Inter-American Development Bank

Time goes by: recent developments on the theory and practice of the discount rate

Infrastructure and Environment Sector

Javier Campos
Tomás Serebrisky
Ancor Suárez-Alemán

TECHNICAL NOTE Nº IDB-TN-861

September 2015

Time goes by: recent developments on the theory and practice of the discount rate

Javier Campos
Tomás Serebrisky
Ancor Suárez-Alemán

September 2015

IDB
Inter-American Development Bank

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library
Campos, Javier.
Time goes by: recent developments on the theory and practice of the discount rate / Javier Campos, Tomás Serebrisky, Ancor Suárez-Alemán.
p. cm. — (IDB Technical Note ; 861)
1. Social policy—Cost effectiveness. I. Serebrisky, Tomás. II. Suárez-Alemán, Ancor. III. Inter-American Development Bank. Infrastructure and Environment Sector. IV. Title. V. Series.
IDB-TN-861

http://www.iadb.org

Corresponding author: Tomás Serebrisky | tserebrisky@iadb.org

Table of contents

List of Tables

List of Figures

Executive summary

The concept of a "discount rate" is central to any economic decision involving the use of resources in different periods of time. This is particularly relevant in the evaluation of policies and public investment projects in developing countries by both governments and international institutions, where the social consequences of incorrect or suboptimal decisions may be very significant for its long-term development. Although economic theory suggests that a project's discount rate should reflect the competitive, risk-adjusted opportunity cost of funding the project, there is no consensus on how to measure this cost. Furthermore, since many countries in Latin America and elsewhere have recently improved their macroeconomic fundamentals, and – subsequently – reduced their costs of accessing to credit, it seems reasonable to review the criteria to determine their required social discount rate (*SDR*). In fact, during the last decades, the academic debate on this topic has been passionate, but economists have not yet reached a compromise on how to finally close it. This document critically reviews the existing literature from the 1950s to 2015 to categorize the main contributions in this field, to provide an adequate context to the existing controversies and to jump from the theory to real world to see what countries and international institutions are doing with respect to the social discount rate.

Approaches to choosing *SDR* are generally placed into two categories: the *descriptive approach* and the *prescriptive approach*. The descriptive approach is often justified on Pareto efficiency grounds, using a description of how society discounts instead of having analysts impose their own discounting views on society (using equity considerations). Authors in this approach favor the use of a fixed or constant exponential SDR, calculated according to one of three dominant methodologies: the marginal rate of time preference (which represents the view of the consumers), the social cost of capital (representing the investors' positions), or a weighted average of both (as advocated by Harberger). Alternatively, the prescriptions concern who has standing (i.e. who is included) in society, how the views of these individuals are measured, and how the measurements are aggregated. Departing from hyperbolic discounting and social experiments, authors on this current tend to favor a declining *SDR* so as to give more relevance to future values, which may be relevant for environmental and other (very) long-term projects. There is no specific methodology for calculating the social discount rate thus becoming a complementary (rather than a substitute) of the descriptive approach.

From an empirical point of view, the review of the existing evidence and current practices around the world confirms that there are significant differences in the underlying *SDR* methodologies, although – in most cases – a single, constant discount rate is still widely recommended for project evaluation. International institutions – such as The World Bank, the Inter-American Development Bank or the Asian Development Bank – also use an *administrative*

constant rate in the range of 10-12%, not always with adequate background justification. In general, developed countries tend to apply lower rates (3-7%) than developing countries (8-15%), although in most cases these rates have been reduced in recent years.

It is possible that these variations do not only reflect different theoretical approaches, but also differences in the perceived marginal social opportunity cost of public funds that the *SDR* tries to measure in order to ensure efficient allocation of resources, or differences in the extent to which the issue of intergenerational equity is considered. However, there is no enough detailed evidence on this issue and it demands more research. In general, there are strong policy implications from the findings of this work. A low discount rate policy will help propel a large and growing economy further while a high discount rate policy will cushion a no growth or declining economy. With the steady increase in the physical cost of extracting natural resources, steady economic growth has become increasingly difficult. For example, in such conditions, a gradual increase of discount rate would help stabilize economic outputs, whereas a low discount rate policy would possibly generate wide gyration of social systems that we have witnessed in the recent years. Choosing the appropriate social discount rate seems still central in the economic analysis.

JEL Codes: D60; D61; H43.
Keywords: social discount rate; cost-benefit analysis.

1. Introduction

In a hypothetical world without *time,* everything would be instantaneous.[1] There would be no past, no present and no future. Having (or not) something 'now' or 'later' would be totally indifferent for everyone. Any reward or punishment could be indefinitely postponed and incentives to make decisions or to act (or not) in a given direction would be extremely weak. Fortunately, such a dismal and boring world is not the one we live in, and *time* makes things different. Individuals do distinguish and have preferences over present wealth versus future or past wealth, and the same can be said about consumption, investments, payments, benefits, revenues, costs, etc. Time has an economic meaning because individuals have preferences about when do they want to receive their rewards and punishments. In fact, most individuals exhibit some natural degree of impatience/patience and most tend to think 'better now than later' with respect to positive outcomes, and just the opposite with regard to negative ones. Thus, to make intertemporal comparisons it is necessary to take into account 'a compensation for waiting' that is gained when one translates values from present to future (compounding) or foregone when future values are translated into present ones (discounting).

