of the economy as a whole, would be a transfer of wealth from buyers to sellers of the good (Financial Services Authority, 2000). The price increase becomes a proper impact for inclusion as soon as it starts altering behavior of people and thus affecting the people's well-being – due to the price increase people would start purchasing less of the good. Considering environmental policies/projects, another example of proper impacts' inclusion can be stated. Impacts of depletion of ozone layer on human health are proper impact for inclusion in the CBA because illnesses affect individuals' well-being. However, impacts of depletion of ozone layer on plants (e.g. delay in flowering, a shift in the distribution of leaves, a change in leaf structure, a change in a plant's metabolism) would not be proper impacts for inclusion in the CBA unless they start affecting individuals' well-being (e.g. decrease in fertility or disappearing of some plants). Identification and listing of the important impacts may thus depend on the scientific or social science knowledge about the impact and its connection to human well-being (Boardman 2006).

Apart from the concern to include all known impacts that affect individuals' well-being, the analyst also has to be aware of the possibility that certain impacts (i.e. flooded land) can bear costs (i.e. damage of houses) to one group of people but, in the same time, benefits to another group (i.e. hunters as the flooded land attracts ducks) (Boardman 2006). Therefore the values of these benefits and costs should be both considered in the separate impact categories.

[11] This issue of so called time horizons will be discussed in greater detail in the section 3.6.

Economic Impacts Types

The guides on CBA performance, in countries where CBA is obligatory in decision-making process into certain extent, state many possible groups of impacts the analyst should look for. In reality, each individual case (project/policy) that undergoes CBA has its own specific economic impacts. However, in general, speaking about projects/policies implementing by public bodies, there are three types of economic impacts (costs and benefits) that need to be summed in the overall cost-benefit equation:

- Compliance Impacts
- Regulatory Impacts
- Environmental Impacts

Compliance impacts are those economic impacts that fall on the business sector and households while implementing the project/policy (Pearce, 2006). Considering, for example, command-and-control regulation, these sectors face mostly costs in this category of impacts at the outset of the project/policy. Due to suppliers' meeting the minimum energy performance standards, households might bear compliance cost in form of, for example, decrease in purchase of the goods - directly (i.e. energy) or indirectly (i.e. bread) regulated – due to their price increase, or lower salaries of workers. Later on, however, households can also face benefits in this category of impacts: energy cost savings due to, for example, purchase of non-regulated source of energy – solar energy panels.

In case of the regulated firms, the side of cost includes, first, 'visible' costs (i.e. installation and maintenance of pollution-control equipment and end-of-pipe emission treatment costs) (Joshi, Krishnan, Lave, 2001). Second, there belong so called 'hidden' costs (i.e. substitution of less polluting and more expensive inputs for more polluting but cheaper inputs, indirect labor costs to monitor and report emissions, or increase in administrative costs) that the firms' accounting systems often fail to identify separately as incremental costs due to the environmental regulation. And third, there are external costs to society for which firms are not currently accountable but which may become material in the long run (i.e. restriction of outputs into economic process – i.e. land – due to global warming). Later on, the regulated firms also might face benefits. The supporters of the command-and-control regulation claim that useful innovation often

costs a lot at the outset but then the costs of using innovation fall as producers learn better the production techniques and realize savings through economies of scale (Driesen, D. M., 2002).

Regulatory Impacts are the economic impacts that fall on the government while implementing policy/project. In this category of impacts it is often spoken about direct costs/benefits (Financial Services Authority, 2000). Designing, monitoring and enforcing regulations requires financial resources whereas fines imposed on firms that do not fulfill the regulatory standards might bring resources into the State budget. Apart from these direct impacts, public institutions also have concerns about the impact of regulatory policy on, mainly, competitiveness, employment, and innovation (Pearce, 2006).

Environmental Impacts are either environmental damages (costs) or environmental damage evasions (benefits) caused by a project/policy (Pearce, 2006). This category of impacts should not be present only in CBA performed directly on environmental policies/projects but, in fact, on any kind of policy/project because, as we have stated earlier, all human activities have an impact on the environment. The case of command-and-control regulation usually leads to a specific level of emission abatement that can bear lots of environmental benefits. These, for example, include: decrease in respiratory diseases or evasion of global warming effects (i.e. increase in the sea level, frequent and radical weather changes, migration and/or extinction of species due to ecosystems' change).

Complementary Impacts

We have stated earlier that CBA requires all impacts of the policy/project that affect individuals' well-being to be included. However, the analyst should be aware of the existence of so called complementary impacts. These are the side impacts that were not originally intended to gain by the project/policy (Pearce, 2006). For example, an energy efficiency policy was designed to reduce energy consumption but, apart from this primer benefit, it also reduces emissions that might entail various complementary benefits such as decrease in: diseases, smog formation, damages to forests and forest soils, acidification of lakes and rivers, harm to agriculture and biodiversity, corrosion of buildings and infrastructure, danger of global warming effects etc. Thus we can observe that an example of environmental impacts - decrease in diseases - from the previous

paragraph might at the same time be a complementary impact depending on whether the impact was or was not originally intended to gain by the realized project/policy. The CBA executor, while listing the impacts, should be aware of the following issues.

First, the analyst has to decide how deep he/she wants to go in the analysis because a project/policy might cause a chain of impacts where one cost/benefit causes another cost/benefit (Pearce, 2006). The more detailed analysis he/she decides for, the more time and financial recourses he/she invests into the analysis. No matter how much into detail he/she decides to go, he/she should always start with the most important impacts and working downwards (rather than starting with the impacts for which monetary value is easy to find) (Financial Services Authority, 2000).

Second, the analyst has to be careful not to, on one side, omit or, on the other side, double the complementary benefits (Sieber, 2004). To demonstrate the double counting, the benefit of lower harm to agriculture can be measured in change in quantity or quality of agricultural products obtained after the policy is imposed and the benefit of decreased illnesses in change of amount of patients of various illnesses. These two benefits can overlap into certain extent in the sense that some of the illnesses were caused by the lower quality of agricultural products before the policy was imposed. General rule to avoid double counting is to include impacts in primary markets[12] and impacts in distorted secondary markets[13,14], counting effects in undistorted markets should be exercised with a great caution (Boardman, 2006). The double counting or omission of some impacts might occur for strategic reasons of the analyst or the entity assigning the CBA to obtain a specific result that would be convenient to him/her or for not sufficient scientific knowledge due to which not all cause-and-effect relationships are known and as a consequence to this, it is impossible to fully discover all the proper impacts.

Third, Pearce points out that some of the impacts, that we put on the policy account, might happen even without the policy and that some of the policy benefits might be achieved by another policy but in more cost-effective way (Pearce, 2006). In practice, these impacts are often included in the CBA. The analyst should, however,

[12] Primary markets are "markets that are directly affected by a policy/project". These are the market where the policy/project is realized by the government and factor markets where the government purchases the inputs needed for the policy/project.
[13] Secondary markets are "markets that are indirectly affected by a policy/project".
[14] Distorted, or inefficient, market is one where price does not equal marginal social cost. It can be caused by a variety of circumstances: market failures (i.e. monopolies, public goods, externalities, markets with few sellers, and information asymmetries), government failures (market distortions caused by, for example, taxes, subsidies, price ceiling) and absence of market.

give careful thought to the conceptual foundations before making a decision about the impact (or its extent) inclusion in the CBA

Even though theory is quite straightforward about the proper inclusion of economic impacts in CBA, the practice bears mentioned difficulties, intended or unintended, due to which it is not so easy to perform this stage of analysis well and due to which this stage might often be a source of substantial errors in CBA performance.

3.5. Physical Valuation of Economic Impacts

Some of the economic impacts (i.e. decrease/increase in workers' wage) that we have decided to include in the CBA are already specified in monetary units because it results from their essentials. For the rest of them we have to decide for proper measurement indicators – quantify them in physical units. The theory suggests us to choose such measurement indicator (for each economic impact) for which data is available and the transfer into monetary units will be easy (Boardman, 2006).

It can happen that there is not any way to directly measure a certain impact. The analyst might choose a surrogate indicator to express the physical value of the impact (Boardman, 2006). He/she has to, however, be very careful of doing so because such surrogates might give us misleading information about the actual physical value of the impact. The reason is that there does not exist a direct cause-and-effect relationship. For example, to measure the number of crimes avoided due to a policy, the analyst might choose to look for a change in conviction rate. The conviction rate might be decreasing but the actual crime rate might stay unaffected.

Especially in case of projects/policies with substantial environmental impacts it is often difficult to find out cause-and-effect relationships as we have already said. For example, there are multiple linkages between causes and impacts of climate change that are, in many cases, not completely understood. This makes a huge obstacle for the analyst who cannot with certainty determine the impacts (and their physical values) in order to avoid or mitigate them using appropriate policies. For this reason, the European Environment Agency adopted the framework of indicators DPSIR which stands for Driving forces - Pressures - States - Impacts – Responses (European Environmental Agency, 2009). Due to the driving forces (human activities – e.g. industrial production), the pressures (variables that may cause environmental problems – e.g. greenhouse gas emissions) are exerted on the environment, as a consequence come the state (the current

condition of the environment – e.g. climate change) and as a consequence of the state come the impacts (the ultimate effects of changes of the states – e.g. on human health, ecosystems, materials). Studying, observing and monitoring all types of these indicators can help to present and explore these complex relationships and thus to demonstrate the impacts (and their appropriate indicators to quantify the impacts in physical values) of climate change on different environmental and socio-economic sectors which will facilitate decision-making in this field because reliable CBAs will be able to be conducted (European Environmental Agency, 2002).

3.6. Issue of Time Horizons

At this stage, when we already know the economic impacts yielding from the policy/project and their corresponding physical values, there arise the following two issues[15]: Determination of time horizon, the point beyond which the impacts of the policy/project are already not estimated, and prediction of the impacts over this time horizon in each time period (year).

3.6.1. Determination of Time Horizon

Physical or Economic Life of the Project

Regarding the first issue, Pearce (2006) suggests the time horizon to be equal to physical or economic life of the project. He claims that to decide this for investment projects is not that difficult task. He presents the following examples: For infrastructure projects the time horizon can be set from 30 to 50 years and for housing 100 years and more. However, this rule might be valid only for financial analyses that count with only private, not social, benefits and costs.

The infrastructure projects are often conducted by the public sector whose interest in the project does not finish by the project's physical or economic life termination because, bearing the duty to act in the social will, the government has to ensure an alternative use of such project or its dismantling. Such actions of course yield further costs and benefits which prolongs the project's time horizon.

[15] Although these issues might arise in the same time of economic impacts and their physical values' specification because, as we have stated earlier, the impacts might arise in whatever stage of the policy/project life cycle.

However, in case of private projects the Pearce proposed rule might but also might not be valid. The time horizon of private sector projects might be determined by the physical or economic life of the project because beyond such a life no more private costs and benefits are flowing to the private investor. If for example a private owner of a building uses it for a business objective and after the 100 years the building is not suitable for the objective anymore (its physical life is finished), he/she might decide not to renovate it if it is not profitable for him/her and instead leave the building decaying. In such a case, the time period of 100 years would be the project's time horizon. However a law often binds the owner to ensure the building not to represent a danger for public (e.g. the building or its parts might endanger pedestrians passing it). In such a case, the time horizon is longer than 100 years and includes the time period of the necessary maintenance before the owner for example decides to sell the building. We could have observed thus that neither for private projects there is not hard and fast rule for determination of time horizons. For this reason, the time horizons have to be determined individually according to the nature of the project.

Uncertain or Insignificant Estimates about the Impacts

However, the toughest task comes if we have to decide upon the time horizon for policies, especially if they contain a significant environmental aspect (e.g. global warming control policies). It is because, as we have said earlier, there are multiple linkages between causes and impacts of climate change that are, in many cases, not completely understood. Such a situation bears uncertainty about longitude of the climate change effects (which is predicted to be extensive) and the effects of the policies designed to mitigate it or to adapt to it. Literature suggests two ways how to deal with this difficulty.

First way is to set the time horizon at point in which estimates about the impacts becomes uncertain. We cannot say with accuracy what will happen after 30 or 40 years, therefore we cannot include these poor estimates of the impacts into CBA and pretend we perform an accurate CBA. This rule, however, fails to analyze those policies whose impacts arise far in the future (i.e. the status quo policy of not introducing any emission regulation since the emission released today into the atmosphere will provoke serious impacts still in the far future).

Second way suggests that the time horizon should be set at point at which social discounting[16] makes the future impact estimates insignificant. Any positive social discount rate chosen leads to smaller and smaller present values of expected impacts of the policy/project until the present value becomes negligible. Further discussion of social discounting in the section 3.8. will reveal that for certain situations the positive discount rates cannot be used. In the cases where zero or declining discount rates are applied (especially in cases of environmental policies), this rule can be hardly used because the present values of expected impacts will not necessarily bear smaller and smaller numbers while going further into the future.

Thus we can see that determination of time horizons for policies is also not straightforward and such has to be considered individually according to the nature of the policy.

3.6.2. Prediction of Impacts over Time Horizon

Regarding the second issue of prediction of the impacts over this time horizon, Boardman (2006) states that it is quite straightforward to predict quantitatively the impacts for which statistical data exists. For example, a benefit - of a new highway construction - a number of lives saved can be quantified for each year using the known data such as distance of the highway or death occurrence per kilometer. However, even if we have statistical data at our disposal today, we have to be cautious using them for predictions of impacts arising far in the future. The reason is the uncertainty of people's tastes and technology development undergone in the future. People might prefer flying to driving or would have much safer cars. Both changes would lead to a higher number of lives saved than today's statistics predicts.

We can see that even with the known statistical data, the prediction of impacts over the time horizon is not an easy task. Literature often states other three reasons why the prediction of impacts over time horizon is difficult.

First reason lies in existence of so called compensating or offsetting behavior (Boardman, 2006). It means that individual responses to a policy are often unpredictable which can result in diminution or even reversal of the policy's intended effect. For example, a policy of obligatory use of seat belts in cars was intended to bear a benefit of

[16] Social discounting is "the process of assigning a lower weight to a unit of benefit or cost in the future than to that unit now".

safety increase in traffic. It might increase drivers' safety but as a consequence of this benefit, the drivers might engage in riskier driving behavior that might diminish the overall safety increase benefit (i.e. due to increased injury to pedestrians) or even reverse it into unintended effect – decrease in the overall traffic safety.

Second reason lies in substitution or spillover effects (Boardman, 2006). A policy can affect third parties' behavior in a way that alters the overall net present value of benefits. For example, an obligation of helmets for children while cycling might affect their parents' behavior in a way that they would start wearing helmets too (positive spillover) or this obligation would lead the parents to drive the children more and thus to generate more traffic accidents (negative spillover).

Third reason is the already mentioned scientific knowledge (e.g. about climate change) that is still uncertain about the time horizon determination. In the same way, that knowledge is not sufficient yet to make precise and uniform predictions especially of the impacts where the cause-and-effect relationships are not known yet and those that will happen far in the future (environmental impacts).

We have seen that the more complex and unique the project/policy is, its impacts happen far in the future and where the cause-and-effect relationships are not known, the more obstacles for time horizon determination and impacts prediction over the time horizon arise. Because of these difficulties, which some of them will certainly vanish together with scientific development, this stage in conducting CBA might be a source of substantial errors. We will refer to the complicating issue of time horizons in the section

3.7. Monetary Valuation of Economic Impacts

Once all proper impacts along the time horizon of the policy/project are determined and quantified in physical units, we need to express them in monetary units. Expression of impacts in uniform units and, moreover, in units that financial system uses, allows us to compare the costs and benefits and to use elaborated apparatus of business finances to make final conclusions about the alternatives (Sieber, 2004).

The impacts should be measured in terms of either ***willingness to pay*** (WTP) or ***willingness to accept compensation*** (WTA) in order social value of benefits and costs to be expressed (Pearce, 2006). The costs and benefits can be expressed by both, WTP and WTA. The cost of "losers" due to the policy/project can be expressed as the sums of the maximum amounts they would be willing to pay to avoid the cost or, if the "losers"

have a legitimate property right related to what they lose, their cost can be expressed by WTA – the sums of the maximum amounts they would be willing to accept as a compensation for the cost. In the similar matter, the benefit of "beneficiaries" due to the policy/project can be expressed as the sums of the maximum amounts they would be willing to pay to assure the benefit (the policy/project to be carried out) or, alternatively, as a WTA – the sums of the maximum amounts they would be willing to accept to give up the benefit. Although theory suggests identity of costs and benefits' expression in terms of WTP and WTA, the practical observations indicate that these two can differ substantially[17].

In practice, if ***shape of demand and supply curve is known***, the social gains (benefits) and loses (costs) that affect individuals' well-being, due to policy change or a project, are measured by changes in consumer and producer surplus, opportunity cost plus net government revenues generated by the policy/project. Consumer surplus is "the difference between the amount that a consumer would be willing to pay for a commodity and the amount actually paid" (Samuelson, 1992). Changes in consumer surplus are used to express the costs and benefits of consumers when demand schedules are known (Boardman, 2006). The reason for this is that, in most cases, consumer surplus can serve as a good approximation of the society's willingness-to-pay for a policy change or a project. Producer surplus is the economic profit - difference between the revenues from selling a certain amount of good and the variable costs to produce that amount of good. Producer surplus is an equivalent to consumer surplus in cases when supply schedules are known. The sum of consumer and producer surplus is social surplus. Net government revenues are the difference between income that government receives and expenditure it realizes for a project/policy. And opportunity cost is the value of what must be given up by society today and in the future, not what has already been given up[18], to realize the project/policy. In fact, opportunity cost serves as a good approximation of the society's willingness-to-pay to avoid the cost of a policy/project.

In practice, however, the ***shape of demand and supply curve is usually not known*** (Boardman, 2006). In competitive markets, one point of demand and supply curves is known - it is given by the intersection of market price and quantity supplied. In this case market prices provide good indicators of points on appropriate supply and

[17] For deeper discussion of this issue, please, refer to Horowitz, J., McConnell, K. (2002).
[18] The latter are sunk costs that are not represented by the areas under supply schedules, are not connected to project realization and therefore are not included into the costs of the project.

demand curves. To be able to measure changes in social surplus and opportunity cost, it is necessary to estimate entirely these curves. If suitable data are available, it is achieved by econometric techniques. However, in case of distorted and nonexistent markets, where there may not have been even one point on the appropriate demand and supply curve available, the analyst has to use alternative means (direct and indirect methods) to value the project/policy impacts.

Monetary valuation is, due to its complexity and a number of imperfections and biases in the alternative means of monetization (that we will not deal with in this work), one of the most difficult steps in the CBA performance and as such is a source of substantial errors. To illustrate the logic behind the monetization of impacts under the framework of known shape of demand and supply curve (perfect competitive market framework and distorted market framework) and under the framework of unknown shape of demand and supply curve (direct and indirect methods), please, refer to appendix 1 of this work.

3.8. Discounting Benefits and Costs in Future Time Periods

At this stage we already have all the proper impacts across the determined time horizon specified in physical and possibly in monetary units such that we can include them into the CBA. At this point we will deal with the issue of discounting of the specified benefits and costs in future time periods across the determined time horizon.

3.8.1. Constant Discount Rate or Exponential Discounting

Discounting refers to "the practice of placing progressively lower numerical values on future benefits and costs the further into the future they occur" (Markandya, Perelet, Mason, Taylor, 2001). There exist two rationales for discounting. First one is time preference of people. Human beings are impatient and thus attach less weight to a benefit or cost in the future than they do to a benefit or cost now. Second one is expressed by marginal productivity of capital argument. The markets value a monetary unit now more highly than a monetary unit in the future since capital is productive and thus a monetary unit's worth of resources now will generate more than a monetary unit's worth of goods and services in the future.

To be able to compare policy/project's options under consideration and their impacts that arise in different time periods across the time horizon, we might use ***net***

present value analysis[19] (Boardman, 2006). If the weight that is assigned to a benefit or cost in any period[20] *t* for *t = 0,1,...,n*, is w_t, then discounting implies:

$$w_t = \frac{1}{(1+s)^t}$$

where w_t is called the present value factor, or the discount factor, and is smaller than 1 and s is the discount rate which is nominal[21] or real[22] interest rate, a constant represented as a percentage (chosen according to whether we valued the impacts in real or nominal monetary units respectively) which is constant in time (the reason for name "constant discount rate"). It can be observed that this equation is simply compound interest upside down. For this reason this type of discounting is sometimes called "exponential" (Pearce, Atkinson, Mourato, 2006).