The use of discounting (or compounding) techniques in trade and commercial agreements dates back at least as far as the Old Babylonian period (c. 1800-1600 B.C.) in Mesopotamia, although its generalization did not start until the dissemination of the works of Simon Stevin (1548-1620), a Dutch mathematician and accountant who set the basis of modern financial calculus **(Parker, 1968)**. The early economists and social philosophers of the XVIII century (Adam Smith or David Hume, among others)[2] started to worry about the consistency of preferences over time and how to make reasonable comparisons not only at the individual level, but also with respect to aggregate decisions involving government projects and policies. In principle, the fundamentals seemed unquestionable: the idea of valuing time was obviously associated to the key concept of opportunity cost. Time was considered a resource – a valuable one – that could be used by the society in a similar way to labor or capital. Therefore, it had a value, and it was related to the best available alternatives missed when selecting a particular policy or project.

However, finding this value has resulted much more controversial, due both to the very meaning of the 'opportunity cost of time', and to the nature of public decisions, which often

---

[1] Literally: "something new at every instant or moment", from Medieval Latin *instant* (= present) and the Greek particle *neo* (= new).

[2] The issue of intertemporal analysis was recurrent in the works of many other classical economists such as Malthus, Jevons, Marshall or Pareto. See **Palacios-Huerta (2003)** for details.

involve ethical and political considerations. From the point of view of private investors, determining the adequate 'price of time' to be used for discounting intertemporal flows of benefits and costs in a project is relatively easy: this price should reflect the opportunity cost of the capital (invested on that particular project), taking into account the existence of potential distortions with regard to the origin of the funds and the structure of the project (subsidies and taxes, uncertainty about the future and the subsequent risks, etc.). On the other hand, the *social* discount rate (*SDR*) should reflect the rate at which a (large and heterogeneous) group of individuals is willing to sacrifice present and future benefits and costs (measured for instance in terms of wealth or consumption). Therefore, in addition to the usual markets distortions, aggregate preferences over time should play now a significant role and the result could (and generally does) differ from the *private* discount rate **(Harberger, 1976)**.

Government decisions may generally involve not only selecting whether (or when) a particular project or policy should be carried out, but also the ranking of alternative projects. Cost-Benefit Analysis (*CBA*) and other related tools have increasingly become a crucial element for policy evaluation involving intertemporal flows **(Priemus *et al.*, 2008)**. However, the discounting procedure itself it is not necessarily the same for private and social projects. The *SDR* has usually adopted the form of a fixed or constant rate, implemented through exponential discounting, with the implicit consequence that the future becomes less valuable as time passes by. As an alternative, the use of time-varying (declining) rates or other forms of hyperbolic discounting has been advocated in many concerned forums for projects or sectors involving environmental or (very) long-term effects **(Lind, 1982)**.

In fact, and with respect to the difficulty of defining an *appropriate* social discount rate, a vast majority of government projects and policies – transport infrastructure, hospitals, schools, energy policies, etc. – involve (large) investments at their beginning whereas benefits are received (in the best cases) only after several months or years (sometimes, decades). In other cases, they also imply commitments in terms of repair or maintenance (e.g., roads, buildings) or even disposal costs (e.g., nuclear waste) that go well beyond the living generation. Uncertainty about future and a natural desire to claim noticeable results within the current political cycle tend to create a trade-off in *CBA* between valuing the future in terms of short-term efficiency (assigning the current resources in the best possible way as perceived today) or long-term equity (in intergenerational terms, increasing the weight attributed to the future), which depends on the choice of the *SDR*.

All these ideas have been explicitly present in the economic debate for decades and persist as critical in many areas of public policy. Since 1950, more than 150 influential papers and books[3] have been published on the specific question of what is the optimal (social) discount rate to use in evaluating government projects, but the debate remains unsolved and, although an academic consensus seems still distant, a number of key ideas on fundamentals, methodologies and procedures have progressively emerged. The question is particularly relevant nowadays, when governments are increasingly questioned about their use of (scarce) public funds and when intertemporal issues – the environmental debate – are gaining momentum in the political agenda. In the case of developing countries, and especially in the Latin American and Caribbean region, many of them have greatly improved their macroeconomic situation and fiscal position, and – as a result – their costs of accessing to credit have been reduced, making it reasonable to investigate whether or not to insert flexibility mechanisms and criteria to the required social discount rates.

In this context, the objective of this document is to discuss these ideas by conducting a critical review of the literature of social discount rates from the central point of view of its usefulness for policy evaluation. To achieve this objective, **Section 2** will provide after this introduction a quick review – with theory and short examples – of the basic mechanics and economics underlying individual and social discounting and the main issues associated to them. **Section 3** will focus – following a chronological approach – on the large debate in the economic literature about the principles that should inform the practical calculation of *SDR*, centering the discussion on the merits of selecting a single constant *SDR*. **Section 4** reviews the most recent contributions to this debate, focusing on the ideas that advocate the use of a variable *SDR* for particular sectors and/or (very) long-term projects. In **Section 5,** we will review the international evidence on what countries and international institutions actually do on this issue and present the methodologies and recommended values currently in use. Finally, **Section 6** summarizes – as a conclusion – the merits of setting a constant vs. a variable social discount rate.

2. Individual and social discounting: some basic principles

Discounting is associated to the existence of a *natural* time preference for the present over the future, which can be ultimately related to the idea that we know (or care) less about our future than we know (or care) about our present.[4] If you have $1 today but are asked to wait one year

---

[3] This estimated figure corresponds to the surveyed scientific literature in English, including the leading economic journals and most acknowledged editorials. The references section provides a summary list of these documents.

[4] The economic, philosophical and even psychological foundations of this premise have been long discussed in the literature **(Broome, 1994)**, even with opposing views **(Cowen and Parfit, 1992)**. For an extensive and critical review

to spend it you will surely demand a compensation for foregoing the potential happiness you cannot enjoy today. On the contrary, if you are promised $1 to be received in a year but demand it today, you will probably have to accept a penalty as a punishment to your impatience. These effects are multiplicative when you consider multiple years, since they affect not only to the original $1, but also to the corresponding compensations or penalties, which are also proportionally increased or reduced. However, the implications of discounting go well beyond these simple rules, not only in mathematical but also in economic terms, particularly when we move from one individual's preferences to the society's aggregated ones.

2.1. The magic of discounting: comparing present and future values

In formal terms suppose, as described above, that the *present value* (*PV*) of your wealth (at $t = 0$) is one unit. According to the previous reasoning, only if you receive an adequate compensation (X) you would be willing to wait until a future period ($t = 1$). The basic principle of financial equivalence states then that *future value* is $FV = 1\cdot(1 + X) = PV\cdot(1 + X)$, which in turns leads to the simplest expression of discounting:

$$PV = \frac{FV}{(1+X)} = \delta \cdot FV \ , \qquad \textbf{(1)}$$

where X is the *discount rate* and δ is the *discount factor*. In general, $X > 0$ and $\delta < 1$, and the larger is the discount rate, the lower is the weight attached to the future (measured through the discount factor) and vice versa.[5]

The discounting expression **(1)** above can be easily extended to (waiting) more time (say T years) just by taking into account the corresponding compensations or discount rates of each of these years (X_t):

$$PV = \frac{FV}{(1+X_1)\cdot(1+X_2)\cdot\ldots\cdot(1+X_T)} = \delta_1 \cdot \delta_2 \cdot \ldots \cdot \delta_T \cdot FV \ ,$$

which – for the particular case where the discount rate is always the same – simply becomes the well-known exponential expression:

---

of time preferences, see for example, **Frederick *et al.* (2002)**. More recently, **Chen (2012)** argues that there is a relationship between discounting and physical and biological principles.

[5] Discount rates are often expressed as percentages, whereas discount factors as fractions. Note that a negative discount rate (with $X < 0$, $\delta > 1$) would imply a (rare) more optimistic view of the future than the present. A zero discount rate (with $X = 0$, $\delta = 1$) would apparently imply a time neutrality, but in an economic context of changing consumption patterns, uncertainty, inflation, etc. this assumption is also unreasonable **(Harvey, 1994)**.

$$PV = \frac{FV}{(1+X)^T} = \delta^T \cdot FV \ . \quad \textbf{(2)}$$

Again, note that the discount factor, which is a function of *X* and *T*, δ = δ (*X*, *T*) does not only attach a lower weight to the future, but also that this weight declines with *T* as showed in **Table 1**.

Table 1. Present value of 1 unit to be received in *T* years with a discount rate of *X*%

	T **= 1**	***T*** **= 5**	***T*** **= 10**	***T*** **= 50**	***T*** **= 100**	***T*** **= 500**
X **= 1%**	0.99010	0.95147	0.90529	0.60804	0.36971	0.00691
X **= 5%**	0.95238	0.78353	0.61391	0.61391	0.00760	0.00000
X **= 10%**	0.90909	0.62092	0.38554	0.00852	0.00007	0.00000
X **= 25%**	0.80000	0.32768	0.10737	0.00001	0.00000	0.00000
X **= 50%**	0.66667	0.13169	0.01734	0.00000	0.00000	0.00000
X **= 100%**	0.50000	0.03125	0.00098	0.00000	0.00000	0.00000

For example, at a discount rate of 1% the present value of 1 unit to be received at *T* = 1 is 0.99010, but if the time span is multiplied by 10 (*T* = 10) the same *PV* is reduced by 8.6%; when *T* = 50 the reduction is just a 38.6%, and it is 99.3% when *T* = 500. This pattern of *exponential* decline is intensified for higher values of *X* and confirms not only that the future is less and less relevant as time passes by, but also that the 'relevance of that irrelevance' is not constant: it is more important when the future is closer.[6]

2.2. Cost-benefit analysis and the social rate of discount

One of the most extended uses of time discounting in economics is found in the field of cost-benefit analysis (*CBA*). In this area, a project can be broadly defined as a flow of benefits (B_t) and costs (C_t) that accrue over several periods (from *t* = 0 to *t* = *T*), whose *net* present value (*NPV*) encompasses into a single number all the future characteristics of the project:[7]

---

[6] Note for example that, in **Table 1**, with a rate of 5% the *PV* of 1 unit is almost zero after 500 years. With 10% it requires only 100 years, 50 years with *X* = 25% and so on.

[7] As discussed below, the *NPV* is not the only feasible decision criterion in *CBA*. A large number of authors favor instead the use of the *Internal Rate of Return* (*IRR*), that is, the value of *X* that solves the equation *NPV*(*X*) = 0 in **(3)**. For private investors, a project that yields an *IRR* higher than the opportunity cost of capital is clearly acceptable; for public projects, the answer is not so clear. **Osborne (2010)** summarizes the main features of this debate, which has also received contributions from **Promislow and Spring (1994)** or **Hartman and Schafrick (2004)**. Other

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+X)^t} = \sum_{t=0}^{T} \delta^t \cdot (B_t - C_t) \; . \qquad \textbf{(3)}$$

Expression **(3)** can then be used indistinctly to decide whether to build a factory, a new hospital or to introduce a new regulation but whereas private projects can be easily defined in pure financial terms, government projects generally involve decisions that affect future consumption and social welfare. In both cases, if all the relevant benefits and costs have been *adequately measured* and that the discount rate *X* reflects the true *opportunity costs* associated to waiting, a project with a *NPV* > 0 is, in principle, worthwhile and leads to a Pareto-improving resource allocation.[8]

These two ideas – measurement of benefits and costs and the choice of the discount rate – are crucial for the validity of the *NPV* to perform intertemporal comparisons. Its underlying assumptions and simplifications are relevant to make final decisions about to proceed or not with a particular proposal or to rank alternative projects in a context of limited funding.