If we assign the appropriate value of the discount factor to every impact across the time horizon, we obtain the impacts in a common and therefore comparable metric – the present value (PV) (Boardman, 2006). Then we can count up the whole stream of benefits and costs arising in different time periods according to the following formulas:

Benefits:
$$PV(B) = \frac{B_0}{(1+s)^0} + \frac{B_1}{(1+s)^1} + ... + \frac{B_{n-1}}{(1+s)^{n-1}} + \frac{B_n}{(1+s)^n}$$

$$PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t}$$

Costs:
$$PV(C) = \frac{C_0}{(1+s)^0} + \frac{C_1}{(1+s)^1} + ... + \frac{C_{n-1}}{(1+s)^{n-1}} + \frac{C_n}{(1+s)^n}$$

$$PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+s)^t}$$

[19] There exit other two methods how to make the inter-temporal comparison – ***future value analysis*** and ***present value analysis*** – but the net present value analysis is the one most commonly used by CBA analysts.

[20] Period of discounting in almost all public-sector applications is a year. In practice, interest can be compounded in a shorter period of time (semiannually, monthly or daily) and sometimes even continuously. The difference in results in case of continuous and annual compounding is, however, not great.

[21] The nominal or (money) interest rate is the interest rate paid on different assets (Samuelson, 1992). This represents a monetary unit return per year per monetary unit invested.

[22] Real interest rate is "the interest rate measured in terms of goods rather than money. It is thus equal to the money (or nominal) interest rate less the rate of inflation" (Samuelson, 1992).

Now we can express net present value (NPV) which is the difference between the present value of benefits and the present value of costs shown by the following equation (Boardman, 2006):

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+s)^t}$$

According to the NPV the analyst can compare the policy/project options. The one with the greatest value of the NPV should be naturally undertaken. In case only one policy/project option is under consideration, it should be carried out if the NPV is greater than zero.

3.8.2. Inflation

Conventional private-sector financial analyses make all the measurement in nominal monetary units, in the units that take in rate of inflation[23]. The CBA analyst might project all benefits and costs in nominal monetary units as well (Boardman, 2006). Only, he/she has to take care in order to use the same units of measurement of the discount rate – the nominal discount rate *i*. However, in case of public projects/policies, which we mostly deal with in this work, it is often easier and more intuitive to express all the benefits and costs in real monetary units and to discount using a real interest rate *r*. For example, it makes more sense to think about the impacts of a project of a library improvement, which should bring cost savings to the library and benefits to users in the terms of the number of hours of use, in today's and not future prices.

If the analyst has at his/her disposal only nominal impact values but wishes to work with real impacts (e.g. to see directly if annual benefits increased due to rise in real benefits or only due to rise in inflation), he/she might use the following formulas to convert nominal costs and benefits into real ones and nominal interest rate into real one:

$$\text{Real cost or benefit}_t = \frac{\text{Nominal cost or benefit}_t}{(1+m)^t}$$

[23] "The rate of inflation is the percentage of annual increase in a general price level" (Samuelson, 1992). Inflation thus denotes that we could have bought for, for example, 100 CZK more in 1960 than now.

$$r = \frac{i - m}{1 + m}$$

where r is the real interest rate, i is the nominal interest rate and m is the expected rate of inflation during the project[24].

3.8.3. Practical Approach to Discount Rates

The European Commission (EC) distinguishes two types of discount rates – financial and social discount rate (European Commission, Directorate General Regional Policy, 2008). Both of them are constant discount rates. The ***financial discount rate*** is a rate at which future values in the financial analysis are discounted to the present and it reflects the opportunity cost of capital. The EC's estimate recommendation for this rate is 5% in real terms. As we have stated earlier, we do not deal with financial analysis here but rather with economic analysis that takes into account not only private but also social impacts of projects/policies. We are thus rather interested in the ***social discount rate*** (SDR) which is a rate at which future values in the economic analysis are discounted to the present and which reflects the social view on how net future benefits should be valued against present ones. Moreover, since economic analyses can also be conducted by private bodies[25] (e.g. in case of private projects co-financed by public financial means - from the EU Structural Funds), we will devote in our analysis only to public projects (and also policies) that might be defined as projects that are realized for a good of citizens and for which a public body places an order. And since public projects are not always entirely financed by public financial means and since the source of the projects financing play an important role in the market SDR determination (as we will see later), by "public" projects here we refer to such public projects which are by a great part financed from public financial means.

For the 2007-2013 period, the EC has suggested using two benchmark SDRs for **investment projects**: 5.5% for the Cohesion countries[26], thus also for the Czech

[24] Analysts might use consumer price index (CPI) to obtain the estimate of future inflation. However, due to certain bias of CPI serving as an inflation estimate (for deeper discussion we refer the readers to Moulton (1996)), it is recommended to rather use one of a number widely available forecasts as a more precise expected rate of inflation.

[25] Economic analysis has to be conducted for all projects whose total expenses exceed 10 mil CZK (Regionální rada regionu soudržnosti Moravskoslezsko, 2009).

[26] "The Cohesion Fund is a structural instrument that helps Member States to reduce economic and social disparities and to stabilize their economies since 1994. The Cohesion Fund finances up to 85 % of eligible

Republic (even though the specific SDR counted by the EC for the country is 5.7%) and 3.5% for the others. The EC's guide to CBA adds that these SDRs are based on estimates of long term growth potentials and other parameters. The EC's recommendations, 5% for financial analysis and 5.5% for economic analysis, are frequently used in the CBAs in the Czech Republic (Young, T., Mott Macdonald, 2009). However, as the European Commission adds: "SDRs that differ from the benchmarks may, however, be justified on the basis of individual Member States' or Candidate countries' specific socio-economic conditions. Once a social discount rate is set at country level by a planning authority, it must be applied consistently to all projects belonging to the same country (the only possible exceptions being significant differences in expected growth rates at NUTS I[27] or macro-regional level within the country)" (European Commission, Directorate General Regional Policy, 2008). For this reason there might be exceptions present in the use of the European Commission's SDR benchmarks. For example, the Road and Highway Directorate of the Czech Republic uses SDR of 6% in their CBAs (Čihák, M., Road and Highway Directorate of the Czech Republic, 2009).

In January 2009, the EC suggested to use a SDR of 4% for **policies** (there is no special recommendation for the Czech Republic, this rate is recommended for the EU as a whole). The EC in case of policies also opens a space for variation in the SDR use by the following words: "For impacts occurring more than 30 years in the future, the use of a declining discount rate could be used for sensitivity analysis, if this can be justified in the particular context" (European Commission, Secretariat General (2009).

The above discussion might create a feeling that the step of discounting is one of the few straightforward steps in the CBA. However, as we will see in the next chapters, discounting does not belong to easy tasks because of high uncertainty being present.

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expenditure of major projects involving the environment and transport infrastructure. This strengthens cohesion and solidarity within the EU. Eligible are the least prosperous member states of the Union whose gross national product (GNP) per capita is below 90% of the EU-average (since 1/5/2004 Greece, Portugal, Spain, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia)" (European Commission, Regional Policy - Inforegio, 2009).

[27] Classification NUTS (La Nomenclature des Unités Territoriales Statistiques) was established by the European Statistical Office in cooperation with other EU institutions for the necessity to classify united and uniform structure of territorial units (Fondy Evropské unie, 2009). NUTS I stands for a territorial unit of large region of countries, macro-regions of a given state, in the case of the Czech Republic it is the territory of the whole Czech state (the variant of Bohemia and Moravia was not approved because of unclear boundaries of these territories.

3.9. Distributional Weights

Let's first define the word distribution in economics. It is "the manner in which total output and income is distributed among individuals or factors (e.g. the distribution of income between labor and capital)" (Samuelson, 1992). There are thus two concerns of distribution in CBA (Pearce, 2006). The first one is the one of output[28] – in case of environmental policies/projects - goods and bads (e.g. clean or dirty air). This concern is usually carried out by the design of the project/policy and is justified by efficiency increase. The concern does not necessarily favors/hurts only, the most commonly treated social groups in the distributionally weighted CBA, either lower or higher-income individuals (e.g. losers in an environmental tax design might be poor as well as rich individuals). The second concern of distribution is the one of income[29] that might be carried out by both the design of the project/policy (e.g. income tax system setting) and/or by the distributional weights and is usually justified by equity or fairness increase. Equity criterion rather than in minimizing costs looks for "right" or "just" distribution of social welfare (Markandya, Perelet, Mason, Taylor, 2001). Thus equity traditionally goes counter to economic efficiency in terms of overall evaluation of social welfare. The income concern of distribution usually favors/hurts certain group(s) of society (e.g. either high or low-income to make the distinction clear).

The CBA was originally designed to evaluate the net financial benefits of private investment projects and as such the primer goal of the extended CBA, that we are dealing with here and that takes into consideration also external benefits and costs, is to assess efficient allocation of resources for policies/projects[30] considering not only private but also external impacts. However, throughout this chapter we have seen that in almost every step of the CBA conduction there is a quiet large space for distributive considerations which are under the justification of not efficiency but equity.

These redistributive considerations are mostly of implicit nature and are a consequence of nonexistence of universal rules for CBA conduction which would be

[28] Output or total product is the total amount of a commodity (e.g. emissions under the EU Emission Trading Scheme) produced, measured in physical units (e.g. tons of CO2) (Samuelson, 1992).
[29] Income is "the flow of wages, interest payments, dividends, and other receipts accruing to an individual or nation during a period of time (usually a year)" (Samuelson, 1992).
[30] An efficient allocation is such in which the costs of a policy/project are minimized (Markandya, Perelet, Mason, Taylor, 2001). Economic efficiency perspective of CBA looks for options with benefits greater than costs or, alternatively, allocation of available funds across those options, which collectively secure the largest net benefits (Pearce, 2006).

applicable mechanically for any option under CBA consideration. These implicit redistributive mechanisms via CBA available to governments start at the selection and design of the policy/project and go through choice of individuals with "standing", inclusion of economic impacts, determination of time horizon and prediction of the impacts over the time horizon and end up at monetary valuation of economic impacts. In fact, the only explicit redistributive mechanism that we have dealt so far in this analysis is the choice of discounting rate. Discounting deals with the social desirability of a particular distribution of benefits and costs among generations. In this section, we will be discussing second explicit redistributive mechanism of CBA, ***distributional weights*** which deal with concerns about distributional justice or equity within the current and every subsequent generation within the determined time horizon. Higher or lower weights are assigned to the benefits and costs accrued for separate categories of individuals under consideration (the most commonly treated social groups in the distributionally weighted CBA are lower and higher income individuals).

The NPV formula $NPV = \sum_{t=0}^{\infty} \frac{NB_t}{(1+s)^t}$ stated earlier would modify if distributional weights to be used into $NPV = \sum_{j=1}^{m} \left[W_j \sum_{t=0}^{\infty} \frac{NB_{t,j}}{(1+s)^t} \right]$

where W_j is the distributional weight for societal group j, $NB_{t,j}$ are the net benefits received by group j in period t, and m is the number of groups (Boardman, 2006). However, not all economists agree with the use of the distributional weights. For a more detailed discussion of the pros and cons arguments of the weights, please, refer to the appendix 2 of this work.

To be able to obtain such a distributional NPV, the analyst needs firstly to identify and catalogue how project/policy-related impacts are distributed. It means the analyst needs to decide upon different groups of interest (e.g. producers versus consumers, men versus women, program participants versus non-participants, citizens versus non-citizens of a nation state or as we have already mentioned the most often treated groups – lower and higher income individuals) that might be affected by the project/policy (Pearce, 2006). To be able to identify and catalogue distribution of these groups' impacts, we sometimes have at disposal only aggregated data on, for example, households but not on higher and lower income households. The data of non-market impacts' distribution (e.g. socioeconomic or demographic data) are, however, often contained in the alternative ways of monetary valuation of economic impacts (e.g.

contingent valuation method). Those being against distributional weights' use could stop the process of "equity" here by simply cataloguing "winners" and "losers" of the policy/project considered and conduct the undistributional CBA (placing $W_j = 1$ for $j = 1, 2, \ldots, m$), leaving the decision (equity issue) upon success or failure of the policy/project upon decision-makers.

Those in favor of distributional weights' use might go on to the second step in the process and assign the actual weights to the economic impacts of the groups selected (Pearce, 2006). To derive "correct" values of the distributional weights W_j assigned to the groups selected is not an easy task. It can be done by various ways: to derive them on base of findings of past studies, judgement about the importance of income to those who gain or lose from the policy/project etc.

The last, third, step of this process is to actually compute the NPV according to the formula that contains distributional weights and that is shown above. Such a NPV does not only inform us about the degree of efficiency of the policy/project but also about its income distribution justice (supposing the groups selected are the higher and lower-income ones).

The above discussion and the appendix 2 indicate that this step belongs to the CBA's controversies as well. The issue of distributional justice and the complexity of the weight's value determination are the basic reasons for it. In fact, there is no objective truth of whether to use or not to use the distributional weights and what value the parameter would optionally have. The choice upon this parameter may substantially influence the resulting NPV value.

3.10. Decision Rules upon Adoption and Suspension of a Policy/Project

After the analyst has managed to aggregate all benefits and costs of a policy/project according to the steps above, he/she needs in this point to determine the appropriate decision criterion for comparing the aggregated costs and benefits and thus for deciding upon admission or suspension of a policy/project.

Net Benefits Criterion

In chapter 3.8. we introduced net present value or net benefits criterion. It is a decision rule according to which any single policy/project alternative (relative to status

quo) with a positive NPV should be adopted (Boardman, 2006). Thus the necessary condition for adoption of a policy/project is: PV(B) > PV(C) or alternatively NPV > 0. In case of more alternatives that are all mutually exclusive (one policy/project can only be undertaken to the exclusion of another policy/project since these are, for example, two different ways of achieving the same objective), the policies/projects should be ranked by their NPVs and the one with the highest positive NPV should be adopted (Pearce, 2006). Since NPV stands for present value of net social benefits, selecting a policy/project with the largest NPV, we select a policy/project with the largest present value of the net social benefits. This criterion is backed up by the already mentioned Kaldor-Hicks improvement criterion.

It is the most appropriate criterion but it surely has a weakness which, however, does not come from the criterion nature. This criterion does not choose the most efficient alternative but only one that is more efficient than the status quo (Boardman, 2006). The reason for that is the space for equity dealing within the CBA (that we have discussed in the previous section) from which the choice of the alternatives is probably the most important one since the most efficient option does not have to be even considered. This do happen because of cognitive capacity limitations (we do not know the most efficient alternative), budgetary or political constraints.

Although this criterion always gives correct answers, it needs some modifications in the presence of: constraints on objective function (e.g. budgetary constraint), in the light of allowances of other distributional concerns (e.g. equity discussed in the previous section), and under risk and uncertainty (Pearce, 2006). For an example of such modifications and description of alternative but subordinate decision rules, please, refer to the appendix 3 of this work. Compared to the two previous steps, however, this one is quite straightforward.

3.11. Sensitivity Analysis

We have seen throughout this chapter that there exist uncertainties in almost every step of the CBA performance (e.g. issue of “standing”, inclusion of economic impacts, determination of time horizon, prediction of the impacts over this time horizon, monetary valuation of economic impacts, discounting benefits and costs in future time periods, distributional weights). As it was stated in the appendix 3 of this work, for this reason the analysts frequently conduct sensitivity analysis with respect to a determined

parameter. To perform sensitivity analysis means to vary each parameter about which there is uncertainty and recalculate the NPV (Boardman, 2006). If the NPV sign states positive/negative under all plausible values of the parameter, we can have greater confidence about recommendation – adoption/suspension of the policy/project considered. Alternatively, we can compute breakeven parameter (the parameter value at which the NPV equals zero) and proceed analogously as it is suggested in the case of internal rate of return (breakeven discount rate) in the appendix 3.

In practice, the analysts focus only on potentially the most important parameters since there is a limit to the amount of sensitivity analyses that is feasible. Even though the choice of the parameters for the sensitivity analysis is thus vulnerable to biases of the analysts, very often well-thought scenario for the sensitivity analysis is more informative than the mere mindless varying of parameters.

3.12. Conclusion

There are many controversial points in the practical CBA performance. The controversies are caused by uncertainties and normative considerations. The most controversial parameters are discount rates and distributional weights since a single normative statement upon their values can significantly influence value and thus also sign of the resulting NPV of the considered policy/project. Discount rate is so controversial because of high uncertainty about the future and distributional weight because of different justice principles. To keep this work narrowly focused, let's, however, focus on discussion of only one parameter. We choose discount rate because, compared to distributional weights, it cannot be omitted in the CBA performance.

4. Social Discounting

In the previous chapter we have introduced the problem of discounting which, according to what we have said so far, seems one of the most straightforward steps in the CBA performance. In this chapter we will discuss in a greater detail the reason why this parameter is so controversial – intergenerational justice and uncertainty about the future.

In the section 4.1. we, firstly, present other two types of discount rates and their advocates. Secondly, we address the questions of what value(s) should the SDR have for the case of the Czech Republic whether is/are such value(s) in compliance with the EC's recommendation introduced in the section 3.8.3.? To be able to answer these questions, we need to find the most appropriate way for the SDR's determination.

In the section 4.2. we deal with this issue. In the section 4.2.1 we will be looking for the most appropriate model for the Czech Republic within the market way of the SDR determination that is preferred by some economists because, even though being normative from the point of view of conclusion, have characteristics of positive economy, at least as for the quantitative estimates of discount rate value. In the section 4.2.2. we subject this way of the SDR determination to criticism, discuss the assumptions under which such a SDR might be applied and the role the social time discount rate (or "pure" rate of time preference) plays in this way of SDR determination. The section 4.2.3. is devoted to an alternative way of the SDR determination - intergenerational approach to social discounting. We discuss values of its parameters and, due to the complexity of the issue, our attention is concentrated on the social time discount rate, its different role in this model, the necessity of being derived in a different (in purely normative) way and argumentation for a specific value of the parameter. And, finally, the most appropriate value(s) of the SDR for the public environmental policies/projects are discussed and compared to the EC's recommendations.

4.1. Types of Social Discount Rates and their Advocates

4.1.1. The Exponential Discounting and Its Advocates

We have introduced this type of discount rate in the preceding chapter. Its application to environmental projects/policies is advocated, might be said, by neoclassical economists[31] who affirm that economic growth does not have any limits. They are believers of so called weak sustainability.

Let's first define sustainable development as such. According to the report Our Common Future (also called Brundtland Report) which was issued in 1987 at the World Commission on Environment and Development (WCED) held by the UN, sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Bruntland, 1987). However, this definition, even though being the most cited one, is not of much use for economists for various reasons: e.g. needs and not preferences are considered, it is spoken about future generations and not about efficiency. For this reason later on other definitions have been developed. According to Labandeira, León, and Vázquez, this term includes two basic concepts, development and sustainability (Labandeira, León, Vázquez, 2007). The first concept refers, in the restricted meaning, to economic growth. However, the modern and broader version of the concept definition says that development does not necessarily mean economic growth (it is not necessary condition for development). It rather incorporates qualitative changes (structural reforms - economic, social and environmental) and thus refers rather to welfare or utility. The second concept, sustainability, refers to continuation of this (growing or time constant) welfare or utility in the long-run, until infinite future. So the sustainable development is a development socially desirable, environmentally feasible and economically viable which can last forever.

Weak sustainability means that in order to maintain the welfare or utility at least constant in time, we need to maintain total capital[32] per capita constant in time (we

[31] Neoclassical economics is the conventional mainstream economics which is founded on the concepts of economic efficiency and optimality, using tools of marginal analysis (Markandya, Perelet, Mason, Taylor, 2001). The neoclassical "rules of the game", however, lead to depletion of natural capital.

[32] Total capital consists of physical capital, human capital, natural capital (natural resources – renewable and nonrenewable – and environmental resources – e.g. atmosphere, water - that serve as receptors of waste generated by economic activity). In reality the total capital is a modern version of the traditional three factors of production: capital, labor and land (Labandeira, León, Vázquez, 2007).

cannot allow the total capital vary inter and among generations) (Jimenéz, 1996). The exponential discounting advocates believe, due to technological development, in total substitution of natural capital for other types of capital. In fact, they use the assumption of growing economies in time. Thus it does not matter if natural capital decreases unless the total capital decreases. In this sense, they view the economy and the economic rules working independently from the environment which does not set any boundaries for such economy's expansion. For this reason, speaking about projects/policies with substantial environmental impacts appearing far in the future, the exponential discounting advocates find the impatience of people and the marginal productivity of capital as rational arguments for placing progressively lower numerical values on future benefits and costs the further into the future they occur. The advocates do not necessarily base their attitude on lack of interest in future generations. In this sense, thus, the exponential discounting is consistent with the idea of sustainable development.

4.1.2. Zero Discount Rate or Zero Discounting and Its Advocates

Apart from the exponential discounting, there, however, is zero discounting or sometimes called "not discounting" (Pearce, 2006). It means that discount rate s equals to zero and the discount factor w_t always thus equals to one no matter the time period t. The analyst, therefore, treats all the future impacts as if they occurred at present, he/she treats everyone "equal" no matter if living now or in the future.

Application of zero discounting to environmental projects/policies is advocated by ecological economists[33] who affirm that economic growth is limited by the environmental capacities. They are believers of so called strong sustainability.

Strong sustainability means that in order to maintain the welfare or utility at least constant in time, we need to maintain natural capital per capita constant in time (we cannot allow the natural capital vary inter and among generations) (Jimenéz, 1996). The ecological economists are skeptical about whatever substitution of natural capital for other types of capital. The natural capital is unique, it surrounds and maintains the economy to work (provision of natural resources for production processes, absorption of waste created by economic activity, provision of recreational services). In this sense,

[33] Ecological economics is "a transdisciplinary approach to economics which emphasizes the relationships between economic and ecological systems" (Markandya, Perelet, Mason, Taylor, 2001). Humans are not considered to be central and dominant component of the overall economic-ecological ecosystems (anthropocentrism) but rather as only a major component (biocentrism). This approach explains the necessity of natural capital conservation inter and among generations.

they view the economy and the economic rules working under the boundaries of the environment. For this reason, speaking about projects/policies with substantial environmental impacts appearing far in the future, the zero discounting advocates consider the future impacts equally important as the ones appearing now. They consider well-being of the future generations as having the same importance as the well-being of current generation. Since there will be lots of future generations, so that whatever the increment in natural capital savings now, and whatever the cost to the current generation, the future gains will substantially outweigh current losses in foregone consumption of natural capital. For this reason the ecological economists treat all impacts along the time horizon as equal in its weight. Based on this reasoning, the zero discounting is consistent with the idea of sustainable development.

4.1.3. Declining Discount Rate and Its Advocates

Between the two extreme considerations of discounting lies another, more moderate one – declining discount rate (Pearce, 2006). It means that discount rate s_t, now written with index t to signal the change of s with time, declines as time goes on. Thus as the discount rate declines in time, discount factor w_t also declines like in case of the exponential discounting but it declines at a more moderate rate.

Regarding the projects/policies with substantial environmental impacts and the natural capital discussion, the declining discounting, can be said, is preferred by environmental economists[34]. They stay between the two polar views. As neoclassical economists they use the market mechanisms but contrary to the neoclassical economists, they are skeptical about the total substitution of natural capital for other types of capital. And as the ecological economists, they believe in the necessity of natural capital for humankind but contrary to the ecological economists, they are not as radical and do not intend to keep natural capital constant inter and among generations. Instead they intend to assign to it a just price in order its over-exploitation to be

[34] Environmental economics follows the conventional neoclassical economics in the sense of having as its central concern the efficient allocation of scarce resources among competing uses (Markandya, Perelet, Mason, Taylor, 2001). This branch, in contrast to the neoclassical economics, however, brings the scarce natural resources into mainstream economic analysis framework. Thus it deals with issues such as pollution control, the efficient setting of emission standards, the conservation of natural capital etc. The overall objective is to identify policies (government's intervention is desired here in contrast to the neoclassical economics) which would move the economic system towards an efficient allocation of natural capital (policies which would internalize environmental externalities). This branch differs from the ecological economics in the sense of reaching environmental objectives by using market mechanisms. These two branches, however, overlap into certain extend.

prevented. Thus it could be stated that the environmental economists are in fact neoclassical economists who take into account uncertainty about future economic growth rates (and thus interest rates) due to over-exploitation and deterioration of natural capital.

As these economists have uncertainty up to what extent the human and physical capital will be able to substitute the natural capital in future, they rather consider a range of possible interest rates scenarios, let's say from s_1 = 1% to s_{10} = 10% like in the Table 1 below, with equal probability of occurrence: $p_1 = p_2 = \ldots = p_{10} = 0.1$ (Pearce, 2006). (This type of determination of the declining SDR is based upon the work of Martin Weitzman (2001).)

Table 1

Interest rate scenarios	Discount factors in period *t*				
	10	50	100	200	500
1%	0.91	0.61	0.37	0.14	0.01
2%	0.82	0.37	0.14	0.02	0.00
3%	0.74	0.23	0.05	0.00	0.00
4%	0.68	0.14	0.02	0.00	0.00
5%	0.61	0.09	0.01	0.00	0.00
6%	0.56	0.05	0.00	0.00	0.00
7%	0.51	0.03	0.00	0.00	0.00
8%	0.46	0.02	0.00	0.00	0.00
9%	0.42	0.01	0.00	0.00	0.00
10%	0.39	0.01	0.00	0.00	0.00
Certainty-equivalent discount factor	0.61	0.16	0.06	0.02	0.00
Certainty-equivalent discount rate	4.73%	2.54%	1.61%	1.16%	1.01%

Source: Pearce 2006.

We compute discount factors w_t for let's say t = 10, 50, 100, 200, 500 according to the same formula like for the constant discount rate $w_t = 1 / (1 + s)^t$ but in this case we repeat the computation for every interest rate scenario which will give us the numbers (in the rounded form) of the five columns in the Table 1. Now if we take an average of these discount factors (weights) for any given time period, we obtain the so called certainty-equivalent discount factors which reflect the same possibility of different discount factors' occurrence. At this point we need to obtain the discount rates, or the so called certainty-equivalent discount rates s*, for any given time period. To compute these we use the following formula:

$$Certainty-equivalent\ discount\ factor\ = \frac{1}{(1+s^*)^t}$$

In this way we get the declining discount rates for any given time period (stated in the last raw of the Table 1). It is important to state two important observations. First, as said in the introduction to this type of discounting, both certainty-equivalent discount factor and certainty-equivalent discount rate declines in time. Second, as time goes to infinity, the discount rate converges on the most pessimistic scenario - the lowest possible discount rate which is 1% in this case.

4.2. Determination of the Social Discount Rate

To be able to answer the normative question of what type of SDR is the most appropriate to use, especially in the public projects/policies with substantial environmental impacts, we firstly need to answer the normative question of the way of the social discount rate's determination (what model/approach to social discounting to use). Apart from answering what type of SDR should be used, we will answer in the same time the question of whether the same model of SDR derivation and thus the value of the SDR should be applied to all possible projects/policies considered.

4.2.1. Market Determination of Social Discount Rate

4.2.1.1. Perfect Competition Framework: SDR Equals Market Interest Rate

The idea to use market interest rate as SDR under the assumption of perfect competition where interest rates for borrowing and lending equal is quite straightforward (Boardman, 2006). In this situation, interest rate equals to individual's marginal rate of time preference (MRTP). MRTP is a rate that measures trade-offs that individual makes between consumption now (spending) and consumption in the future (saving). If an individual has a MRTP of for example 10% it means that he/she is willing to sacrifice 100 CZK additional consumption next year (considering a loan of for example 1,000 CZK) to consume the extra 1,000 CZK borrowed today or alternatively, it means that he/she requires 100 CZK more next year in order to lend

1,000 CZK and thus to decrease his/her current consumption by this amount. Thus if the interest rate the bank offers (e.g. 5%) falls to this individual's MRTP, the individual will be willing to shift his/her consumption from the future to the present and will borrow but if the interest rate the bank offers (e.g. 15%) exceeds the individual's MRTP, the individual will rather shift his/her consumption from the present to the future and will rather save. And if the interest rate the bank offers just equal to his/her MRTP, the individual will be indifferent between spending and saving.

If we assume that every individual is the same[35] (the individual MRTP equals the social one), MRTP equals the interest rate and we accept the positive approach to discounting (behavior of economic subjects – consumers and firms – over a time horizon) for a normative one (ethical assessment of future costs and benefits' weights of public projects/policies over a time horizon), then the model of using market interest rate as a measure of SDR is an appropriate one (Dvořák, Brůha, Brůhová-Foltýnová, Melichar, Ščasný (2007). If interest rate (therefore MRTP and SDR) is high, then individuals are willing to sacrifice high amount of additional consumption next year to consume an extra amount borrowed today or, alternatively, it means that they require high amount of consumption next year in order to decrease their current consumption by an amount. It means that the individuals are more impatient in this case and thus should discount future benefits and costs (put them lower weight) of public projects/policies more. (If interest rate is low, the logic works in an analogous logic and individuals would be less impatient in that case and thus should discount future costs and benefits of public projects/benefits less.)

Two-period model can be used to demonstrate clearly the equality of individual's MRTP and market interest rate under the perfect capital market conditions. Let's suppose a consumer utility function over two-year period: C_1 denotes current consumption (in year 1) and C_2 denotes consumption in next year (in year 2) (Boardman, 2006). The consumer maximizes his/her utility $U(C_1, C_2)$ subject to a budget constraint:

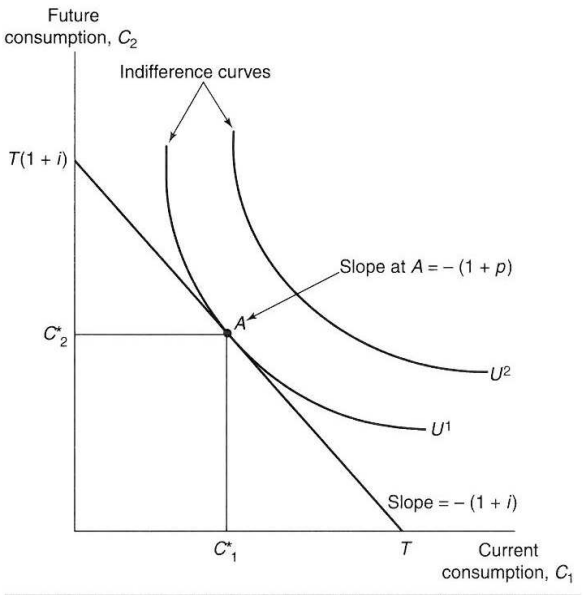
$$\text{Max } U(C_1, C_2)$$

[35] If an individual had $MRTP > i$, he/she would borrow and consume more now (Boardman, 2006). Thus this increase in the current consumption would increase the relative value of future consumption which would lead to his/her *MRTP* to decline until it equaled *i*. (If an individual had $MRTP < i$, the logic would be analogous.)

$$\text{s.t } C_1 + \frac{C_2}{1+i} = T$$

where T denotes the present value of total income over the two years and i denotes the market interest rate. The situation is demonstrated in the figure 3 below.

Figure 3



Source: Boardman 2006.

The slope of the indifference curves U^1 and U^2 is negative indicating the fact that the consumers prefer present consumption to the future one (require more consumption in the next period in order to give up consumption in this period). The absolute value of the slope of the indifference curve is called consumer's marginal rate of substitution (MRS) and measures the rate at which the consumer is indifferent between substituting current consumption C_1 for future consumption C_2. And p is the MRTP. Both MRS and MRTP are decreasing which means that as consumption increases the consumer requires relatively smaller additional amounts of future consumption for the forgone current consumption.

The utility maximization problem supposes that the individual receives all of his/her income in the first year and can save/invest all or part of it at interest rate i (Boardman, 2006). If the individual spent all the income in the first year, then $C_1=T$ and $C_2=0$ and if the individual saved/invested all the income in the first year, then $C_1=0$ and

$C_2=(1+i)T$. Apart from these extreme situations, the individual can consume at any other point on the budget constraint with slope $-(1+i)$ indicating that each additional unit of consumption in year 1 costs $(1+i)$ units of consumption in year 2 and each additional unit of consumption in year 2 costs $1/(1+i)$ units of consumption in year 1.

To determine the optimal consumption levels in which the consumer maximizes his/her utility, we need to find the point in which the budget constraint is tangential to an indifference curve. This occurs at point A where the optimal consumption levels are C_1^* and C_2^*. At this point, the slope of the indifference curve equals the slope of the budget constraint and the consumer's MRTP equals the market interest rate:

$$-(1+p) = -(1+i)$$
$$p = i$$

The same results holds for a two-period model with production in closed economy, under the perfect production market conditions where, moreover, $p = i = r$ where r denotes the marginal rate of return on private investment (Boardman, 2006). If interest rate (therefore r and SDR) is high, then firms (according to the marginal productivity of capital argument presented in the previous chapter) value a monetary unit now much more than a monetary unit in the future (capital is productive and thus a monetary unit's worth of resources now will generate more than a monetary unit's worth of goods and services in the future). If we again accept this positive approach to discounting for a normative one, then the future benefits and costs of the public policies/projects should be discounted much more (should be put a lower weight) as well. (If interest rate is low, the logic works in an analogous logic and firms would not see such a huge difference between the value of today's monetary unit and the future one in that case and thus the future benefits and costs of the public policies/projects should be discounted less as.)

Criticism

The main criticism of this model is that in the reality, under the conditions of imperfect market (that means in majority of cases), due to presence of taxes and transaction costs, MRTP does not equal the market interest rate neither the marginal rate of return on investment. Instead, there holds the following relationship which will be

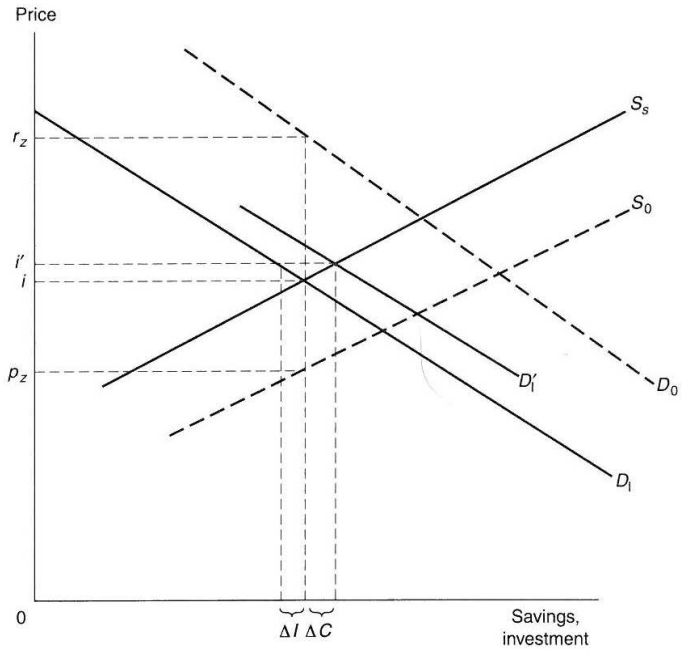
explained in detail later in the next model: $r > i > p$. Because MRTP does not equal i, there is no obvious choice for SDR and this model therefore cannot be used.

In reality, moreover, there are five different types of interest rates. First, it is the repo rate which is the maximal interest rate under which commercial banks save at central bank during the minimum of 14 days (Czech National Bank, 2009). Second, it is the discount rate which is the rate under which commercial banks save at central bank overnight. This rate represents the lower limit for short-term interest rates' movement in the monetary market. Third, it is the lombard rate which is the rate under which commercial banks can borrow at central bank. This rate represents upper limit for short-term interest rates' movement in the monetary market. Fourth, there is the interest rate offered by commercial banks to borrowers. And fifth, there is the interest rate offered by commercial banks to savers (which is lower than the one for borrowers). All the types of the interest rates differ so not only that MRTP does not equal the interest rate, we even do not know which type of the interest rate.

4.2.1.2. Imperfect Competition Framework: SDR Equals the Marginal Rate of Return on Private Investment

The idea to use r as SDR is that government by carrying out a policy/project crowds out the private sector investment and thus the government needs to demonstrate that before the government actual policy/project performance, it is able to receive a greater return out of its action than if it left the resources in the private sector (Boardman, 2006).

Figure 4



Source: Boardman 2006.

Harberger managed to present a compelling case for the use of such SDR (Boardman, 2006). In the figure 4, under the conditions of perfect market (e.g. there are no taxes or government borrowing), the demand curve of private borrowers for investment funds is represented by D_0 and the supply curve of the funds from savers (or lenders) is represented by S_0. The intersection of these curves indicates a high number of investment and saving and $p = i = r$. However, under conditions of imperfect market (e.g. there are taxes and government borrowing present), the reasoning will change.

First, consider introduction of corporate income and personal tax. Due to this government's action, demand as well as supply curve will decrease to D_I and S_s because the borrowers will have to pay a part of their returns from investment and savers a part of the interest on savings to the government (Boardman, 2006). At the intersection of these curves, borrowers would pay an interest rate of i to borrow and savers would receive an interest rate of i before paying the taxes. Due to the taxes, the borrowers would now have to have a vision of much higher r (we denote it r_z to distinguish it from the perfect market one) than in the case without taxes because they have to pay the taxes out of it (the gab between r_z and i). r_z is in fact the opportunity cost of private investment. And also due to the taxes, the savers would now have to have a much lower MRTP or p (we denote it p_z to distinguish it from the perfect market one) to be willing

to save because they receive a lower interest on their savings after paying the taxes (the gab between p_z and i). p_z is in fact the opportunity cost of forgone consumption and is equal the marginal return on savings after taxes. Thus we can see why, under the imperfect market framework, $r_z > i > p_z$.

Second, suppose that the project/policy the government intends to carry out is financed entirely out of borrowing in a closed, domestic financial market. (This is a viable assumption for the case of the Czech Republic since the Czech government runs deficit budgets. Please, look at the table 2 below to see the Czech general government net borrowing in last several years.)

Table 2: Czech General Government Net Borrowing

Years	Czech general government net lending (+) / net borrowing (-) in bn CZK
1997	-68.8
1998	-100.1
1999	-77.3
2000	-81.5
2001	-135
2002	-166.8
2003	-170
2004	-82.7
2005	-106.6
2006	-85.5
2007	-34.2

Source: Czech Ministry of Finance

The government's borrowing thus increases the demand curve from D_I to D_I' and thus increases interest rate from i to i' (Boardman, 2006). Because of the raise of interest rate, private investors would decrease its borrowing by the amount of ΔI and private savers would increase its savings by the amount of ΔC (increase in private savings equals decrease in private consumption).

Harberger recommends the SDR to be equal to the contribution of the public policy/project realization to the relative sizes of forgone private investment and consumption: $\text{SDR}=ar_z + bp_z$ where $a = \Delta I / (\Delta I + \Delta C)$ and $b = (1-a) = \Delta C / (\Delta I + \Delta C)$. There is an empirical evidence that increase in interest rates does not really lead to increase in savings (S_s curve is close to vertical) and thus ΔC is close to zero. Then the value of the parameter a is close to 1 and the value of b is close to 0 and the SDR is the

following: $SDR = ar_z$ which means that almost all the resources used for financing the public project/policy would be obtained by crowding out private investment and we get to the idea of this model presented at its introduction. If we accept this positive reasoning for the normative approach to discounting, then this model of using marginal rate of return on private investment as a measure of SDR is an appropriate one.

Numerical Value of r_z

There are various proxies of r_z: e.g. average rate of return on private physical capital, before-tax rate of return on corporate bonds or before-tax average rate of return on corporate bonds (Boardman, 2006; Kubíček, Vítek, 2009).

Due to data accessibility restrictions, we are referred to the only proxy of r_z - average rate of return on private physical capital - suggested by Kubíček and Vítek (2009). We follow the instructions of Kubíček to obtain it (Kubíček, J., Czech National Bank, 2009). To obtain the average rate of return on private physical capital, we use the available data for the years 2001 – 2007 which can be observed in the table 3 below. To obtain the average rate of return on private physical capital, we deducted consumption of fixed capital[36,37] (column 2) from the gross operating surplus and mixed income[38] (column 1) and we divided it by the state of gross fixed capital[39] (column 3), multiplied by 100 and made an average for the given years. The resulting average rate of return on private physical capital and thus the estimate of r_z we obtained, in the rounded form, is 3.9% (column 4).

[36] Fixed capital (fixed assets) is physical capital that is not used up in the production of a product (Czech Statistical Office, 2009). It distinguishes between material (e.g. buildings and constructions, machines and equipments) and immaterial (e.g. software, geological investigation, cultural and art works) fixed capital

[37] Consumption of fixed capital "represents volume of fixed assets consumed over the course of time period monitored as a result of normal wear and foreseeable absolence including compensations for fixed assets' losses due to result of accidental damages against which it is possible to insure" (Czech Statistical Office, 2009).

[38] Gross operating surplus (including the mixed income) is the income which the production units gain from their own usage of their production resources. It can be divided into consumption of fixed capital and net operating surplus (Czech Ministry of Finance, 2009).

[39] Formation of gross fixed capital is defined as "increments in fixed capital (e.g. purchase, restitution) minus diminution of fixed capital (sale) plus increases in value of the assets not used up in the production (e.g. land)" (Czech Statistical Office, 2009). And state of gross fixed capital is addition of this formation of gross fixed capital to the actual state of gross fixed capital from previous years.