With respect to measurement, a cost-benefit analysis of a government project generally focuses on the efficiency effects of a change, aiming at calculating the net value of the gains and losses for all the concerned people. It is based on the willingness to pay: finding how many dollars individuals would pay (if necessary) to obtain (or avoid) a change, measures how much it is worth to them. The amount could be positive or negative, depending on whether the change makes them better or worse off. Summing all these amounts gives the society's total willingness to pay for the change. If the sum is positive, the benefits exceed the costs.

Note that this procedure separates resource allocation from distribution effects (that is, efficiency from equity) but that does not mean distributional considerations are unimportant or should be neglected. It means that they should be brought into account as a separate part of the overall analysis of the policy proposal in question. This efficiency criterion can be extended

---

authors, notably, **Ramsey (1969)** or **Seagraves (1970)**, have even preferred the *IRR* to the *NPV* criterion as a mechanism to escape from the *SDR* discussion (see **Section 3**). Equity considerations and even practical issues (such as the credit-rating concerns about public debt) have been also introduced into this debate (**Levy and Pauzner, 2014**).

[8] The use of *CBA* from a social viewpoint is not as straightforward as in the private case. Projects should be defined in incremental terms, as compared to a baseline case that should include the 'do-nothing' option or the postponement of a given action. In this context, identifying the costs and benefits of the project, involves comparing outcomes that occur with the proposed change to outcomes without the change. Sometimes, analysts can measure the value people place on these by observing market tradeoffs, but this is not always the case and indirect estimations are used. For a more detailed discussion on *CBA* principles (out of the scope of this document), see **Layard and Glaister (1996)**, **Boadway (2006)**, **Boardman *et al.* (2006)**, or **de Rus (2010)**.

to the case where costs and benefits occur over time by using the relevant (social) discount rate. According to the reasoning discussed at the beginning of this section, the social discount rate (*SDR*) should reflect the 'opportunity costs' of waiting for the society as a whole, that is, the compensation (*X*) for the forgone benefits of the displaced resources from alternative uses that the society (the government) decides to invest today on a particular project or policy. When the *SDR* is correctly defined, a positive net present value would certainly indicate that the project increases efficiency or raises wealth: it produces enough benefits to fully compensate all individuals (even although this compensation can be just theoretical).[9]

The relevance of the social rate of discount arises from two sources. The first one is related to the time profile of the projects and the mechanics of discounting as derived from expressions **(2)** and **(3)** above. Thus, when the costs are borne in a different time frame than the benefits, the net present value of any project is crucially determined by the chosen discount rate. As showed in **Table 2**, a higher discount rate favors projects with benefits that accrue earlier (*Project C*) whereas it tends to penalize those projects whose costs are higher at early years and benefits mostly arise in the long run (*Project A*). Without discounting, the sum of benefits and costs would be very similar in all three cases.

Table 2. NPV of projects with different time profiles and discount rates

	$B_0 - C_0$	$B_1 - C_1$	$B_2 - C_2$	$B_3 - C_3$	$B_4 - C_4$	$B_5 - C_5$	NPV (X = 1%)	NPV (X = 10%)
Project A	-100	0	0	20	20	100	**33.7**	**-9.2**
Project B	-100	25	25	25	25	30	**26.1**	**-2.1**
Project C	-100	130	0	0	0	0	**28.7**	**18.2**

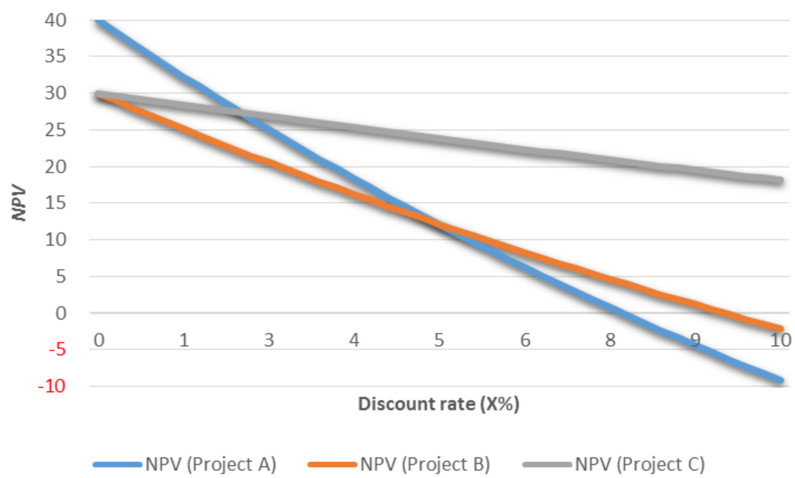
Again, this is a formal feature associated to the use of exponential discounting. In general, the discount factor associated to each period can be considered as an *exponential function*, with a declining slope, represented by the mathematical expression

$$\delta(X,t) = \exp\left[-\int_0^t X(\tau)d\tau\right]. \quad \textbf{(4)}$$

[9] This is the so-called 'Kaldor-Hicks criterion' **(Kaldor, 1939)**, which provides political support for *CBA* in cases where benefits and costs are not borne by the same social groups. In these cases, fairer procedures (e.g. a voting) could probably paralyze or reject a valuable project **(Johansson, 1993)**.