Table 3: Average Rate of Return on Private Physical Capital

Years	(1) Gross operating surplus and mixed income	(2) Consumption of fixed capital	(3) State of gross fixed capital	(4) Rate of return on private physical capital
	nominal	nominal	nominal	(in %)
	in m CZK	in m CZK	in m CZK	
2001	1,164,938	477,428	18,884,547	3.64
2002	1,188,563	491,562	19,497,241	3.57
2003	1,229,402	508,676	20,200,433	3.57
2004	1,345,320	537,528	21,148,340	3.82
2005	1,418,000	553,824	22,083,248	3.91
2006	1,544,000	576,164	22,875,627	4.23
2007	1,698,000	605,596	23,733,353	4.60
Average	**1,369,746**	**535,825**	**21,203,256**	**3.91**

Source: Czech Statistical Office and Own Calculations

Kubíček adds that he does not trust to the amount of the state of gross fixed capital estimated by the Czech Statistical Office (Kubíček, J., Czech National Bank, 2009). He thinks that the estimates are too high. In all other countries the state of gross fixed capital ranges from 2.5 to 4 times of the year-production. In the Czech Republic it is, according to the Czech Statistical Office, five times of the year-production. Naturally, the higher the state of gross fixed capital, the lower the resulting estimate of r_z. He, however, concludes that as he does not have any own estimates of the state of gross fixed capital, he cannot confute the Czech Statistical Office data. At the table 4 below can be observed the estimates of the average rate of return on private physical capital for selected countries (Kubíček, Vítek, 2009 and Own Calculations). The column 1 shows it for years 1970-1990, the column 2 for the years 1991-2000 and the column 3 the average for the two time periods. The SDR determined on the basis of this model for these countries is, in average, 5.56%. Due to the doubt of Kubíček about the excessive estimates of the state of gross fixed capital in the Czech Republic, due to the relatively short time period used for the SDR determination and due to the fact of the Czech Republic being convergence economy[40], **we recommend to estimate r_z for the Czech Republic at 3.9%, with sensitivity analysis at 5.6%.**

[40] The Czech Republic being a convergence economy means that it intends economically to catch up with the more advanced European countries). It is a conditional convergence implying that if the country's certain indicators (e.g. expectations of complementary investment, human capital, population growth, saving rate) would differ from those in the advanced countries, the country would converge to different, a lower, steady state. (Debray, 1998).

Table 4: Average Rate of Return on Private Physical Capital in Selected Countries (in %)

	1970-1990	1991-2000	Average
Belgium	6.9	6.9	6.9
Denmark	4.4	6.7	5.55
EU 15	4.8	5.8	5.3
Finland	4.2	6.1	5.15
France	4.9	6.7	5.8
Italy	5	6.4	5.7
Japan	4.2	4.8	4.5
Germany	4.3	5.4	4.85
Netherlands	4.6	6.5	5.55
Portugal	8.8	7.6	8.2
Austria	1.3	4	2.65
Greece	3.7	3.7	3.7
Spain	6.6	6.9	6.75
Sweden	4.4	5.6	5
USA	7.6	8.8	8.2
Great Britain	5	5.3	5.15
Average	**5.04**	**6.08**	**5.56**

Source: Kubíček, Vítek, 2009 and Own Calculations.

It might seem that the European Commission has derived the SDR of 5.5% for investment projects in the Cohesion countries according to this model. As we will see later on, the EC used different model to determine its recommendation.

Criticism

In spite of the Kubíček's criticism of the SDR (determined according to this model) being too low in the Czech Republic compared to other countries, many critics (including Kubíček) argue that derivation of SDR upon this model is inappropriate and as a result, it leads to too high SDR (Boardman, 2006). There are the following most cited contra arguments:

First, it is because the model does not count with market distortions caused by, for example, negative externalities or monopolies which cause the private rates of return might being pushed upward (Boardman, 2006).

Second, the SDR derived out of this model is too high because the rate of return on private investment apart from the premium for consumption postponement

incorporates also a higher risk premium compared to the rate of return on public investment[41] (Kubíček, Vítek, 2009). Some economists think that if the project/policy is financed by issuing government bonds that have lower risk premium than corporate bonds, the government's borrowing rate should be the one used to discount future costs and benefits of public projects/policies[42].

Third, the SDR derived out of this model is inappropriate because the public projects/policies do not have to be necessarily financed only by loans but also by taxes (Boardman, 2006). In that case, rather than investment, consumption would be crowded out because most of the taxes are collected from individuals through income, payroll and consumption taxes which affect mainly consumption. Some economists argue that most of the public projects/policies are financed by taxes and therefore the appropriate SDR should be the rate at which individuals in society are willing to postpone a small amount of current consumption in exchange for additional future consumption and vice versa (at social MRTP or p_z)[43].

Fourth, this model assumes that 1 CZK of public project/policy crowds out 1 CZK of private domestic investment. In an opened capital economy, this assumption does not hold because the public project/policy might be partially financed by foreign investors (Boardman, 2006). The assumption does not hold, however, even in a closed capital economy framework assumed in this model. In reality, due to public projects/policies (e.g. infrastructure ones), some private investment can be allowed and/or return of private investment can be increased even though due to interest rate increase some private investment is crowded out (Kubíček, Vítek, 2009). Thus the public projects/policies might conversely lead to increase in private investment which would make the use of the marginal rate of return on private investment as the SDR meaningless.

Not considering the critical arguments upon the excessive value of the SDR derived out of this model, even if we suppose that majority of public projects/policies in the Czech Republic are financed mostly by loans and not by taxes, we cannot recommend the SDR derived out of this model for the country because the public investment does not necessarily lead to crowding out of the domestic private

[41] Government bonds have lower risk because government holds a broader portfolio of projects than any private entity does and therefore pays a lower interest rate than private investors (Boardman, 2006).
[42] This is the basic idea of the model for the SDR determination where SDR equals government's borrowing rate. It will be explained in a greater detail later in this chapter.
[43] This is the basic idea of the model for the SDR determination where SDR equals social MRTP. It will be explained in a greater detail later in this chapter.

investment, moreover, if we consider the fact that the country is opened capital economy.

4.2.1.3. Imperfect Competition Framework: SDR Equals the Social Marginal Rate of Time Preference

As has been pointed out in the third criticism of the preceding model, some economists claim that, in reality, many public projects/policies are financed not by loans but by taxes. In the table 5 we can observe that this assumption is a viable one: taxes and social contributions form the biggest source, by 88.29% (own calculations), of the Czech general government revenue (Ministry of Finance, Department for Financial Policies, 2008).

Table 5: Taxes and Social Contributions' Proportion of the Total Revenue

Years	Total Czech general government revenue (in bn CZK)	Taxes and social contributions (in bn CZK)	Taxes and social contributions' proportion of the total revenue (as %)
1997	713.6	634.2	88.87
1998	761.7	666.7	87.53
1999	802.3	709.6	88.45
2000	833.9	741.8	88.96
2001	911.4	800.5	87.83
2002	974.4	858.7	88.13
2003	1049.4	922.6	87.92
2004	1187.7	1048.6	88.29
2005	1235.7	1098.6	88.91
2006	1324.2	1172.2	88.52
2007	1470.3	1290.9	87.80
Average	**1024.05**	**904.04**	**88.29**

Source: Czech Ministry of Finance and Own Calculations

In this case, rather than domestic private investment, consumption is crowded out[44] (positive statement) and the appropriate SDR should be therefore the rate at which individuals in society are willing to postpone a small amount of current consumption in

[44] Tax financing crowds out more likely consumption because taxes reduce consumers' disposable incomes that is by a bigger part consumed rather than saved (Boardman, 2006). There is an argument of the Ricardian equivalence which says that if the government raises taxes, the private consumption will stay unaffected (Romer, 1996). However, there exist some reasons for which the Ricardian equivalence might not hold exactly. The most important one is that people do not live forever and thus the generation affected by the tax increase reduces its budget constraint, cannot be sure of still being alive when the government decides to cut the taxes.

exchange for additional future consumption and vice versa, at social MRTP or p_z (normative statement). To express this reasoning formally: If a public project/policy is financed entirely by taxes, then in the equation $SDR=ar_z + bp_z$ we might set $a = 0$ and $b = 1$ and we get $SDR = p_z$.

If p_z is high, then individuals (under the assumption of all having the same p_z) are willing to sacrifice high amount of additional consumption next year to consume an extra amount borrowed today or, alternatively, it means that they require high amount of consumption next year in order to decrease their current consumption by an amount. It means that the individuals are more impatient (appreciate more consumption than saving) in this case and thus, as the public projects/policies crowd out consumption, should discount future benefits and costs (put them lower weight) of public projects/policies more. (If p_z is low, the logic works in an analogous logic and individuals would be less impatient in that case and thus should discount future costs and benefits of public projects/benefits less.)

Numerical Value of p_z

The best proxy of p_z is the real, after-tax return on savings (if individuals have high p_z, are more impatient, higher interest rates on savings are needed to attract them to save) and because, as already discussed, it is better to discount at a risk-free rate, the best proxy is the real, after tax return to holding government bonds (they have the lowest risk) (Boardman, 2006). Boardman states that the average nominal return to long-term (10-year), instead of short-term (1-year), government bonds should be used because these better reflect the rates of individuals' willingness to postpone consumption.

The long-term government bonds have existed in the Czech Republic since the year 2001. For this reason Kubíček and Vítek (2009) use data for years 2001-2007 to determine the pre-tax real return to 10-year government bonds. The average nominal before-tax return to 10-year government bonds they got was 4.5%. Then they found out the average GDP deflator[45] for those years - 2.5% - and deducted it from the average nominal before-tax return. Thus they obtained the average real before-tax return to 10-year government bonds of 2.0%. The tax rate of government bonds' returns (tax base

[45] It is the broadest measure of inflation (Kubíček,Vítek, 2009).

being the whole amount of those returns) since the year 2000 until now has been 15% (Program ASPI, 2009). Thus, considering the average real before-tax return to holding 10-year government bonds of 2.0%, the amount of the return that is transferred to the State is 0.3 % and the after-tax return that stays to the holder is 1.7% (own calculations). The estimate of p_z and therefore of SDR according to this proxy for the Czech Republic is thus 1.7%.

However, as Kubíček and Vítek (2009) add, because the long-term government bonds have not been used in the country before 2001, they suggest to be used instead the percentage of 3.3% for the estimate of the average real before-tax return on 10-year government bonds. This number is the average pre-tax return on holding 10-year government bonds for other developed countries. Since these countries dispose of the necessary data already from 1971 and since the Czech Republic is a convergence economy, the percentage of 3.3% gives a better idea of this average for longer-time horizon. Moreover, the years 2001-2006 for these countries showed relatively lower returns than in other years so the present average of 2% for the Czech Republic is probably too low for a longer-time horizon. However, to get the real, after tax return to holding government bonds, we still need to deduct tax on capital returns. The tax rate of government bonds' returns used to be, since the Czech Republic creation, 25% and, as we have already stated, since the year 2000 until now the tax rate has been 15% (Program ASPI, 2009). Let's therefore apply the average of these two tax rates for this longer data time horizon: 20%. Thus, considering the average pre-tax return on holding 10-year government bonds of 3.3%, the amount of the return that is transferred to the State would be 0.66 % and the after tax return that stays to the holder would be 2.64% (own calculations). Therefore, due to the relatively short time period used for the SDR determination and due to the fact of the Czech Republic being convergence economy**, we therefore recommend estimating p_z for the Czech Republic at 1.7%, with sensitivity analysis at 2.6%.**

Criticism

The first critical argument is that people, among themselves, differ in their marginal rate of time preference because they simply have different preferences and opportunities (Boardman 2006). Thus we cannot assume the individual p_z to be equal the social one and that the real, after-tax return to holding government bonds is an

appropriate proxy of social p_z. Even if all face the same after-tax return to holding government bonds (although in reality they might face different ones), it does not mean that all will necessarily have the same p_z - some will prefer to save but others will prefer to consume (e.g. prefer it per se or feel obligated to consume to buy clothes and food for their children). For this reason the real, after-tax return to holding government bonds is not an appropriate proxy for social p_z.

Second, the individuals themselves, moreover, seem to have various p_z because many of them simultaneously pay mortgages (save to decline their debt), buy government bonds (save) and borrow at their credit cards at high interest rate (consume) which make it difficult to aggregate them even into a single p_z for a single individual (Boardman, 2006). This fact supports the preceding criticism of the real, after-tax return to holding government bonds not being an appropriate proxy for social p_z.

Not considering the rate of suitability of the real, after tax return to holding government bonds as a proxy for the SDR, this model also cannot be recommended for the Czech Republic because its public projects/policies are not financed entirely by taxes. The Czech government runs not balanced but deficit budgets. Thus it cannot be assumed that no investment but rather consumption is crowded out due to public projects/policies implementation.

4.2.1.4. Imperfect Competition Framework: SDR Equals the Government's Borrowing Rate

As it has been pointed out in the second criticism of the model where SDR should equal the marginal rate of return on private investment, if public project/policy is financed by borrowing (which is probable in the Czech environment, as it has been already stated, because of the unbalanced budget), it should be discounted rather by the government's long-term borrowing rate i. The assumption of discounting at the rate of return to corporate bonds emitted by companies operating on the Czech market was not a realistic one for the Czech environment since, as it has been mentioned, the country is an opened economy and thus it is more likely that the government borrows from foreign investors (not only private but also public ones). At the table 6 below we can see that more than three quarters of the central government debt is in hands of foreign holders.

Table 6: Central Government Debt by Type Holder – 4th Quarter 2008 (in %)

Foreign holders		Domestic holders	
Sector/Sub-sector title	**%**	**Sector/Sub-sector title**	**%**
Non-financial corporations	***0.04***	***Non-financial corporations***	***1.11***
Foreign controlled non-financial corporations	*0.04*	Public non-financial corporations	0.86
		National private non-financial corporations	0.25
Financial Corporations	***58.3***	***Financial Corporations***	***9.48***
Other monetary financial institutions - foreign controlled	31.72	The central bank	5.23
Other financial intermediaries - foreign controlled	2.35	Other monetary financial institutions - public	1.27
Financial auxiliaries - foreign controlled	0.01	Other monetary financial institutions - national private	0.34
Insurance corporations and pension funds - foreign controlled	24.22	Other financial intermediaries - public	0.04
		Other financial intermediaries - national private	0.54
		Financial auxiliaries - public	0
		Financial auxiliaries - national private	0.77
		Insurance corporations and pension funds - public	0.68
		Insurance corporations and pension funds - national private	0.61
		General government	***2.17***
		Central government	2.08
		Local government	0.09
		Social security funds	0
		Households	***1.02***
		Nonprofit institutions serving households	***0.07***
Rest of the world	***27.81***		
TOTAL	**86.15**	TOTAL	**13.85**

Source: Czech Ministry of Finance and Own Calculations

Moreover, in comparison to the return to corporate bonds, the government bonds have lower risk premium and thus the long-term rate for which the government borrows is a more appropriate one to use for discounting future costs and benefits of public projects/policies. If we accept this positive reasoning for the normative approach to discounting, then this model of using *i* as a measure of SDR is an appropriate one.

Despite the EC does not state it clearly neither in its Impact Assessment Guidelines (2009) nor in the Annexes to Impact Assessment Guidelines (2009) what model it uses for the SDR determination for policies, it is very probable, due to the used proxy, it was inspired by this model as we will see shortly.

Numerical Value of i

An appropriate proxy of the government's long-term borrowing rate *i* is the real return (interest rate) to holding 10-year government bonds as is suggested by Kubíček, Vítek (2009) as well as by Boardman (2006). In the previous model we had the same proxy only with the difference it was an after-tax return. We already know that the before-tax return and therefore the SDR for the Czech Republic according to this model proposed by Kubíček, Vítek is 2.0%.

Due to the relatively short time period used for the SDR determination and due to the fact of the Czech Republic being convergence economy**, we recommend estimating *i* for the Czech Republic at 2.0%, with sensitivity analysis at 3.3%[46].**

The EC's value for the SDR for policies, as the EC's Annexes to Impact Assessment Guidelines states, broadly corresponds to the average real yield on longer-term government debt in the EU over a period since the early 1980s and is estimated to be 4% as it was mentioned earlier and which is probably too high for the case of the Czech Republic (European Commission, Secretariat General (2009).

[46] This percentage is the average pre-tax return on holding 10-year government bonds for selected developed countries determined by Kubíček and Vítek (2009) that is discussed in greater detail in the previous model.

Criticism

The SDR derived from this model might not be appropriate one, however, because it does reflect only a part of the consequences of the government's borrowing and therefore of the public project/policy implementation. If a government borrows to realize a project/policy, there arise the following consequences.

First, the government needs to pay the year's interest to the foreign investors for the loan. This consequence is reflected by this model. Its assumption is that since the Czech Republic is an opened economy, it is more likely to assume the government borrows from foreigners.

Second, as the government borrows, it is too simplifying to assume that it borrows only from foreigners. From the table 4 we can see that approximately 13% of the Czech central government debt is held by domestic holders. If we admit that the government borrows from domestic investors as well, the private domestic investment would be crowded out, (or conversely increased or nothing would happen to it[47]) and the parameter r_z should also have some weight. Moreover, the proxy of the government's long-term borrowing rate i - the real return (interest rate) to holding 10-year government bonds – is not an appropriate proxy of such a rate because the real return to holding the long-term government bonds incorporates also part of the return hold by the domestic investors. Therefore, this proxy is too high for the rate used in this model.

Third, since the payment of the debt (plus interest), to be paid to the foreign as well as domestic investors, is transmitted back to citizens in the form of taxes, domestic consumption is also crowded out but less than one-by-one. It will be like that, first, because, naturally, the debt plus interest has to be paid to both foreign and domestic investors, however, the process of paying back to the domestic investors might be viewed only as a transfer since these investors are, in the same time, Czech citizens that are later burdened with the taxes. Thus the domestic consumption might be crowded out only by the amount (debt plus interest) owned to the foreigners. Second, as the government runs deficit budgets, there are smaller amount of taxes than should be to pay off implementation of public projects/policies.

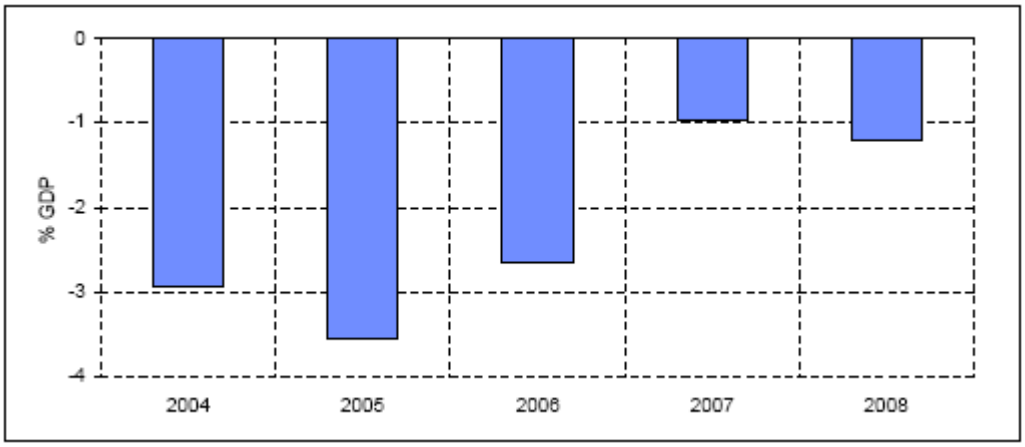
Fourth, the foreign borrowing has, however, also a negative effect on domestic investment (Boardman, 2006). Such a borrowing causes financial capital inflow into the

[47] Please refer to criticism of the model where the SDR equals r_z.

country and thus appreciation of the Czech crown (under a flexible exchange rate regime, more precisely inflation targeting regime which the country has had since the end of 1997). The appreciation in turn reduces net exports and thus investment as well.

Since the second, third and fourth consequences are not incorporated in this model, the SDR of 3.3% derived from this model cannot be recommended. Moreover, as for several consecutive years the Czech general government deficit has been decreased, has not exceeded the limit of 3% of GDP given by the Maastricht convergence criteria (as can been observed in the figure 5 below), it might be nowadays more realistic to assume the public project/policies are financed mainly by taxes and not by borrowing (Ministry of Finance, Department for Financial Policies, 2008). However, facing the world's economic crisis and its uncertain course makes it very difficult to predict development of the public projects/policies' source financing for coming years.

Figure 5: Czech General Government Net Lending (+)/ Net Borrowing (-)



Source: Czech Ministry of Finance

4.2.1.5. Imperfect Competition Framework: SDR Equals the Weighted Social Opportunity Cost of Capital

We have seen so far that public policies/projects in the Czech Republic are financed by domestic and foreign borrowing and by taxes. Thus this model intends to incorporate all the three parameters – r_z, p_z and i - into one single model. Some economists claim that the SDR should be calculated in terms of the social opportunity cost of the required resources with weights based on the relative contributions of the different sources of the resources (Boardman, 2006).

If *a* is the proportion of the project/policy's resources that crowd out private domestic investment, *b* is the proportion of the resources that displaces domestic consumption, and *(1 – a – b)* is, as Boardman (2006) suggests, the proportion of the resources that needs to be paid to foreign investors in the form of interest, then the weighted social opportunity cost of capital (WSOC) method computes the social discount rate as the weighted average of these rates:

$$WSOC = ar_z + bp_z + (1 - a - b)i$$

The previous models of SDR equals r_z, SDR equals p_z and SDR equals *i* (the government's borrowing rate) are, in fact, special cases of this more general model. If we accept this positive reasoning for the normative approach to discounting, then this model of using WSOC as a measure of SDR is an appropriate one.

Numerical Value of WSOC

The estimates of r_z, p_z and *i* are already founded out. They are 3.9%, 1.7% and 2.0% respectively. However, to obtain estimates of *a*, *b* and hence of *(1 – a – b)* is more difficult.

Boardman (2006) suggests an individual project/policy approach. It means that if the project/policy is most likely to be deficit-financed, WSOC would be similar to r_z (if more resources is borrowed from domestic investors) or *i* (if more resources is borrowed from foreign investors) because *a* and *(1 – a – b)* will be relatively large and *b* would be small. Thus if the project/policy is deficit-financed, its SDR would range from 3.9% to 2.0%. If the project/policy is, however, most likely tax-financed, WSOC would be similar to p_z because *b* would be large, *a* small and *(1 – a – b)* would probably equal 0. Thus if the project/policy is tax-financed, its SDR would be close to 1.7%..

Since in the last few years there is a call for additional taxes rather than increase in the government's deficit for the purpose of public projects/policies realization in the USA, Boardman (2006) suggests using in most of the cases SDR that equals p_z. Due to the world's economic crisis, as we have said, the tendency of public projects/policies realization in the coming years might differ however.

Let's analyze actual situation of public projects/policies financing in the Czech Republic to obtain the estimates of *a*, *b* and hence of *(1 – a – b)* for the country. If we assume taxes (altogether with social contributions form the biggest source of the Czech general government revenue that makes the assumption viable) and financial resources borrowed (expressed by government's deficit) are the only sources for financing public projects/policies, then their proportion in the financing can be found out. If we furthermore know that 86.15% of all the resources borrowed are from foreign investors and 13.85% are from domestic investors, we are able to compute proportions of these two sources of borrowing. Thus according to the table 7 below, taking data of taxes (altogether with social contributions) revenue (column 2) and magnitudes of the government's deficit (column 3) for the years 1997 – 2007, public projects/policies in the Czech Republic are in general financed 89.60% by taxes (column 5), 8.96% by borrowing from foreign investors and 1.44% by borrowing from domestic investors. The parameter *a* would be of value 0.0144, the parameter *b* of value 0.896 and parameter *(1 – a – b)* of value 0.0896.

Table 7: Taxes, Foreign and Domestic Borrowing Proportions in the Czech Public Projects/Policies Financing

Years	Taxes	Deficit - finances borrowed	Total finances for public projects/policies	Proportion of taxes in the total finances	Proportion of finances borrowed in the total finances	Proportion of foreign debt holding	Proportion of domestic debt holding
	(in bn CZK)	(in bn CZK)	(in bn CZK)	(as %)	(as %)	(as %)	(as %)
1997	634.2	68.8	703	90.21	9.79	8.43	1.36
1998	666.7	100.1	766.8	86.95	13.05	11.25	1.81
1999	709.6	77.3	786.9	90.18	9.82	8.46	1.36
2000	741.8	81.5	823.3	90.10	9.90	8.53	1.37
2001	800.5	135	935.5	85.57	14.43	12.43	2.00
2002	858.7	166.8	1025.5	83.73	16.27	14.01	2.25
2003	922.6	170	1092.6	84.44	15.56	13.40	2.15
2004	1048.6	82.7	1131.3	92.69	7.31	6.30	1.01
2005	1098.6	106.6	1205.2	91.15	8.85	7.62	1.23
2006	1172.2	85.5	1257.7	93.20	6.80	5.86	0.94
2007	1290.9	34.2	1325.1	97.42	2.58	2.22	0.36
Average	**904.04**	**100.77**	**1004.81**	**89.60**	**10.40**	**8.96**	**1.44**

Source: Czech Ministry of Finance and Own Calculations

If we insert the estimates of the parameters into the WSOC equation:

$$WSOC = 0.0144 * 0.039 + 0.896 * 0.017 + 0.0896 * 0.02$$

We obtain the SDR of value, in the rounded form, 1.8%. Thus according to the WSOC model, **we recommend estimating *WSOC* for the Czech Republic at 1.8%, and since this estimate is only one decimal number higher than p_z, with sensitivity analysis at 2.7%**

Criticism

First criticism incorporates all the contra arguments of the individual special cases of this model (Boardman, 2006).

Second critical argument, used by governments, is that this model does not lead to a single SDR which could be applicable to all projects/policies considered (Boardman, 2006). There would be problems of physical and financial feasibility to monitoring assumptions about the sources of resources required for specific projects/policies and of explaining why different SDRs are used on different projects/policies. For this reason the governments prefer a single SDR applicable in all cases. This, however, does not mean that this objection rules out the propriety of the varying SDR according to different nature states of specific projects/policies[48]. Moreover, we have shown here that this model can be generalized for all the public projects/policies and thus a single SDR can be derived so this critical objection does not have too much weight.

Third, there is an additional weakness which we have not mentioned yet. Since, as previously discussed, r_z and p_z differ due to market distortions, flows of investment should be treated differently from flows of consumption (Boardman, 2006). Consumption provides an immediate benefit while investment generates a stream of benefits that occur in future periods. Such a distinction is missing in this model and therefore, not mentioning the insufficiencies of the individual special cases of the model, it cannot be recommended to be used.

[48] We will answer if it is more appropriate to use a single SDR to all projects/policies or instead apply different SDR according to specific nature of the projects/policies later in this work.

4.2.1.6. Imperfect Competition Framework: SDR Equals the Social Marginal Rate of Time Preference but with the Necessity of Shadow Price of Capital Use if Applicable

This model considers the public policies/projects having impact on domestic consumption and private investment as the significant ingredients for SDR formation, leaving the government's borrowing rate out of the scope since, as mentioned in its model criticism, it also affects domestic consumption and private investment. This model intends to remove the weakness of the previous one mentioned in its third critical argument. Any public project/policy can produce costs and benefits in the form of changes in consumption, investment or both (Boardman, 2006). The shadow price of capital method intends to distinguish between project impacts that affect investment and those that affect consumption. Since consumption provides an immediate benefit and investment a stream of benefits that occur in future periods, conversion of investment impacts in each period into consumption equivalents allows us to treat all projects/policies' impacts as consumption ones (positive statement) and thus to discount them all at p_z, at the rate at which individuals in society are willing to postpone a small amount of current consumption in exchange for additional future consumption and vice versa (normative statement).

The process of discounting under such a framework is done according to the following four steps (Boardman, 2006).

First, the project/policy's costs and benefits in each period are divided into those that directly affect consumption and those that directly affect investment (Boardman, 2006).

Second, investment benefits and costs (flows into and out of investment) are multiplied by a parameter θ to convert them into consumption equivalents (Boardman, 2006). The parameter is called shadow price of capital because the price of capital cannot be directly observed in a market but must be inferred. Suppose that one Czech crown is invested in the private sector for an indefinite period and that it earns return of r_z each period and this return is immediately consumed each period and the original one crown is reinvested. Then, to obtain the present value of such a perpetual consumption stream of r_z, we discount the amounts received each period at p_z:

$$\theta = \frac{r_z}{p_z}$$

Since r_z is greater than p_z, the parameter θ is greater than one, indicating a higher weight of investment flows or, analogously, a higher cost of investment displacement because of investment (compared to consumption) providing a stream of benefits. The expression for the shadow price stated above is based on two simplifying assumptions. First one is that capital invested does not depreciate. Second one is that the entire return from the investment is consumed when it occurs. In reality, it is more likely the capital depreciates and some of the return from the investment, when it is generated, is reinvested. To match this more realistic picture, we need to use the following, more general, expression for the shadow price of capital:

$$\theta = \frac{(r_z + \delta)(1-f)}{p_z - r_z f + \delta(1-f)}$$

where δ is the depreciation rate of the capital invested, f is the fraction of the gross return that is reinvested and p_z and r_z as before are SMRTP and the net return on capital after depreciation consecutively[49].

Third step in discounting according to this model is to add changes in consumption (consumption costs and benefits) to the consumption equivalents in each period and to obtain thus net benefits in each period.

And the last step is to get NPV of the net benefits (those consumption ones as well as those converted into consumption ones). To obtain this, the net benefits will be discounted at SDR equal p_z[50] (SMRT) (indicating all the impacts will be consumption affecting):

$$NPV = \sum_{t=0}^{n} \frac{NB_t}{(1+p_z)^t}$$

[49] If there is not reinvestment and depreciation present ($f = 0$ and $\delta = 0$), the formula for θ reduces to its initial equation (Boardman, 2006).

[50] Although in one extreme case, the impacts are in fact discounted at r_z (Boardman, 2006). Suppose a project yields real annual benefits of B indefinitely. If all of these benefits are consumed as they arise, then the present value of this consumption flow at p_z is B/p_z. Further let's assume that all costs of the project C occur in time 0 and that all of them displace investment. Under such assumption, the NPV rule implies the project to be accepted if $B/p_z > \theta C = (r_z/p_z) C$ or, equivalently if $B/r_z > C$.

Numerical value of the ShadowPrice of Capital θ

From the previous models we already know the value of p_z, which is 1.7%, and the value of r_z which is 3.9%. Thus the value of the parameter θ for the Czech Republic in its reduced initial form is, in the rounded form, 2.3%, with sensitivity analysis at 1.5% to 3.3% (considering the sensitivity analysis for both parameters p_z and r_z).

To obtain the estimate of the value of the parameter θ for the Czech Republic, in its extended form, we additionally need the estimate of δ and f.

As for the value for the depreciation rate of the capital invested δ, a possible estimate could be found as the proportion of the consumption of fixed capital on the state of gross fixed capital that is depicted in the table 8. We computed the average of these proportions from the data of the consumption of fixed capital and the state of gross fixed capital for the years 2001-2007. The resulting estimate of the value for the depreciation rate of the capital invested δ we obtained is, in the rounded form, 2:5%. Due to the already mentioned Kubíček's criticism of too high estimates of state of gross fixed capital in the Czech Republic, the estimate of the depreciation rate of the capital invested for the Czech Republic might be too low. Therefore, we recommend estimating δ for the Czech Republic at 2.5%, with sensitivity analysis at 4% (the rate traditionally used in other developed countries).

Table 8: Depreciation Rate of the Capital Invested

Years	(1) Consumption of fixed capital	(2) State of gross fixed capital	(3) Depreciation rate of the capital invested
	nominal	nominal	(in %)
	in m CZK	in m CZK	
2001	477,428	18,884,547	2.53
2002	491,562	19,497,241	2.52
2003	508,676	20,200,433	2.52
2004	537,528	21,148,340	2.54
2005	553,824	22,083,248	2.51
2006	576,164	22,875,627	2.52
2007	605,596	23,733,353	2.55
Average	**535,825**	**21,203,256**	**2.53**

Source: Czech Statistical Office and Own Calculations

As for the value for the fraction of the gross return that is reinvested *f*, the gross investment rate (the ratio of real gross fixed investment to real GDP) can be used as an estimate of the fraction of the gross return that is reinvested *f* (Boardman, 2006). The real gross fixed investment might be in fact the real formation of gross fixed capital. We add the data of real GDP for the years 2001-2007 and by the proportion of the two we obtain the needed gross investment rate for the Czech Republic of, in the rounded form, 28.7% that is depicted in the table 9 below (column 3). Boardman found a much lower gross investment rate for the USA (the average of 17%). However, as the Czech Republic is a convergence economy, the higher gross investment rate might be well justifiable.

Table 9: Gross Investment Rate in the Czech Republic

Years	(1) Formation of gross fixed capital (in m CZK, in the year 2000 prices)	(2) GDP (in m CZK, in the year 2000 prices)	(3) Gross investment rate (in %)
2001	652,851	2,242,943	29.11
2002	686,128	2,285,488	30.02
2003	689,117	2,367,818	29.10
2004	716,285	2,474,006	28.95
2005	729,043	2,630,273	27.72
2006	776,498	2,808,784	27.65
2007	828,316	2,975,921	27.83
Average	**725,462.57**	**2,540,747.57**	28.63

Source: Czech Ministry of Finance and Own Calculations

Thus the value of the parameter θ for the Czech Republic in its extended form, for our central estimates of p_z = 1.7%, r_z = 3.9%, δ = 2.5% and f = 28.7%, is 0.988%, which is roughly 1%. It implies that one CZK of private-sector investment would produce a stream of consumption benefits with an NPV equal to one CZK. This estimate in fact thus does not differentiate between consumption and investment. Earlier we suggested using a range for r_z of 3.9 to 5.6%, a range for p_z of 1.7 to 2.6% and a range for δ of 2.5 to 4%. Using different combinations of these numbers, with f = 28.7%, results in values for θ of between 0.983 and 0.994% which is also roughly 1%. **To make a difference between investment and consumption, we, therefore, recommend using the value of 2.3%, with sensitivity analysis at 1.5% to 3.3% (considering the sensitivity analysis**

for both parameters p_z and r_z), for the parameter θ in its reduced form for the Czech Republic

Criticism

Since in the reality a public project/policy execution affects investment and consumption and not only in negative (as was assumed in the previous models) but also in a positive way, the shadow price of capital model provides, in theory, the best approximation to the reality. However, there exist various objections to its implementation in practice that constitute the reason for its rare use.

First criticism is related to the governments' objections of this model complexity. It is difficult to explain to policy makers why a single SDR which would be inserted into the NPV formula is not used and how the process under the shadow price of capital framework is executed (Boardman, 2006).

Second, this model requires more information than the other ones. As Boardman (2006) states, the most problematic one is the decision to allocate benefits and costs between investment and consumption. Since it is not unambiguous, a great space for political manipulation (although we have seen such a space being present in other parts of the CBA execution as well as into a certain extent in other models of social discounting) is left here.

Third, since the shadow price of capital depends on p_z and r_z, this model is subject to the same criticism that pertains to calculation of these parameters (Boardman, 2006).

In general we can assume that the Czech public project/policies' financing comes by 89.60% from taxes, by 8.96% from foreign borrowing and by 1.44% from domestic borrowing. Thus public projects/policies' implementation affects consumption (e.g. provides an immediate benefit) and investment (e.g. generates a stream of benefits that occur in the future). For such a framework, the approach to social discounting where SDR equals the SMRTP but with the necessity of shadow price of capital use might be the most appropriate one.

However, to avoid the objections related to the model's complexity and a high probability of political manipulation, we might apply the model where SDR equals the SMRTP only. This model would be applicable under the following circumstances. First, the model might be an appropriate one in projects/policies where the percentage of costs

and benefits that comes from investment is the same in every period (Boardman, 2006). Second, there is little evidence of responsiveness of the supply of loanable funds from abroad to interest rate and thus of foreign borrowing to crowding out of domestic net exports and therefore of domestic investment. In cases of small projects/policies, however, it would be reasonable to assume extreme responsiveness of the supply of foreign funds to the interest rate and thus almost no crowding out of private investment. Since almost 90% of borrowing in the country is of foreign origin, in circumstances of small projects, the application of the SDR equal the SMRTP only might be the appropriate one. Third and the most convincing argument is the fact that taxes constitute almost 90% of the Czech public projects/policies' financing. Thus we might afford to simplify and use the model of SDR being equal SMRTP.

4.2.2. SDR Market Determination Criticism

All the SDR derived from the market are in fact constant (exponential) discount rate type which implies placing the same SDR to net benefits in every period of the project/policy's time horizon and thus placing progressively lower numerical values on future benefits and costs the further into the future they occur.

Some economists, like Kubíček and Vítek (2009), support the SDR market way determination because these approaches, even though also being normative from the point of view of conclusion, have characteristics of positive economy, at least as for the quantitative estimates of discount rate value. Even though, in particular, these two economists think of the model where SDR equals the government's borrowing rate being as the most appropriate one, their final conclusion applies for the SDR market determination models in general: "Since the real observed interest rates served us as the initial data, we have worked with the empirical, showed off preferences".

However, even if we accept the positive reasoning being appropriate for the normative approach to discounting and we agree on the SDR being equal to the SMRTP as the most appropriate reflection of the SDR, the chosen estimate derived from the market – after-tax holding of government bonds – does not reflect the SMRTP. The reason is that capital markets are not perfect and human beings do not live forever and as a consequence the individuals do not behave as the models suggest (Boardman, 2006). We list here the most important evidences to support such a statement.

The first (already mentioned but for convenience placed here again) argument is that since people simply have different preferences and opportunities, they differ in their marginal rate of time preference (Boardman 2006). Thus we cannot assume the individual MRTP to be equal the social one and thus that the real, after-tax return to holding government bonds is an appropriate proxy of the social MRTP. Even if all face the same after-tax return to holding government bonds (although in reality they might face different ones), it does not mean that all will necessarily have the same MRTP - some will prefer to save but others will prefer to consume (e.g. prefer it per se or feel obligated to consume to buy clothes and food for their children).

The second (also already mentioned but for convenience placed here again) argument is that since people simultaneously pay mortgages (save to decline their debt), buy government bonds (save) and borrow at their credit cards at high interest rate (consume), an individual himself/herself seems to have various private MRTPs. Individuals namely use different rates to discount large versus small amounts, costs and benefits, short-term versus long-term decisions and choices about immediate consumption and its delaying. Thus it is difficult to aggregate these single private MRTPs even into an overall private MRTP for a single individual (Boardman, 2006).

The third argument is the so called “time inconsistency” or “incongruence”. It is referred to a situation where plans that are made at one point in time are contradicted by later behavior (Pearce, D., Groom, B., Hepburn, C., Koundouri, P., 2003). Even if one discount rate is currently preferred, due to change of individual preferences (everything else stays the same), another one might be preferred later in time of their lives. Thus individual and therefore also social preferences differ with time. This argument is directed generally against the constant discount rate whose constant value is applied to all periods of time horizon. Thus this argument suggests time-varying discount rates.

The fourth argument (related to the previous one) is that preferences also differ among generations (Pearce, D., Atkinson, G., Mourato S., 2006). Thus the currently derived, constant, SDR applied to policies/projects lasting for generations (especially environmental policies/projects) might reflect preferences of the individuals currently alive but might contradict preferences of those yet being born. This argument is also directed generally against the constant discount rate use, suggesting time-varying discount rates.

The final argument against the market determination of SDR is uncertainty about the future (Pearce, D., Groom, B., Hepburn, C., Koundouri, P., 2003). Although we

have always used several-year horizon of the data to derive the estimates of the different SDR from the market, we cannot be sure of this trend (especially of economic growth) to continue in the future[51]. This argument is also directed generally against the constant discount rate use, suggesting time-varying discount rates.

Due to the great complexity of private MRTP aggregation of even single generation into SMRTP, we might not put much weight to the critical arguments related to the improper aggregation of private MRTP within one generation and consider our market determined SDR of 1.7% with sensitivity analysis at 2.6% (being an approximation of SMRTP for one generation) as an approximate estimate of SDR for public policies/projects with time horizon up to one generation[52] (short-term projects), so up to approximately 30 years. Thus public projects with such a time horizon (e.g. publicly financed construction of block of flats on a natural space, until the time of construction almost untouched by humankind) with short-term environmental effects (e.g. noise) might use this SDR. The issue of choice of time horizon longitude is not as such the subject of our research in this thesis and thus we will respect the choice of shorter time horizon for projects that might have, according to our consideration, not only short-term but also long-term environmental impacts (in the example of the block of flats construction e.g. a loss of animals in the adjacent zone to the natural space which might result in, for example, impossibility of hunting). For this reason, the choice of this SDR for the public projects/policies with short-time horizon would be an appropriate one and it could be used for economic analyses conducted as a part of the application process for financial means from, for example, the EU Structural Funds because the time horizon required does not usually exceed the boundary of such a short-time horizon (Fondy Evropské unie, 2009).

This market determined SDR thus in fact might reflect the social time discount rate (or "pure" rate of time preference) of one generation with the simplifying assumption of zero economic growth rate[53] in that short-run. Or it reflects the social time discount rate of more generations under the assumptions of, firstly, keeping the same preferences from one generation to another (disregarding the problems with private MRTP within one generation) - keeping the after-tax return to holding 10-year government's bonds constant - secondly, of zero

[51] We devote in greater detail to the problem of uncertainty later in this work.
[52] A generation we define as the average interval of time between the birth of parents and the birth of their offspring (Slovník cizích slov, 1998).
[53] SDR of one generation can be imaginable as a two-period model with no economic growth..

economic growth rate and, thirdly, of the vision of humanity extinction, due to not our own behavior but due to outer source, (e.g. due to a cosmic objects hitting the Earth) within our timescale.