This expression simplifies into $\delta(X, t) = \exp[-X \cdot t]$ when the discount rate is constant, and finally into the more usual $\delta(X, t) = (1 + X)^{-t}$, when time is defined in discrete intervals instead of continuous ones. The usage of exponential discount factors implies that the implicit valuation attached to future events is lower than the value of present events. In fact, this intertemporal weight tends to zero as t increases (provided that $X > 0$) and this is not neutral in project evaluation. **Figure 1** confirms that the ranking of *Projects A*, *B* and *C* in terms of their corresponding *NPV*s may change with the choice of the discount factor: *Project A* is preferred over *Project C* if $X < 3\%$ (approximately), and over *Project B* if $X < 5\%$.[10] Thus, the profitability of a project depends not only on the magnitude of its benefits and costs, but also on when they occur.

Figure 1. Exponential discounting: NPV as a function of the discount rate



Finally, the second and probably more controversial source of relevance for the social rate of discount in *CBA* lies in its very economic meaning. Even if we could agree on focusing just on a single efficiency-based social discount rate, there would remain plenty of room for disagreement. Complications do not only include the valuation of benefits and costs, but also the effects of capital taxes, market imperfections or uncertainty about the future. In general, when government decisions affect the consumption pattern of future as well as present generations, the relevant issue is how to compare these different generations' utilities. Nevertheless, such a comparison clearly resides in the realm of ethical value judgments, and the discipline of economics has very little to say as to the 'correct' weighting of

[10] **Figure 1** also illustrates the calculation of the internal rate of return (see **Note 7**). For *Project A*, $NPV = 0$ if $X = 8\%$. Therefore, if the 'opportunity costs' associated to this project are less than 8% (its *IRR*), it is a worthwhile option for the society (or for a private investor).

intergenerational utilities. Therefore, when equity considerations are added, not only the basic principles but also even the mechanisms of exponential discount may be subject to criticism. In fact, the *true* social discount rate depends on parameters that little is known about, or that are difficult to estimate, and reasonable people can always make different judgments about them (**Zuber and Asheim, 2012**). The theory is far ahead of our empirical knowledge, as we will now review in the following sections.

3. A constant social discount rate: a descriptive review

In general, two main types of discount rates have been advocated in the economic literature: the *social opportunity cost* and the *social time preference*. The first one derives directly from the efficiency criterion presented in **Section 2**, and is a measure of the value to the society of the next best alternative use to which funds employed in a public project might otherwise have been put. In a perfectly competitive world, the opportunity cost of these funds could be represented by the market interest rate; but the distortions existing in real markets suggest that a simple rate of return cannot always measure the opportunity costs of public funds. The social time preference also stems from the efficiency criterion, but changes the focus towards the ultimate recipients of the policies: the individuals (considered as consumers). The social time preference is a normative function that intends to reflect the society's evaluation of the relative desirability of consumption at different points in time.

Some authors label the analysis of these efficiency-based social discount rates as the *descriptive approach*, and instead argue for a *prescriptive approach* which tends to favors equity over efficiency, especially when considering policies that affect future generations. The descriptive versus prescriptive debate has also been described as the 'positivists' versus the 'ethicists' and remains unsolved **(Baum, 2009)**. This section focuses on the first one whereas **Section 4** discusses in more detail the second.

3.1. A descriptive theory of the social rate of discount

Received economic theory provides several undisputed postulates about what a social discount rate *should* be. It usually departs from the economic analysis of individuals' intertemporal choices, where the compensation an individual requires in excess of a unit of future consumption (x_1) in exchange for giving up a unit of consumption today (x_0) is called the *marginal rate of time preference* (ξ). Therefore, the individual is indifferent between one unit of x_0 and $(1 + \xi)$ of x_1. However, (capital) markets compensate the individual for his foregone consumption (in the form of savings) with a return (in the form of an interest rate, i) that does not necessarily coincides with ξ. There is a third rate in the analysis of intertemporal decisions:

the marginal productivity of capital, *r*, which indicates what the individual receives as a return if he invests one unit of his savings on productive projects.

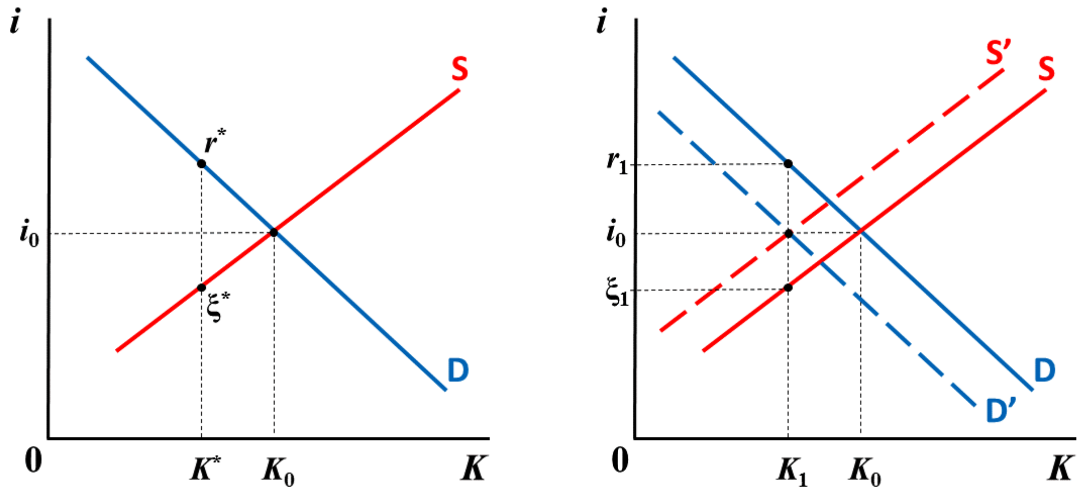
Leaving aside the existence of distortions such as taxes or uncertainty, if $r > i$ then investing in a project is obviously attractive because it yields higher returns than putting the money in the bank. The same is true if all the available projects are ordered according to their profitability, from highest to lowest. The individual will then undertake all those that satisfy the $r > i$ condition until he runs out of funds. An individual who allocates his funds according to this criterion maximizes the present value of his wealth, and once the *NPV* is the maximum possible, he makes his consumption choices present and future according to his marginal rate of time preference. If $\xi < i$ he will lend his savings to the bank, whereas if $\xi > i$ he will borrow. The equilibrium condition for individual intertemporal decisions in a world where capital markets are not subject to restrictions is then given by