The first assumption requires the problem of time-inconsistency not only within one but among generations to be ruled out. We might afford ruling it out (might conclude this assumption holds) for two reasons. First, time inconsistency admission would oblige us to distract our attention from the main objective of this thesis for such a while that another work of a similar length might be written. Second, some economists (Henderson, Bateman or Heal) see the time inconsistency as the most unnatural requirement (Pearce, 2006). They find it legitimate to change the SDR as time moves on if preferences of people change. And the other two assumptions, compared to the first one, might not always hold. Those believing in no economic growth in the long-term and in a catastrophic end of the humanity not caused by the humans itself within our timescale (considering the assumption of unchanged intergenerational preference as possible), might still use such a SDR even for long-term projects/policies. However, the probability of these two assumptions, holding both at the same time, is quite low. Some economists (e.g. Heal or Boardman) therefore suggest an alternative, intergenerational, approach to SDR determination that would not require such stringent requirement. We will find out if the perception of the social time discount rate ("pure" rate of time preference) under such a framework change (and possibly how) and what consequence of such a change would have on the value of SDR. Since the projects/policies with significant environmental impacts are, more rationally, often of long-term nature (e.g. reduction of CO2 emissions), the elaboration of the subsequent model and the role of the social time discount rate ("pure" rate of time preference) within it, will be very important for us.

4.2.3. Intergenerational Approach to Social Discounting and Determination of the Social Time Discount Rate

As we have already said, the second and third assumptions for the market determined SDR' use in the intergenerational social discounting are too stringent and therefore, we present an alternative approach to social discounting that enables us to weaken these assumptions if necessary. This approach was also used by the EC to determine the SDR of 5.5% conduct economic analyses for investment projects in the

Cohesion countries (in particular, the SDR of 5.7% for the Czech Republic) (European Commission, Directorate-General Regional Policy, 2008).

4.2.3.1. Optimal Growth Rate Approach Specification

The alternative approach suggested is to derive the SDR from the model on optimum saving following the work of Frank Ramsey (1928) (Puttaswamaiah, 2002). The central idea of the model is to derive an optimal economic growth path (the maximum growth rate over a specified time horizon) out of the rates at which society saves and consumes out of the national income, where the rates are determined by a discount factor reflecting the SMRTP and thus SDR.

The most important model's simplifying assumption is that there is a single, representative individual (society) that lives forever and obtains utility from consumption (Boardman, 2006). The model assumes that policy makers use a well-behaved social welfare function that describes the values society places on different amounts of per capita consumption (both private and public) over time. Policy makers choose the amount of public investment in order the social well-being to be maximized now and in the future.

The SDR that reflects the SMRTP, or p_x[54], consists of two elements (Boardman, 2006):

$$\text{SDR} = \text{SMRTP} = p_x = d + ge$$

Let's first define the component *d*. It is the social time discount rate (or "pure" rate of time preference) we already know reflecting people's impatience. It can be defined in the following ways. First, it reflects purely a preference for well-being in the present over the future (e.g. impatience), regardless of economic growth (Boardman, 2006). Second, it measures the extent to which we discount future welfare or utility per se (Persson, Sterner, 2008).

The second term of the equation, sometimes called as the consumption discount rate, consists of the long-run rate of growth in real per capita consumption g and the elasticity of marginal utility of consumption *e* (Puttaswamaiah, 2002). If we assume the

[54] The *x* subscript indicates that this result holds for the first-best, or optimal, growth path (Boardman, 2006).

time inconsistency ruling out and thus assuming unchanged people's preferences in time, then we might state that the real per capita consumption grows proportionally with economic growth which is conventionally measured as the percent rate of increase in real GDP. This allows as to look for the long-run growth rate in real per capita GDP to estimate value of the parameter *g*.

As for the elasticity of marginal utility of consumption, sometimes also called inequality aversion parameter, *e*, it can also be defined in different ways. First, it is the elasticity of marginal social welfare with respect to public expenditure (European Commission, Directorate General Regional Policy, 2008). Second, it is the percentage change in the welfare derived from a percentage change in consumption (or income) (Pearce, 2006). Or third, it is the rate that measures how fast the social marginal utility of consumption falls as per capita consumption rises or, vice versa, it measure how fast the social marginal utility of consumption rises as per capita consumption falls (Boardman, 2006). The mention of become richer or poorer is meant in time as well as spatial sense. Since we deal in this work with a specific territory, the Czech Republic, we disregard the spatial perspective and will devote to the time one only.

4.2.3.2. Long-Run Rate of Growth in Real Per Capita Consumption (Parameter g) Value

To discuss the most accurate value of the long-run rate of growth in real per capita consumption (thus of the long-run growth rate in real per capita GDP or growth-rate of productivity) would be a topic for a separate research work. There is a lot of uncertainty. Let's devote some time to outline the complexity of the long-run growth rate in real per capita GDP projections, in our case for the Czech Republic.

Short-term horizon

In the table 10 below, we can see a projection of the growth-rates in real per capita GDP in the Czech Republic for the years 1995-2007. The average rate of 2.95% cannot, however, be considered to be a good estimate of the long-run rate because the time period over which the projection is run is very short and therefore cannot present the rate of growth in the long-run.

Table 10: Growth-Rates in Real Per Capita GDP in the Czech Republic for Years 1995-2007

Years	GDP (in m CZK, in the year 2000 prices)	Number of inhabitants	Real per capita GDP (m CZK, (in the year 2000 prices)/habitant)	Growth-rate in real per capita GDP (in %)
1995	2,033,699	10,321,344	0.20	
1996	2,115,605	10,309,137	0.21	4.15
1997	2,100,143	10,299,125	0.20	-0.63
1998	2,084,203	10,289,621	0.20	-0.67
1999	2,112,121	10,278,098	0.21	1.45
2000	2,189,169	10,266,546	0.21	3.76
2001	2,242,943	10,206,436	0.22	3.06
2002	2,285,488	10,203,269	0.22	1.93
2003	2,367,818	10,211,455	0.23	3.52
2004	2,474,006	10,220,577	0.24	4.39
2005	2,630,273	10,251,079	0.26	6.00
2006	2,808,784	10,287,189	0.27	6.41
2007	2,975,921	10,381,130	0.29	4.99
Average	2,340,013.31	10,271,154.31	0.23	**2.95**

Source: Czech Statistical Office and Own Calculations.

Long-term horizon

To obtain a more accurate estimate we might follow one of the following ways:

First, it might obtained by the approach that consists of extrapolating past trend growth. It has the merit of being simple and reasonable if the growth rate is computed over a long and fairly homogeneous time period, e.g. the period starting from the first oil shocks of 1973, rather than the very recent past which has been very heavily affected by the business cycle (European Commission, Directorate-General for Economic and Financial Affairs, 2006). **The EC used this approach to estimate the value of the parameter *g* which was 3.5%** (European Commission, Directorate General Regional Policy, 2008). However, we might not use this percentage with certainty as the estimate of the long-run rate of growth in real per capita consumption because the future trend might differ substantially from the past. One reason why the future trend might differ is

the fact that the Czech Republic is in the convergence process[55] (it intends economically to catch up with the more advanced European countries). Thus the estimate of *g* obtained by the extrapolating method might be higher than the actual future growth-rates as the country's rate of growth might decrease to the growth rates of the more advanced countries after the "catching-up".

For this reason, there is a second approach called "convergence to a benchmark" (European Commission, Directorate-General for Economic and Financial Affairs, 2006). In this framework, the choice of the benchmark (US, EU as a whole, EU excluding some catching-up countries, etc.) and the horizon of convergence are crucial. However, as MPRA states: "This method can appear too mechanical, as specific factors may hinder the convergence in some countries. Moreover, the process of convergence may be even unexpectedly reversed". The estimate of g obtained by this approach thus also might not reflect the actual future growth-rates well.

For this reason, instead of the mechanical approaches explained above, economic approaches started to be conducted. One of them is a "statistical" method embedded in a production function framework and used by the European Commission for long-term labor productivity and GDP projections for the EU25 Member States (2006). This method uses combination of established time series methods to extrapolate very short-term developments (2 or 3 years) and of reasonable ad hoc assumptions (initial conditions and country-specific factors: e.g. ageing, total factor productivity) for the long-run (until 2050). For this reason, this method should give the most accurate value of parameter *g*. **We thus suggest for projects/policies in the Czech Republic with time horizon up to 50 years using the estimate of 2.3% for the long-run rate of growth in real per capita consumption *g*.** The details can be seen in the table 11 below.

[55] It is a conditional convergence implying that if the country's certain indicators (e.g. expectations of complementary investment, human capital, population growth, saving rate) would differ from those in the advanced countries, the country would converge to different, a lower, steady state. (Debray, 1998). Poorer countries do in fact grow relatively faster and consequently do converge over time, but not necessarily to the same steady state standard of living if the country's indicators differ from those in the more advanced countries (European Commission, Directorate-General for Economic and Financial Affairs, 2006).

Table 11: Projected GDP Per Capita Growth Rates (Period Averages) for the EU25 and the Czech Republic Based upon "Statistical" Method Embedded in a Production Function Framework

	2004-2010	2011-2020	2021-2030	2031-2040	2041-2050	2004-2050
BE	2.1	1.8	1.2	1.5	1.7	1.6
DK	1.8	1.8	1.2	1.3	2.0	1.6
DE	1.6	1.7	1.1	1.4	1.6	1.5
GR	2.6	1.8	1.3	1.0	1.2	1.5
ES	2.0	2.3	1.5	0.8	1.0	1.5
FR	1.7	1.6	1.5	1.5	1.7	1.6
IE	4.2	3.1	1.9	1.3	1.1	2.2
IT	1.6	1.8	1.4	1.0	1.5	1.5
LU	3.0	2.1	2.0	2.3	2.4	2.3
NL	1.3	1.5	1.2	1.5	1.9	1.5
AT	1.9	1.9	1.1	1.3	1.5	1.5
PT	1.5	2.3	2.0	1.1	1.2	1.6
FI	2.4	1.7	1.5	1.7	1.7	1.8
SE	2.3	2.3	1.7	1.6	1.8	1.9
UK	2.4	2.2	1.4	1.5	1.6	1.8
CY	2.9	3.1	2.3	2.0	1.3	2.3
CZ	3.6	3.2	2.5	1.4	1.1	2.3
EE	6.6	4.2	2.8	2.0	1.2	3.1
HU	3.9	3.1	2.6	1.4	1.3	2.4
LT	7.0	4.8	2.5	1.7	1.2	3.2
LV	8.3	5.0	2.8	1.9	1.0	3.5
MT	1.3	2.0	2.4	1.9	1.4	1.8
PL	4.7	4.0	2.9	1.6	1.0	2.7
SK	4.7	4.3	2.8	1.3	0.8	2.7
SI	3.6	2.8	2.2	1.5	1.3	2.2
EU25	2.2	2.1	1.6	1.4	1.5	1.7
EU15	1.9	1.9	1.4	1.3	1.6	1.6
EU12	1.8	1.8	1.4	1.3	1.5	1.5
EU10	4.6	3.8	2.7	1.5	1.1	2.6

Source: European Commission, Directorate-General for Economic and Financial Affairs.

Very long-term horizon

However, some environmental projects/policies might have time horizon even longer than 50 years - 100, 200 or even more years (e.g. climate change mitigation policies). The projections over this very long time horizon are complicated by uncertainty, especially, about the degree of natural capital substitution for other types of capital. We have already defined sustainable development (a development that is socially desirable, environmentally feasible and economically viable and which can last forever) and different types of sustainability.

Advocates of weak sustainability – neoclassical economists believe, due to technological development, in total substitution of natural capital for other types of capital (human and especially physical capital) and thus even if natural capital deplete over time, other types of capital will be able to substitute it in order the total capital to stay constant, assuring constant economic growth rate in the very long-run. Thus we might use the value of 2.3% for the estimate of g for projects/policies in the very long-run too.

Neoclassical economists might, however, also add that not only that other types of capital are able to substitute the natural capital in order the total capital stay constant

over time but even that these other types of capital will increase in time in a way which will assure growing total capital in the very long-run. Thus for the time horizon longer than 50 years, a bigger estimate for *g* than the one of 2.3% should be used.

However, the more we go towards the weak type of sustainability (ecological and environmental economists), the more we become skeptical about the natural capital substitution and the more we become questioning future economic growth rates. Therefore, the future generations, in that very long-run horizon, do not have the constant or higher economic growth rate guaranteed (due to natural capital depletion), the economic growth rate might decrease in the very-long time horizon and, therefore, the estimate of g for this very-long time horizon might be then lower than 2.3%.

In this work we support the vision of environmental economists – believe in natural capital substitution for other types of capital but are skeptical about its full substitution and therefore, due to the natural capital depletion, the *g* for this very-long time horizon might be lower than 2.3%. We support our position about the limits of natural capital substitutability by the following points.

First, the physical capital that we construct is not independent from the natural capital (Labandeira, León, Vázquez, 2007). We need natural capital for construction of the physical one.

Second, natural capital offers multifunctional services which physical one can never fully substitute (Labandeira, León, Vázquez, 2007). For example, the man-made monoculture of rubber in the Amazon basin or a monoculture of oil palm in the Congo may offer certain economic functions (e.g. provision of rubber, oil or wood) but can never fulfill all the services of the natural forest (e.g. biodiversity and soil quality might maintain resilience[56] of the forest against outer pests that might otherwise attack the forest and thus decrease or stop the rubber, oil and wood provision.)

Third, physical capital produces whereas the natural one does not produce waste (Labandeira, León, Vázquez, 2007). As not all types of waste products are recyclable, we would face accumulation of waste while substituting natural capital for physical one.

Fourth, as we are uncertain about the degree of the natural capital substitution, it is better to assume the limits of this substitution in order not to face catastrophic consequences of our wrong hypothesis in the future (Labandeira, León, Vázquez, 2007). Such a statement can be demonstrated within the game theory framework where

[56] Resilience is the grade with which a system recovers or returns to his previous state before the action of a stimulus (Labandeira, León, Vázquez, 2007).

everybody maximizes options with minimum risk (maximin strategy). There are two optimums: First, if we act as optimists towards the natural capital substitution (there are no limits in the substitution) and the future shows us the hypothesis is right (optimists are right) and the second, if we act as pessimists (there are limits in the substitutions) and we conserve the natural capital and the future shows us the hypothesis is right (pessimists are right). However, is we think as optimists and the future shows our hypothesis is wrong, we would face catastrophic consequences of our action (e.g. lack of clean water, air or land). Due to existence of, perhaps even a small, possibility in this row of optimistic thinking, it is the least risky option to think as pessimists because even though the future shows we were wrong (the total substitution is possible), we face an acceptable outcome and not a catastrophic one. Please, see the draft of this reasoning below in the table 12 for simplicity.

Table 12: Maximin strategy

	Optimists are right	**Pessimists are right**
Optimistic thinking	**Optimum**	**Catastrophy**
Pessimistic thinking	**Acceptable**	**Optimum**

Source: Own projection.

Fifth, if we think in the optimistic way and we let the natural capital to deplete, such action is irreversible and if the optimists were wrong, we would face a catastrophic scenario that is irreversible (Labandeira, León, Vázquez, 2007).

Sixth, we face uncertainty of future generations' preferences (Labandeira, León, Vázquez, 2007). We do not know, for example, if they will be satisfied with live in commercial centre instead in nice house close to a forest.

Seventh reason to support our skeptical attitude towards the full substitution of natural capital is simply existence of rights of the nature (Labandeira, León, Vázquez, 2007).

For these reasons, we might state, for the time horizon longer than 50 years, values of g lower than 2.3%. The logic is the following: As the natural capital due to e.g. consequences of the man made climate change becomes scarce in the very long

time horizon, its relative price will increase and consumption decrease, compared to the other types of capital (Persson, Sterner,2008). Heal (2008), Persson, Stener (2008) and others therefore suggest decomposing the rate in at least two sectors, the first one containing natural capital and the second one all the others. It might even come out that due to the decreasing natural capital, the resulting *g* would be negative which would not mean discounting anymore but the opposite (we would weight the future impacts more). In such a projection, also the degree of the substitutability of the two sectors would have to be reflected in some way which would determine the resulting value of *g*. For this reason, no such projections are made (further research is needed) and we therefore cannot cite here any exact value of *g* for the time horizon longer than 50 years but we may say that due to the seventh points above, we should rather expect lower value of *g* for the very-long time horizon which suggest use of time-varying, in particular declining, social discount rate (the further into the future we get, the lower SDR we use). Since the value of *g* in the very long-run time horizon might probably be lower than 2.3%, zero or even negative, it might be reasonable to assume the middle value of *g*, the value of 0%, being used for these very far future impacts[57].

For the very long time horizon we therefore recommend using the value of *g* lower than 2.3% which would be declining in time (due to natural capital depletion and its limits in substitutability for other types of capital) the further in the time horizon we get. It even might happen the growth rate being negative as time goes on (implying weighting the future impacts more). Due to the uncertainty and lack of scientific knowledge, we might afford to simplify and use zero value of *g* over the single number of the very "far future" impacts.

4.2.3.3. Elasticity of Marginal Utility of Consumption (Parameter e) Value

The lower the parameter *e*, the less the social marginal utility of consumption falls as people become richer (or vice versa), and the higher the parameter *e*, the more the social marginal utility of consumption falls as people become richer (or vice versa) (Boardman, 2006). Therefore, if we set *e* equal to zero, we treat each unit of consumption received in the future as identical to a unit of consumption in the present (no matter how much richer the people in the future are), signifying a complete lack of

[57] These very far future impacts might be difficult to be evaluated for each time period anyway and thus could be expressed as a single number over which a corresponding SDR would be applied (Boardman, 2006).

concern for intergenerational inequality and thus rejection of distributional weights (utilitarian position). If *e*, on the other side, reaches infinity, society completely discounts each unit of consumption received in the (richer) future, signifying an overwhelming desire to equalize per capita consumption over time and calling for the use of distributional weights (egalitarian position). And if *e* equals one, then the relative weight on society's consumption in each time period equals the inverse of its relative per capita consumption – if, for example, per capita consumption rises by 2% from one period to another, the society will weight the utility of that increase in consumption 2% less because the future society is 2% richer.

In fact, all values of *e* higher than zero are backed up by the utilitarian logic of diminishing marginal utility of consumption - as consumption rises, marginal utility decreases. The choice of this parameter, compared to the choice of *g*, is highly normative one, based upon individual and social preferences. Estimation of *e*, is thus less direct and proves to be less homogeneous (European Commission, Directorate General Regional Policy, 2008). According to the EC, a range of values between 1 and 2 is consistent with the evidence provided by behavioral approaches and revealed social preferences based on tax-based data. Assuming that income tax structures are at least loosely based on the principle of equal absolute sacrifice of satisfaction, then the extent of progressiveness in the tax structure provides a measure of *e* - the more progressive the tax structure, and thus the greater the extent of social aversion to income inequality, then the larger the value of *e*[58]. Based upon this reasoning, the EC determined the *e* estimate of 1.31% for the Czech Republic. **We therefore also use the *e* estimate of 1.31% in our analysis.**

4.2.3.4. Social Time Discount Rate (or "Pure" Rate of Time Preference) (Parameter d) Value

If we assume the parameter *g* being equal to zero (which, as we discussed, is a possible assumption) or the parameter *e* being equal to zero (which, as we discussed, is not probable in the Czech Republic) or both being equal to zero, then the value the SDR would be equal to the social time discount rate only.

If the society treated each unit of consumption received in the future as identical to a unit of consumption in the present (the society treated the marginal consumption

[58] Also upon the estimation of this parameter a separate research work might be done.

utility the same, no matter how rich or poor the people in the future would be), then the SDR would be equal only to the social time discount rate parameter in the optimal growth rate model. We would get the same outcome if there were no economic growth per capita in the long-run.

As we have discussed above, the assumption of *e* being equal to zero is not probable for the case of the Czech Republic, however, the assumption of *g* being equal to zero might be probable in the very long-run. If in that very long-run we also saw the assumption of the vision of humanity extinction, due to not our own behavior but due to outer source, (e.g. due to cosmic objects hitting the Earth) within our timescale very probable, we might apply the SDR of 1.7% with sensitivity analysis at 2.6% (the outcome obtained due to SDR market determination). The behavior is understandable because as the generation(s) in the very far future has (have) a vision of no economic growth and of humanity extinction, their behavior is comparable to the one of one generation and the positive behavior of economic subjects might be acceptable for the normative approach to discounting.

However, even if it was reasonable to assume zero economic growth in the very long-run, we should not apply the market determined social time discount rate for the normative approach to discounting to policies/projects with more then one generation time horizon. The reason is that the probability of humanity extinction due to near-Earth-object impact is extremely low and, moreover, it is not in accordance with the idea of sustainable development - a development (not necessarily economic growth but rather qualitative changes) socially desirable, environmentally feasible and economically viable which can last forever American Institute of Aeronautics and Astronautics (1995)**.** For this reason we should not use the market determined rate not even for the very long time horizon, where the zero value of *g* might be probable, of intergenerational project/policies. And for this reason, we cannot determine the time social discount rate from positive behavior but it needs to have a purely normative nature.

Normative determination of the parameter d

As we have defined earlier the parameter of the "pure" rate of time preference means the extent to which we discount future welfare (in intergenerational framework a

welfare of future generations) per se and we concluded that it needs to be determined in a purely normative way.

If we suppose, according to the optimal growth rate model, that the forever lived society consists of individuals that neither die nor are born new ones (one generation framework), then the society can have a positive or negative value of *d*. A negative one because people, if they are given a time framework, tend to cumulate positive events at the end and the negative events at the beginning of the time framework (Kubíček, Vítek, 2009). However, this view is shared only by few economists (e.g. Loewenstein, Prelec). More likely the value of *d* would be a positive one indicating that people, are impatient and prefer welfare over the future one.

If we, however, suppose a more realistic situation – a society in which people die and are born (the Ramsey's assumption of the society living forever is still satisfied) within the society (thus including different generations), apart from the positive value, also a zero value of *d* can be considered. Zero value of *d* does not mean the society does not have any time preference, instead it implies the public sector is unbiased concerning current and future generations (Kubíček, Vítek, 2009). On one side, the more positive is the value of *d*, the less weight being put on welfare of future generations, preferring the current generation, and the more the short-term projects against the long-term projects (e.g. environmental ones) are preferred because the future impacts are discounted more. It would be a dictation of the present over the future generations (Brůha, Melichar, Ščasný, Dvořák, 2007). On the other side, the more negative is the value of *d*, the more the long-term projects against the short-term projects are preferred because, in fact, an additional value is added to future impacts. It would be a dictation of the future over the present generations. And if the value of *d* is just zero, the public sector considers short-term and long-term projects the same, does not prefer present or future generations and their welfare. The economists favoring the zero "pure" rate of time preference (including Ramsey or Heal) justify their attitude upon the argument that the public sector cannot be a delegate of neither the present nor future generations and thus has to reflect equally preferences of both of them.

The EC says that the parameter *d* is influenced by life expectancy and other individual characteristics (European Commission, Directorate General Regional Policy, 2008). Therefore, the EC thinks that a consistent proxy for the parameter *d* is the

mortality rate[59] and uses the mortality rate of 1% (for the Czech Republic 1.1%) it in its SDR determination.

We, however, do not agree with use of this proxy. First, the proxy arises from the positive reasoning which we dissociate from for the intergenerational discounting. Second, we do not see the reason why people, even within the current generation, should discount their future welfare according to exactly the notion of the mortality rate.

The economists like Heal, Ramsey, Pigou, Rawls, Dasgupta, Sterner or Persson claim that there is no justification against a zero "pure" rate of time preference. We support this view and add that if we want to perform the idea of sustainable development, we in fact do not have another choice than to treat all generations equally.

The only reason why the value of *d* might differ from zero is taking into account the probability of humanity extinction due to outer source. Since this probability is, as we have stated earlier, infinitesimal, the highest value we are willing to accept for the value of the parameter *d* is the one suggested by Stern (2007) and supported by Sterner and Persson (2008) which is 0.1%. **We therefore also normatively determine the social time discount rate (or "pure" rate of time preference, the parameter *d*) at 0.1% and we suggest using it for SDR determination in the optimal growth rate model – for intergenerational projects/policies.**

4.2.3.5. SDR Value

For the environmental projects/policies with time horizon longer than 30 years (one generation) (in reality most of the environmental projects/policies should fall in this longer time horizon) we should use the optimal growth rate model since it reflects changes in the economic growth rate and intends to reflect preferences of the generations that are not born yet. In this model the social time discount rate (or "pure" rate of time preference) is one of the three parameters. We cannot use the market determined estimate of the "pure" rate of time preference but instead a normatively determined one. The reason is nonzero economic growth rate and extremely low probability of humanity extinction due to outer source (two assumptions necessary for such a rate application are not valid). Nor for the very long time horizon the market determined "pure" rate of time preference can be used because the probability of human extinction due to outer source is infinitesimal and, moreover, this rate is not in

[59] Mortality rate is typically expressed in units of deaths per 1000 individuals (Czech Statistical Office).

compliance with the idea of sustainable development (a development that can last forever) since it presumes from the very beginning the development is going to end. Our estimate of the normatively determined "pure" rate of time preference is 0.1% which reflects welfare of all generations having the same weight (implying the public sector is unbiased concerning current and future generations) and infinitesimal probability of humanity extinction due to outer source.

For the short-run time horizon (up to 30 years), the SDR, applying the normatively determined "pure" rate of time preference of 0.1% (which obviously does not change throughout the time horizon), the estimate of the parameter *g* of 2.95% and of the parameter *e* of 1.31% (which obviously also does not change throughout the time horizon), **is 4%.**

For the long-run time horizon (up to 50 years), the SDR, applying the same values of parameter *e* and *d* and the estimate of the parameter *g* of 2.3%, **is 3.1%.**

For the very long-run time horizon (more than 50 years: 100, 200 and more years), in spite of the huge uncertainty concerning the value of the parameter *g* which, due to the limits of natural capital substitutability, might be probably declining in time, we recommend applying zero value of *g*, and the value of **SDR**, applying again the same values of parameters *e* and *d*, thus **is 0.1%.**

5. Conclusions

In this diploma thesis we, firstly, managed to present the environmental CBA, despite of the theoretical fundamentals' criticism (which was not part of the thesis), as an ideal aid to accomplish the objective of a proper assessment of public projects/policies due to inclusion of even social (in our case environmental) impacts in theory, however, as a still imperfect tool to achieve the objective in practice. This might be the reason why the environmental CBA is still rarely used in the Czech public decision-making and, instead, less comprehensive but less controversial decision instruments (e.g. Environmental Impact Assessment) are applied. As the CBA is full of controversies, we further addressed only one - the choice of the SDR, in particular the social time discount rate (or "pure" rate of time preference) – that, due to a great future uncertainty and intergenerational justice, belongs to the most controversial steps in the CBA.

In the table below, we summarize our findings, the EC's recommendation and our recommendation for the Czech Republic concerning the choice of the social time discount rate (or "pure" rate of time preference) together with other components in the SDR determination.

	Our findings for the Czech Republic	The EC's recommendation for the Czech Republic	Our recommendation for the Czech Republic	
Market determined SDR = *d*				
SDR equals the marginal rate of return on private investment (rz)	3.9%, with sensitivity analysis at 5.6%			
SDR equals the social marginal rate of time preference (SMRTP = pz)	1.7%, with sensitivity analysis at 2.6%		1.7%, with sensitivity analysis at 2.6% (for projects/policies)	Assumptions: we are willing to accept positive reasoning for the normative approach to social discounting, time consistency, for project/policies with time horizon no longer than 30 years, zero economic growth-rate
SDR equals the government's borrowing rate (i)	2.0%, with sensitivity analysis at 3.3%	4% (for policies)		
SDR equals the weighted social opportunity cost of capital (WSOC)	1.8%, with sensitivity analysis at 2.7%			
SDR equals the social marginal rate of time preference (SMRTP) but with the Necessity of Shadow Price of Capital Use if Applicable	Investment impacts multiply by the shadow price of capital before discounting (by pz) all impacts in each time period:			
	Shadow price of capital: 2.3%, with sensitivity analysis at 1.5% to 3.3%			

<table>
<tr><td colspan="8">SDR through optimal growth rate model (Intergenerational approach to social discounting)</td></tr>
<tr><td rowspan="5">Term eg: Consumption discount rate</td><td rowspan="4">Parameter g: Long-run rate of growth in real per capita consumption</td><td>Short-run (up to 30 years)</td><td>2.95%</td><td rowspan="4">3.50%</td><td>Short-run (up to 30 years)</td><td>2.95%</td></tr>
<tr><td>Long-run (up to 50 years)</td><td>2.30%</td><td>Long-run (up to 50 years)</td><td>2.30%</td></tr>
<tr><td rowspan="2">Very long-run (more than 50 years: 100, 200 and more)</td><td>Big uncertainty but probably declining in time</td><td rowspan="2">Very long-run (more than 50 years: 100, 200 and more)</td><td rowspan="2">Facing the huge uncertainty, express the "far future" impacts as a single number and apply 0% g over it</td></tr>
<tr><td>(Further research needed)</td></tr>
<tr><td>Parameter e: Elasticity of marginal utility of consumption</td><td colspan="2">1.31%</td><td>1.31%</td><td colspan="2">1.31%</td></tr>
<tr><td colspan="2" rowspan="4">Parameter d: social time discount rate (or “pure” rate of time preference)</td><td colspan="2">1.7%, with sensitivity analysis at 2.6% (market determined d)</td><td rowspan="3"></td><td rowspan="3">0.1% (normatively determined d)</td><td rowspan="3">Even for the very long-time horizon because the probability of human extinction due to outer source is infinitesimal and, moreover, this rate is in compliance with the idea of sustainable development - a development that can last forever</td></tr>
<tr><td colspan="2">(Assumptions: time-consistency of preferences, zero economic growth rate, one generation living or more generations living with vision of humanity extinction due to outer source within our timescale)</td></tr>
<tr><td colspan="2">0.1% (normatively determined d)</td><td>1.10%</td></tr>
<tr><td colspan="2">(Assumptions: time-consistency of preferences, infinitesimal probability of humanity extinction due to outer source)</td><td></td></tr>
<tr><td colspan="2" rowspan="4">SDR = SMRTP = px = d + eg</td><td>Short-run (up to 30 years)</td><td>SDR = 0.1 + 1.31 * 2.95 = 4%</td><td rowspan="4">5.7% (for investment projects)</td><td>Short-run (up to 30 years)</td><td>SDR = 0.1 + 1.31 * 2.95 = 4%</td></tr>
<tr><td>Long-run (up to 50 years)</td><td>SDR = 0.1 + 1.31 * 2.30 = 3.1%</td><td>Long-run (up to 50 years)</td><td>SDR = 0.1 + 1.31 * 2.30 = 3.1%</td></tr>
<tr><td rowspan="2">Very long-run (more than 50 years: 100, 200 and more)</td><td>Big uncertainty but probably declining in time</td><td rowspan="2">Very long-run (more than 50 years: 100, 200 and more)</td><td rowspan="2">SDR = 0.1 + 1.31 * 0.00 = 0.1%</td></tr>
<tr><td>(Further research needed)</td></tr>
</table>

The EU has determined a separate SDR for policies and a separate one for economic analyses of investment projects (and thus also for public projects). Unlike the EC we, firstly, claim that the SDR determined for public projects should not differ from the one determined for public policies since they are both created for a good of citizens (take into account not only private but also social impacts) and they are both financed from the public financial means (even though in case of projects it does not necessarily be like that but we have defined the public projects here as those that are financed by a great part by public financial means). The only reason why the SDR for public projects and policies might differ is their possible different length of time horizon which results in a different value(s) for the parameter g in the intergenerational SDR determination.

Second, out of the all market determined SDR, to avoid the objections related to the complexity of the shadow price of capital use and a high probability of political manipulation (though the market model, where a distinction between consumption as an immediate benefit and investment as a stream of benefits is made, might be probably the most appropriate out of all), we recommend the one which equals only to the social marginal rate of time preference (SMRTP = p_z). The reason is because taxes constitute almost 90% of the Czech public projects/policies' financing and since taxes crowd out mostly consumption (positive statement), therefore the appropriate SDR should be the rate at which individuals in society are willing to postpone a small amount of current consumption in exchange for additional future consumption and vice versa, at social MRTP or p_z (normative statement).

Our estimate found for the Czech Republic is the SDR of 1.7%, with sensitivity analysis at 2.6%, which is a lower SDR than the ones suggested by the EC (4% for policies and 5.7% for investment projects). This SDR in fact reflects the social time discount rate (or "pure" rate of time preference). And this rate might be applied to such public environmental projects/policies under the following assumptions: We are willing to accept positive reasoning for the normative approach to social discounting, time consistency, for public project/policies with time horizon no longer than 30 years (one generation), zero economic growth-rate.

Third, for the environmental projects/policies with time horizon longer than 30 years (one generation) (in reality most of the environmental projects/policies should fall in this longer time horizon) we should use the optimal growth rate model since it reflects changes in the economic growth rate and intends to reflect preferences of the generations that are not born yet. In this model the social time discount rate (or "pure"

rate of time preference) is one of the three components. We cannot use the market determined estimate of the "pure" rate of time preference but instead a normatively determined one. The reason is nonzero economic growth rate and extremely low probability of humanity extinction due to outer source (two assumptions necessary for the market rate application are not valid). Nor for the very long time horizon the market determined "pure" rate of time preference can be used because the probability of human extinction due to outer source is infinitesimal and, moreover, this rate is not in compliance with the idea of sustainable development (a development that can last forever) since it presumes from the very beginning the development is going to end. Our estimate of the normatively determined "pure" rate of time preference has to therefore be lower than the one obtained from the market and lower than the one of 1.1% estimated by the EC for the Czech Republic. We have argued for the estimate of 0.1% because it reflects equal weight of welfare of all generations (implying the public sector is unbiased concerning current and future generations) and infinitesimal probability of humanity extinction due to outer source.

Fourth, naturally a more detailed research should be done upon the normative choice of the value of the parameter *e* (this work has not be dedicated directly to this parameter). Here we accept the EC's parameter determination based upon the assumption that income tax structures are at least loosely based on the principle of equal absolute sacrifice of satisfaction and thus the extent of progressiveness in the tax structure provides a measure of *e*. The EC's estimate is the value of 1.31%. And, naturally, a further research and further scientific knowledge is needed to derive the value of the parameter *g* (the parameter to which this work also is not directly determined). We claim, however, due to the actual huge uncertainty about the degree of the natural capital substitutability and due to the irreversibility of human actions, it is reasonable to assume time declining value of *g*: for the short-run 2.95%, for the long-run 2.3% and for the very long time horizon we afford assuming the approximately middle possible scenario 0%.

Fifth, thus for the short-run time horizon (up to 30 years), the SDR, applying the normatively determined "pure" rate of time preference of 0.1% (which obviously does not change throughout the time horizon), the estimate of the parameter *g* of 2.95% and of the parameter *e* of 1.31% (which obviously also does not change throughout the time horizon), is 4%. For the long-run time horizon (up to 50 years), the SDR, applying the same values of parameter *e* and *d* and the estimate of the parameter *g* of 2.3%, is 3.1%.

And for the very long-run time horizon (more than 50 years: 100, 200 and more years), the SDR, applying the same vales of *e* and *d* and the approximately middle possible scenario for the parameter *g* of 0%, is 0.1%.

We can observe that we have obtained a time declining SDR over the overall time horizon (despite we suppose a constant SDR for the very long-run time horizon which might be, if we could have assumed less uncertainty and greater scientific knowledge, we would have specified the value of *g* more precisely - the value would have probably also be time declining), the SDR beginning at the value of 4% in the short-run, continuing at the value of 3.1% in the long-run and finishing at the value of 0.1% in the very long-run.

Martin Weitzman (2001), though using different way of the SDR determination, came to not very different findings: For the time horizon of 1-5 years, the SDR of 4%; for the time horizon of 6-25 years, the SDR of 3%; for the time horizon of 26-75 years, the SDR of 2%, for the time horizon 76-300 years, the SDR of 1%; and for the time horizon longer than 300 years, the SDR of 0%. We, however, have a reservation to his way of the SDR determination that is basically based upon the following reasoning. There is a great deal of disagreement concerning the choice of the SDR for the long-term environmental projects. For this reason, Weitzman asks Ph.D.-level economists (despite they do not necessarily have to devote to the problems of social discounting) about their "professionally considered gut feeling". These economists shall have answered to the question of what real exponential SDR should be used to discount the long-term environmental projects. According to the distribution of responses, a probability was assigned to every SDR proposal and the time declining SDR was further derived in the similar matter as explained (even though in a more simplified way) in the section 4.1.3. We identify ourselves with the Heal's critics of Weitzman (2008) who claims that although the Weitzman's result is undoubtedly technically correct, he is not totally certain of its philosophical foundations and implications. If we disagree over the SDR, does it make sense to randomize across all the rates that are suggested (and we add), moreover, when the suggestions are given even though by well-qualified economists but not necessarily by the specialists in the social discounting? Facing these doubts lead us to the conclusion that such an outcome is quite controversial.

Sixth, in this work we have found out that the social time discount rate observable in the market cannot be used for SDR determination for intergenerational public environmental policies/projects (some economists might also have a problem

with its use for one generation public projects/policies due to the simplifying assumption of zero economic growth). So there is no other way than to derive the "pure" rate of time preference in a normative way and therefore there is nothing wrong about such a way of determination for such cases.

Seventh, since the assumption of zero economic growth in the market SDR determination is probably too simplifying and since even the one generation (environmental) public policies/projects should be always be in compliance with the idea of the sustainable development, we suggest the intergenerational model to be used even for one generation (environmental) public projects/policies. This implies use of the normatively determined social time discount rate of 0.1% for all (environmental) public projects/policies. Moreover, as the market determined social time discount rate that was determined from the notion of the most probable source of the public projects/policies' financing (taxes), is ruled out, we can extend the use of our normatively determined social time discount rate from the restrictively defined public projects (those for which a public body places an order and which are financed by a great part from the public financial means) to all projects that take into account not only private but also social impacts (so e.g. also private projects applying for the financial means from the EU Structural Funds, exceeding total expenses of 10 mil CZK, and thus requiring to include also the social impacts of the project). In short, the normatively determined social time discount rate might be used for all types of (not only environmental ones because other types of projects/policies should also always be in compliance with the environmental axis of the sustainable development) economic analyses as defined by the EC.

At the real end we afford to state that the further research in the Czech Republic and the EU (and the developed world as a whole) to determine the most accurate SDR (so especially research in the parameter g determination) and to improve all the steps in the CBA performance has no sense if worldwide actions towards the sustainable development are not taken.

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7. Appendices

7.1. Appendix 1:

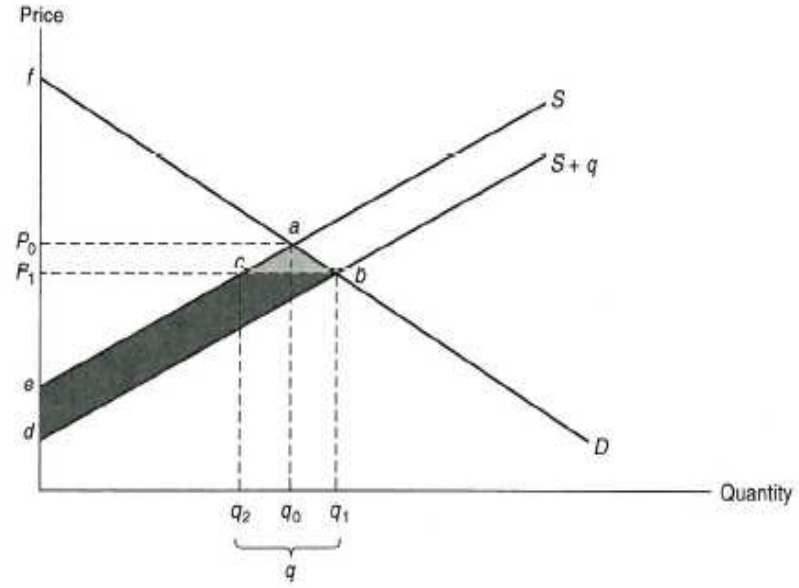
7.1.1. Framework of Known Shape of Demand and Supply Curve

Perfect Competitive Market Framework

To illustrate the logic of monetization under the framework of known shape of supply and demand curve, let's assume conditions of perfect competitive market[60]. Let's consider an example of government's project of deepening a harbor (Boardman, 2006). Let's monetize value of gross benefits on primary markets. This policy results in supply increase of those products that are transported to consumer market via the harbor and/or for which their inputs of production are delivered via the harbor. The deeper harbor allows now larger, more efficient ships floating in and out which results in reduction in transport costs to producers. Thus suppliers can supply profitably the amount of q additional units of a good. The shift of supply curve from S to $S + q$ is depicted in figure 1 below. Thus the perfectly competitive equilibrium shifts from a to b with a new price level P_1. It results in a gain on the side of consumers – consumer surplus increases by the area P_0abP_1. It also results in a gain on the side of producers – producer surplus increases by the area $P_0ae - P_1bd$ that, after cancellation of the common area P_1ce, gives the area $ecbd - P_0acP_1$. Thus the gross gain in social surplus is $ecbd - P_0acP_1 + P_0abP_1$ that is the area $abde$.