$$r = i = \xi \, . \qquad \textbf{(5)}$$

Expression **(5)** also holds for social decisions in a world without distortions. The reason is that most government investment projects or public policies involve compromising public funds obtained from the private sector. The opportunity cost of these funds is then the same as described above: if the money comes from taxpayers, individuals have given up consumption or investment, which was left without funding because of its transfer to the public sector.

The left panel of **Figure 2** represents the capital market in an economy without distortions. The interest rate *i* is the opportunity cost of capital (*K*) available for project financing. The demand curve *D* represents all the investment opportunities ordered according to the declining marginal productivity of capital (as the interest rate falls more projects turn out to be profitable), whereas the supply of funds (*S*) increases with the interest rate (since individuals increase their savings, substituting present consumption by future consumption).

Figure 2. The social discount rate and the capital markets



Note that the value of S at the interest rate i_0 is also the marginal rate of time preference and, therefore, at the equilibrium $r = i = \xi$. What happens when this condition does not hold (for example, when $K^* < K_0$)? In this case, the marginal rate of time preference is less than the marginal rate of return on capital ($\xi^* < r^*$) and there some projects that yield higher returns than those required by lenders to give up present consumption. It is then socially desirable to transfer funds from lenders to investors until a new equilibrium is reached. The same occurs, in the opposite direction, when $\xi^* > r^*$.

The right panel of **Figure 2** finally represents a capital market with distortions caused (for example) by taxes on savings and corporate profits. The supply curve shifts upwards (S^*) and the demand function shifts downwards (D^*), both in the amount of the unit tax, which is assumed to be constant. The new equilibrium interest rate can be equal to, greater than or less than the one in the market without distortions, depending on the elasticities (although we keep it as i_0 for the sake of simplicity). The new amount of total investment (K_1) is clearly lower than K_0 because of the higher costs of borrowing and the lower (after tax) return on investment. In this case the equilibrium condition **(5)** no longer holds, $r \neq i \neq \xi$,and we must decide which of the three rates – the interest, the marginal rate of return or the rate of time preference – is the adequate social discount rate.

The answer prescribed by economic theory seems again straightforward. If the project is financed with consumers' savings, the social discount rate is the marginal rate of time preference (ξ_1), lower than the market interest rate. On the contrary, if the project is financed with funds displaced from private investments, we should use the marginal rate of return on capital ($r_1 > i_0$) as the social discount rate. Although these recommendations seem fairly simple, they are just the beginning of a long-standing controversy, as it will be showed in the following section.

3.2. The descriptive approach in the literature

The issue of the optimal discount rate to use in evaluating government projects is one that has been debated in the economics literature since its early origins as a social science (**Parker, 1968**). As described before, two main theoretical perspectives on the social rate of discount have emerged from contemporary economic doctrine: one focusing on the value of the private investment displaced by governmental programs and the other focusing on the relative preferences of individual citizens and consumers for current versus future income.

a. The earlier contributions

Although both perspectives coexisted for many years in an uneasy relationship with neither able to achieve dominance, until the end of the 1950s, most theoretical and empirical papers seemed to slightly favor the social opportunity costs approach, as it was more clearly connected to the simplest principles of economic theory. It was also best suited for empirical work and was undoubtedly easier to apply (using as reference the rate of interest determined at private capital markets) **(Robinson, 1990)**. However, the increasing number of large government projects in the US – particularly in connection with the water sector – brought the issue to the frontline of the political and social debate (**Eckstein, 1957, 1958, 1961**; **Steiner, 1959**; **Hirshleifer *et al*., 1960**) and more critical views appeared.[11]

In fact, as the literature developed in the following years, the opportunity cost view was gradually undermined by developments in the theory of optimal economic growth. The connection between social discount rates with earlier studies on the optimal rate of saving for a society became more apparent, and the roots of the problem stretched back at least as far as the pioneering work of F. **Ramsey (1928)**. In the early 1960s, papers by **Sen (1961)**, **Marglin (1963a, 1963b, 1963c)** and **Tullock (1964)** revived the Ramsey argument that "the rate of interest determined in an atomistic competitive market need (not) have any normative significance in the planning of collective investment since it does not reflect the same preferences".

---

[11] Several official committees commissioned studies on this issue, but the gap between economists' recommendations and government actions did not close, as explicitly stated in the hearings of the *Joint Economic Committee* of the United States Congress in the summer of 1968 **(Robinson, 1990)**. For the US economy, this was a crucial issue, since the participation of public investment on GDP grew at two-digit figures during these decades.