[60] The conditions of perfect competitive market are the following: There are so many buyers and sellers in each market that no one can individually affect prices, that buyers and sellers can easily enter and exit from each market, that the goods sold in each market are homogenous (i.e. identical), that there is an absence of transaction costs in buying and selling in each market, that information is perfect, and that private costs and benefits are identical to social costs and benefits (i.e. there are no externalities) (Boardman, 2006).

Figure 1: Measuring Benefits in an Efficient Market



Source: Boardman 2006.

Social cost value (that needs to be added to a policy/project assessment to obtain social net benefit) of a project is not, in many cases, equal only to budgetary outlay required to purchase inputs to undertake the project but rather to opportunity cost as a whole (Boardman, 2006). For example, opportunity cost of government purchase of a parcel of land for a park is the government's budgetary outlay to buy the parcel but also a loss in consumer surplus of private buyers that would have bought the parcel if the government did not.

To be able to fully value the impacts of a project/policy, it is necessary to assess impacts not only in primary markets but, as we have already said, also all impacts in distorted secondary markets (e.g. in the example of harbor deepening: lowered emissions due to lowered road truck transport) and valuing effects in undistorted markets should be exercised with a great caution (Boardman, 2006).

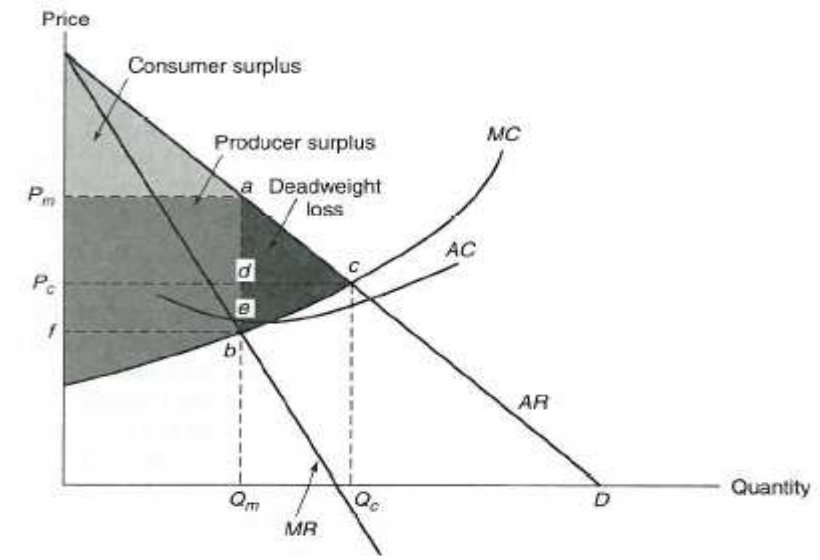
Distorted Market Framework

Under conditions of distorted market framework, unlike perfect competitive market conditions, government's interventions might increase net social benefits because they might correct market or government failures by introducing a more efficient government policy (Boardman, 2006). The net social benefit of a policy/project is monetized in a similar matter like under conditions of perfect

competition market. However, the fact of facing distorted market makes determination of correct social surplus changes and opportunity costs more complicating. Due to present price distortions in inefficient markets, net social benefit is under or overestimated. Therefore, to accurately measure net social benefit, it is necessary to use shadow prices[61] that would prevail in perfect competitive market.

To demonstrate the logic of net social benefits monetization under such framework, let's take an example of a monopolistic production. A monopolist, as being the only firm in the market, faces market sloping downward demand curve depicted in the figure 2 below (Boardman, 2006). Because of this, it also faces downward sloping marginal revenue curve that is below the demand curve. The monopolist maximizes its profit by producing Q_m units where its marginal cost equals its marginal revenue. He/she can, however, charge a higher price P_m that is determined by the demand curve. The monopolistic production results in a gain on the side of the producer - producer surplus increases by the area that begins by the start of marginal cost curve and is further marked out by points P_mab. This production also results in a gain on the side of consumers – consumer surplus increases by the area under demand curve and above the price line. Described like this, it seems that monopolistic production is beneficiary to the society.

Figure 2: Monopoly



Source: Boardman 2006.

[61] Shadow prices are "prices that would prevail in competitive markets" (Pearce, 2006).

However, to assess the net social benefit of monopolistic production fully, we have to assess social cost resulting from it. For this we would need to use shadow price that would prevail in perfect competitive market (Boardman, 2006). It is price P_c that is determined by the point where marginal cost and demand curves intersect and that is lower than P_m. This intersection also determines higher level of output Q_c being supplied. Under this competitive market framework, we gain an additional social surplus determined by the area *abc*. Producer gains additional surplus that is determined below the competitive price line in this segment but in the same time loses greater segment of $P_m adP_c$. This segment is passed to consumers that, moreover, gain an additional surplus that is determined above the competitive price line in the segment *adc*. The fact that producer loses is not viewed as a loss in CBA but rather as a mere transfer because this loss is accrued on the side of consumers. The important is that social surplus as a whole increases by the area *abc* in the perfect competitive framework. That is why, under the present monopolistic framework, the segment *abc* is seen as an opportunity cost because it is foregone. Such a cost that is caused by market moving away from its competitive equilibrium is called deadweight loss. In respect of perfect competition, a monopoly thus results in decrease in net social benefits. That is why a policy that prevents monopoly creation is viewed as a positive one.

7.1.2. Framework of Unknown Shape of Demand and Supply Curve

To demonstrate some of the alternative ways of impacts' monetization, let's use an example of environmental impacts.

Normally environmental goods/services are not traded at all (in this case market for such goods/services does not exist) and if they are traded, the point of intersection of market price and quantity supplied cannot be used as one point of their appropriate supply and demand curve. The reason for this is that in the traditional market this point expresses only a part of the good/service's total economic value[62] considered by

[62] Total economic value is in fact shadow price, which we have introduced earlier. It consists of *use* and *non-use* (or *passive-use)* values. Among the ***use values*** belong *direct* (natural resource extraction – i.e. wood) and *indirect use values* (environmental services of ecosystems - i.e. photosynthesis of a tree). Both these *use values* types can be *present* or *future*. Among the *future use values* belong *option values* (if an individual thinks the good/service will have a use value in the future, he/she gives a value to it) and *quasi-option values* (if an individual thinks the good/service will not have any use value for him/her in the future but he/she gives a value to it because of the nature's right to exist). Among the ***non-use values*** belong *bequest values* (an individual is convinced that the good/service has no value for him/her but gives

environmental economics (Riera, 2005). The value expressed by the conventional market is only direct and present use value of an environmental good/service. Thus as the market intersection observed omits to express a part of the good/service value (in cases where market does not exist, omits the whole value of the good/service), net social benefits (estimated from the derived supply and demand curves) from an environmental policy (i.e. a policy that would lead to conservation of such a good/service or a pollution tax) would be underestimated. There exist, therefore, alternative ways that intend to estimate total economic values of environmental goods/services in order social benefit[63] of policies/projects with substantial environmental impacts (or alternatively, social cost in case of anti-environmental policies/projects or, said in another way, policies/projects not respecting the environment) to be correctly expressed. These methods can be divided in indirect and direct methods.

Indirect Methods or Revealed Preferences

Indirect methods (revealed preferences) use existent markets and substitution or complementation relation between goods/services whose price is well depicted by the traditional market and non-market goods (or bads)/services (i.e. an environmental one) (Riera, 2005). There are various methods inside this group. Let's, however, mention only the two most well known.

The first well known method is **hedonic price method**. It intends to estimate certain environmental values (environmental quality such air pollution or environmental amenities such as aesthetic views) of market goods (e.g. housing) (Riera, 2005). The price of the market goods reflects many characteristics (e.g. number of rooms, proximity to public transport), including the environmental one. If the market goods equal in all their characteristics but the environmental, the environmental value of the goods can be isolated.

The second well known method is **travel cost method**. It intends to estimate environmental values associated with ecosystems or sites that are used for recreation

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a value to it in order others – future generations – to have a right to choose) and *existence values* (an individual is convinced that the good/service will have no value neither for him nor for future generations and still gives a value to it because he/she thinks nature should simply exist). Other sources mention further types of values but those mentioned here are the ones most cited.

[63] Social benefit equals private benefit plus external benefit which is the one that is not expressed in the traditional market.

(Riera, 2005). Due to different distances of the visitors (resulting in different travel costs – price of a market good) and to different numbers of visits the visitors from the different distance zones make we can estimate people's willingness to pay (the recreational value) of the ecosystem or site. This approach is analogous to estimating peoples' willingness to pay for a marketed good based on the quantity demanded at different prices.

Both methods have their own advantages but also a number of limitations[64]. Since these methods infer environmental values based on existing markets, perhaps the biggest deficit is that these methods only depict use values in the estimates. And since we infer the environmental values from the observed behavior, these methods cannot be used to estimate values of those goods (or bads)/services that have not taken place yet (these methods are ex-post methods) which also might serve obstacles in decision-making.

Direct Methods or Stated Preferences

Direct methods (stated preferences) use constructed or hypothetical markets for goods (or bads)/services for which market does not exist at all or for which the market omits to depict their total economic value (Riera, 2005). People are basically asked how much they would agree to pay for avoiding a degradation of the environment (willingness to pay) or, alternatively, how much they would ask as a compensation (willingness to accept compensation) for the degradation[65]. Also, people can be asked to make trade-offs among different alternatives, from which their willingness to pay or willingness to accept compensation can be estimated.

These methods include **contingent valuation method** which is a direct method and **conjoint analysis methods** (contingent ranking, rating, etc.) which are indirect. Both generate welfare estimates of environmental benefits/costs (damages).

[64] For a deeper discussion of these methods and their advantages and limitations we refer the readers to Champ, Boyle, Brown (2003).

[65]To make the analysis easier, one might say, we could ask stakeholders (e.g. experts' or politicians' preferences) rather than to find out public preferences of individuals that have "standing" in order to find out the "social" preference because "stakeholders are those whose interests are affected by the issue or those whose activities strongly affect the issue" (United Nations Center for Human Settlements, 2001) However, we shall rather take into account public preferences. First, it is because the stakeholders dispose of other opportunities, compared to general public, to influence the decision upon the policy/project (e.g. in case of politicians – voting upon the policy/project in parliament, in case of experts - providing theoretical background for CBA) (Pearce, 2006). Second, it is because CBA is in fact a check on decisions made within the political process and as such should reflect public opinion.

Also these methods have their own advantages but also a number of limitations[66]. Among the biggest advantages perhaps rank the ability to depict also non-use values, since these methods are based on hypothetical markets that might reflect this type of values, and the fact that these methods are ex-ante methods – it enables decision-makers to use them also to estimate values of those goods (or bads)/services that have not taken place yet. However, since they are based on surveys, they include a number of biases (e.g. because of the way how the investigator asks the questions, how he/she presents himself/herself) which can lead to misleading estimates.

7.2. Appendix 2:

7.2.1. Distributional Weights' Advocates

The distributional weights might be justified by justice principle – ***Rawls' maximin criterion***. It calls for maximizing the well-being not of the society as a whole but of the least advantaged in the society (Rodriguez, 1981). There are several bases for such an assertion (Boardman, 2006). The first argument for giving to the benefits and costs of the poor higher weight is the danger of social disorder, crime and riots that might evolve under highly unequal distribution of income. Realization of this threat would obviously lead to decrease of overall social welfare. Second argument is that there is a certain income threshold below which no one can live or it saps human dignity to live below it. Thus higher weight to benefits and costs of the poor should be given in policy/project considerations in order the number of individuals living below such a threshold to be as low as possible. Third argument is that some well-off individuals might receive utility by improving the situation of the individuals at the bottom of the income distribution (e.g. charity). And the fourth argument claims that some individuals value greater income equality in and of itself.

From the following argumentation thus results that a monetary unit increase in the income of a low-income person would result in a larger increase in the overall social welfare than would a monetary unit increase in the income of high-income person (Boardman, 2006). This statement would be true even if the marginal utility of income

[66] For a deeper discussion of these methods and their advantages and limitations we refer the readers to Champ, Boyle, Brown (2003).

was not diminishing[67] - if a monetary increase in the income of high and low-income individuals resulted in equal increases in the utilities of these individuals.

Stated algebraically, the statement implies:

$$\Delta SW/\Delta y_l > \Delta SW/\Delta y_h \; if \; \Delta u_l/\Delta y_l > \Delta u_h/\Delta y_h \; or \; \Delta u_l/\Delta y_l = \Delta u_h/\Delta y_h$$

where ΔSW refers to the change in aggregate social welfare, $\Delta SW/\Delta y_l$ is the marginal effect on social welfare of a change in income received by a low-income person, $\Delta SW/\Delta y_h$ is the marginal effect on social welfare of a change in income received by a high-income person, $\Delta u_l/\Delta y_l$ is the marginal private utility of income of a low-income person, and $\Delta u_h/\Delta y_h$ is the marginal private utility of income of a high-income person.

For the advocates of distributional weights, the positive unweighted NPV of a policy/project does not necessarily mean to accept it if it makes income distribution less equal and the other way around, the negative unweighted NPV does not necessarily mean to reject a policy/project if it increases income equality sufficiently (Boardman, 2006).

7.2.2. Distributional Weights' Opponents

Those opposing distributional weights, calling for CBA to be an instrument seeking efficiency criterion only are also backed up by a justice principle, in this case by ***utilitarianism***. It is the idea that the moral worth of an action (policy/project implementation) is determined solely by its contribution to overall utility/social welfare: that is, its contribution to the overall social welfare as summed among all persons. And since the theory suggests that the overall social welfare is maximized in the Pareto-efficient equilibrium[68], CBA should concentrate on Pareto-efficient allocation of public resources. Since Pareto-efficient equilibrium cannot be achieved in practice, CBA should seek a Pareto improvement which is "a reallocation of assets that makes at least one person better off (increase his or her utility) without making anyone else worse off" (Markandya, Perelet, Mason, Taylor, 2001). And since the compensation of losers does not take place in reality, CBA should seek the so called Kaldor-Hicks improvement. It is in fact a Pareto improvement with the distinction of the loosing party(ies) being

[67] Diminishing marginal utility of income is the utility value of a unit change in a poor individual's income is greater than the utility value of the same unit change in income of rich person (Pearce, 2006).
[68] Pareto-efficient equilibrium is an equilibrium in which by a change of allocation of resources you cannot make someone better off without making someone else worse off (Samuelson, 1992).

compensated only hypothetically by the beneficiaries. This criterion provides the basis for the net benefits criterion introduced in the chapter 3.8. The NPV criterion indicates to adopt only policies/projects with positive NPV. Thus winners could potentially compensate losers and still be better off.

There are several justifications for such a justice principle. First, since the overall social welfare is improved, the poor in the society are indirectly helped as the richer societies have greater capability to help their poorest members and if redistribution is a normal good[69], members of society have a greater willingness to help (Boardman, 2006). Second, it is probable that every policy/project realized will have different gainers and losers. In this way the costs and benefits will tend to average out among people so that each individual will realize positive net benefits from the full collection of policies/projects. Third, seeking a Kaldor-Hicks improvement, instead of using distributional weights, means to avoid assigning too much weight to costs and benefits to organized and influential lobby groups which might reduce chances to adopt Pareto-efficient policies/projects. Fourth, even if the decision-makers are dissatisfied with income distribution and desire it more equal, it is better to manage it, at least in theory, through transfers in one single packet (after a large number of efficient enhancing policies have been adopted) than through each particular policy/project in many packages.

7.3. Appendix 3:

7.3.1. Benefit-Cost Ratio

To give an example of such modification of the NPV criterion, imagine circumstances in which a constraint on objective function exists and the alternatives are not mutually exclusive. A modification of the NPV criterion, as have been stated, is needed since it will lead to higher efficiency. Such a modification states that the combination of alternatives that yields the highest aggregate net benefits and that complies with the specific constraint(s) should be chosen (Boardman, 2006).

If you look at the table 2 below, the project that gives the highest net benefits, under the assumption of all projects being mutually exclusive, is the project X with the NPV = 100 (Pearce, 2006). However, imagine there is a budgetary constraint of 100, the

[69] Normal good is any good for which demand increases when income increases and falls when income decreases but price remains constant (e.g. clothes) (Samuleson, 1992)

costs of the projects in the table are incurred all in that year for which the constraint exists and the projects are not mutually exclusive. In such a situation, according to the modified NPV criterion, projects Z and Y should be chosen simultaneously since they bear the highest aggregate net benefit of 130 (60 + 70) for the same cost of 100. Sometimes ranking the projects by the benefit-cost ration PV(B)/PV(C) is used. Such a decision rule secures the correct combinations of projects, namely Z and Y, in this case. The general decision rule of adoption or suspension under this ratio is the following: To accept every policy/project for which PV(B)/PV(C) > 1, in case of more alternatives, to rank them by the ratio PV(B)/PV(C), and in case of mutually exclusive projects, to choose the alternative with the highest benefit-cost ratio.

Table 2

Project	PV (C)	PV (B)	NPV	PV(B)/PV(C)
X	100	200	100	2.0
Y	50	110	60	2.2
Z	50	120	70	2.4

Source: Pearce, 2006.

However, the benefit-cost ratio place often biases into the decision of the most efficient policy(ies)/project(s). First of them is that the ratio favors policies/projects that involve substantially lower costs than the others even though those others yield higher net benefits. For this reason in our example in the table 2 the ratio would choose the least efficient alternative Z if they were mutually exclusive. Second, the ratio is sensitive to whether a negative WTP or WTA is subtracted from benefits or added to costs that obviously makes a difference on the resulting value of the ratio. The NPV criterion does not dispose of such sensitivity and thus is not a subject of such manipulation. For these two reasons, there is a recommendation for analysts to avoid using the cost-benefit ratio and rely fully on the NPV criterion and its modifications for special cases.

7.3.2. Internal Rate of Return

Since discount rate belongs to the most controversial parameters in CBA, the analysts frequently conduct sensitivity analysis (for more details, please, refer to the

next section 3.11.) with respect to this parameter. To perform sensitivity analysis means to vary each parameter about which there is uncertainty and recalculate the NPV (Boardman, 2006). If the NPV sign states positive/negative under all plausible values of the parameter, we can have greater confidence about recommendation – adoption/suspension of the policy/project considered.

For these purposes, for discount rate parameter, another decision rule – internal rate of return (IRR) - is used. It is the discount rate at which the NPV is zero (Boardman, 2006). This rule can be applied only to situations in which only one alternative to the status quo is considered. The decision rule is then the following: If the alternative's IRR computed is greater than the appropriate social discount rate(s) determined, then the analyst should adopt the policy/project since he/she can conclude with high confidence that the NPV will be positive; and if the alternative's IRR computed is less than the appropriate social discount rate(s) determined, then the analyst should not adopt the policy/project since he/she can conclude with high confidence that the NPV will be negative.

However, like the benefit-cost ration, neither the internal rate of return can play the same universal role of CBA decision rule as the NPV criterion does for various reasons. Firstly, in the alternatives where the annual net benefits change more than once from positive to negative (or vice versa) during the discounting period, the IRR cannot be used because there will be more than one discount rate at which the NPV is zero (Boardman, 2006). Secondly, the IRR criterion cannot be used in situations of selection of one alternative out of more mutually exclusive alternatives. Imagine two alternatives X and Y each with a life of 10 years (costs are incurred in the first period of the project life and benefits enjoyed from the next period until the end of the project).

Table 3

Project	Cost	Benefit	IRR	NPV at 8%
X	2	0.40	14%	3.39
Y	4	0.75	12%	7.11

Source: Pearce, 2006.

From the table 3 we can see that under the IRR rule project X would be selected since the project X's IRR is greater than the one of the Y project relative to the determined social discount rate of 8%. However, if we chose project X ahead of Y, we would waste

3.72 units of net benefits. The IRR rule disposes of the same weakness as the benefit-cost ratio does. Since the percentage is in fact ratio, the IRR favors policies/projects that involve substantially lower costs than the others even though those others yield higher net benefits. There is a modification of the IRR rule for mutually exclusive alternatives that removes this shortcoming. However, if more than two alternatives are present, using such a modification would require rather a laborious task.

For the reasons mentioned above, the primacy of the NPV criterion as CBA decision rule is secured, although in case of one alternative with a unique IRR, the IRR conveys to analysts useful information about how sensitive the results are to the discount rate and thus the analysts are able to recommend a decision upon adoption or suspension with higher certainty.