Arrow (1966) specifically formulated the problem of choice of the social rate of discount as one of determining the optimal growth path for an economy, an approach that has been followed (explicitly or not) in most of the formal literature since that time. He noted that the displacement of private investment in one year also displaces the investment and consumption in future years that would have been financed by the returns on the initial displaced investment. Conversely, the returns to public investments ultimately accrue to private citizens as consumers or entrepreneurs and hence finance future higher levels of consumption and private investment than would have been possible absent the initial public investment. In order to evaluate a particular project adequately – Arrow claimed – one needs to evaluate the whole stream of future consequences for the private sector and not just the immediate displacement of private investment.

This argument paralleled one made in a different context by **Feldstein (1964)** (and later by **Sen, 1967**), whose emphasis was on the inability of market interest rates to reflect the positive effects on future private investment of current public investments. He argued that the social opportunity cost generally depends on the source of the particular funds and also reflects (indirectly) the social time preference. It is best therefore to obtain the social opportunity cost of funds directly by placing a shadow price on the funds used in the project and to make all intertemporal comparisons with a time preference rate, which responds to changes in the pure time preference rate, the consumption level and its growth rates (and even the rate of population growth). Thus, according to the so-called 'Ramsey formula', the simplest expression of the marginal rate of time preference could be defined as:

$$MRTP_t = \xi + \eta(C_t) \cdot \frac{dC_t}{C_t} \qquad \textbf{(6)}$$

where ξ would be the utility discount rate (or the rate of pure time preference), η the elasticity of marginal utility of consumption and dC_t/C_t (sometimes also referred to as g) the rate of growth of consumption per capita.[12]

b. The Baumol controversy

In 1968, a provoking paper by Baumol **(Baumol, 1968)** challenged these ideas and provided the spark for a renewed controversy that developed with numerous replies and rejoinders during the 1970s. Baumol returned to basic principles and argued that the social rate of discount

[12] Interestingly, **Lind (1982)** noted that even if the utility discount rate ξ is zero, the social discount rate is positive when consumption growth, g, is positive and $\eta > 0$. Equation **(6)** shows for the first time that in general, the appropriate social discount rate could not be constant over time, but a function of the expected future consumption path.

should always measure ‘the opportunity cost of postponement of receipt of any benefit yielded by a public investment’. He considered that the rate that was optimal from the point of view of the allocation of resources between the private and public sectors was necessarily higher than that which accorded with the public´s subjective time preference because it had to explicitly deal with distortions such as risk or taxes. The corporate income tax – for example – introduces a wedge between the consumer rate of interest (i.e., the marginal rate of time preference) and the ‘before-tax’ rate of return on corporate investment, because ‘after-tax’ returns from corporate investments must equal the returns earned on savings by consumers and investments in the non-corporate sector.

Baumol stated that this leads to a paradox or an inconsistency problem, because the consumer rate of interest is the discount rate that should be used for optimal allocation of resources, but the corporate rate of return before taxes is the opportunity cost of government projects. He concluded that the method of financing government projects was irrelevant to the choice of a social discount rate; that instead, all that mattered was the rate of return that resources diverted to the government could earn if they were in private hands, and he argued that this rate of return was in fact the before-tax corporate rate of return.

The *paradox* that Baumol saw as a result of the corporate income tax reflected the fact that the problem of choice of a social discount rate is a “second-best” problem rather than a “first-best” problem, that is, a problem of optimizing subject to certain *built-in* distortions in the economy. This was pointed out explicitly by **Usher (1970)**, who unraveled the Baumol paradox by deriving the social discount rate associated with an optimal level of government investment in a second-best world, showing that that rate lies between the consumer rate of interest and the pre-tax rate of return on corporate investment. He also pointed out that an essential ingredient in the social discount rate problem is a distinction of kind between public and private investment, resulting from politically imposed restrictions on the types of investment in which the government can engage.

D. **Ramsey (1969)** also criticized Baumol’s conclusion showing that they were merely special cases in a generalized public investment model where ‘first best’ solutions were not applicable. Alternatively, he showed that the social rate of discount was closer to a weighted average of observable pre-tax market rates of return and was not itself directly observable. Those ‘weights’ should depend on how individuals in the private sector reacted to the transferal of resources. With this ‘second best’ solution, both risks and taxes are given their appropriate consideration in this ‘weighting’ process and neither need to be explicitly considered again. Hence, the inconsistency that Baumol found disappears, and the question about what is the appropriate rate of discount from the point of view of social *CBA* should become an empirical one.

Other authors (including Baumol and Ramsey again) contributed to this controversy through several papers and books published in the following years. **Seagraves (1970)**, for example, explicitly acknowledged that it was very difficult for economists to agree on the issues involved. He proposed an operational framework that advocated the complete separation of the calculation of real internal rates of return for projects (which should be fairly stable over time), from calculation of the real social opportunity cost of capital, which may fluctuate for cyclical and other reasons. Thus, he favored the use of the *IRR* criterion (instead of the *NPV*) as a proposal to deactivate the Baumol controversy, but the technical limitations of this concept and its less appealing economic foundation brought little acceptance for this idea.[13]

Sandmo and Drèze (1971) revisited the Baumol-Ramsey framework in the context of international capital mobility and floating exchange rates, introducing for the first time the role of international lenders. For many countries – they argued – a discussion of public investment that did not consider foreign borrowing as a source of funds was seriously incomplete. They developed a model of an open economy in which the bonds issued by the government were also bought by foreign investors. The elasticity-adjusted rate on foreign loans now also entered in the calculation of the social opportunity cost of capital.

Bradford (1975) also elaborated on the Baumol controversy and the apparent impossibility of reconciling the arguments in favor of using a pure time preference rate with those in favor of using the marginal rate of return to private investment. He adopted a pragmatic approach and used a general equilibrium model to identify conditions and properties for the empirical estimation of the social discount rate. However, his results were not convincing enough and, once more, an author concluded that 'one should not be overoptimistic about obtaining a set of coefficients which can be applied to any government investment problem to lead to a correct choice'.[14]

---

[13] He argued that, when *NPV* is used, project assessment depends on the size of the project, the discount rate, and the time profile. In contrast, the internal rate of return does not depend on an interest rate being selected and generally provides a reasonable basis for comparing projects with widely different time. However, the main problem with the internal rate of return pertains to the reinvestment of the flows of receipts as projects mature. It is also less intuitive and more difficult to compute and explain.

[14] There are many more papers in this branch of the literature. **Drèze (1974)** or **Mikesell (1977)**, for example, argue in favor of the two approaches. **Hanke and Anwyll (1980)** follow an empirical approach and test several real projects with different criteria. **Olson and Bailey (1981)** also use a positive approach, whereas **Stiglitz (1982)** discusses second best options. A complete review is found in **Quirk and Terasawa (1987)**, but a quick overview of more recent papers, such as **Bazerlon and Smetters (1999)**; **Grout (2003)**; **Liu (2003)**; **Spackman (2004)**; **Burgess and Zerbe (2011, 2013)**, or **Moore *et al.* (2015a, 2015b)**, confirms that the debate could continue forever in spite of several attempts to find reconciling methodologies (for example, **Almansa and Calatrava, 2007**, or **Burgess, 2013**).

c. The Harberger 'consensus' and its criticisms

Either as a result of his undisputed valuable contributions in many areas of welfare economics, or as a consequence of his (sometimes controversial) opinions at public hearings before several official commissions in the US or because his numerous applied works in many developing countries, Arnold Harberger is broadly regarded as one of the most influential participants in the social discount rate debate. His position – first established in **Harberger (1969a, 1969b)**, and later revised in **Harberger (1972, 1976)** – departed from the established idea that in a perfectly competitive economy operating without any distortions and without any distributional problems, the correct choice of a (*first best*) government rate of discount should be the rate of discount used by consumers and firms. Since both distortions and equity issues are unavoidable, this approach may be unfeasible, but other descriptive options that strictly favored a pure rate of time preference over the opportunity costs of capital were also questionable even if they took into account second best restrictions.

To solve this dilemma, he firstly suggested the use of the observed past average social rate of return to capital as the best approximation of the social rate desirable for cost-benefit analysis. This rate, however, should be modified whenever there were good reasons to expect that in the future the typical rate of social marginal productivity of capital would differ from that observed in the past, and for the present and near-future years should be modified whenever there was evidence of an abnormal scarcity or glut of investible funds. In practice, when the project receives funding from several sources, this amounts to a *third best* principle: the social rate of discount is defined as a weighted average of the marginal rate of time preference (ξ) and the marginal rate of return on capital (r), including the corresponding corrections for taxes and risk. In its simplest form, the 'Harberger formula' leads to a constant discount rate calculated as **(Harberger, 1978, 1984)**:[15]

$$SDR = \alpha \cdot r + (1-\alpha) \cdot \xi \, , \qquad \textbf{(7)}$$

where α is the proportion of funds obtained by the displacement of private investment and (1 – α) the proportion of funds that come from shifting consumption. Distortions are incorporated to expression **(7)** using elasticities on consumption and investment changes, since the calculation of the *SDR* requires detailed information on the source of investment funds **(Harberger and Jenkins, 2002)**.

[15] Although the label 'Harberger consensus' may sound exaggerated, variations of this expression **(7)** are regularly used nowadays by many countries to empirically determine their social rates of discount, as discussed in next section.

As suspected, this approach was not either exempted of criticisms **(Feldstein, 1972)**, and 'fourth best' approaches quickly emerged in the literature. The most successful methodology proposed as an alternative to Harberger's weighted average was the discounting of the flow of benefits and costs using the marginal rate of time preference as the social discount rate, but having previously converted the flow of net benefits into a flow of consumption, using the shadow price of capital and other goods (see **Little and Mirlees, 1974** and **Bradford, 1975**).[16]

The most important implication of this two-step procedure to discounting lies in the renewed focus it places (again) on the role of consumer time preference in evaluating public investment projects. By successfully separating issues of opportunity cost from the discounting issue *per se*, it highlights consumer sovereignty as the dominant principle in contemporary economic thinking on intergenerational transfers. However, although this approach has led to a reevaluation of discounting practices in several countries **(Hartman, 1988; Lyon 1990)**, it is also a more complicated procedure because the information that is required on the destination of the benefits throughout the life of the project. For this reason, in the practice of social economic evaluation, practitioners frequently choose more pragmatic approaches.

d. Dealing with risk

A final issue pertaining the descriptive approach in the academic literature is the treatment of risk in determining the social discount rate. Although there is an overwhelming agreement among economists on the idea that risk assessment should be a standard component of the evaluation of any major public proposal, this does not mean that risks are always well calculated.[17]

Most of the controversy stems from the misinterpretation of a widely cited, classic contribution to public sector discounting theory, **Arrow and Lind (1970)**, who showed that if a government project was 'small' (in relation to the total wealth of taxpayers) and 'the returns from a given public investment are independent of other components of national income', then the social cost of the risk for project flows that accrue to taxpayers tends to zero as the number of taxpayers tends to infinity. That is, government investments with diversifiable risks spread over many households should be evaluated using the riskless rate to discount expected benefits (that is, with no adjustment for risk).

---

[16] This *shadow* or social price would be a reference from perfect competition capital markets, once included both social and private costs.

[17] For instance, **Flyvbjerg *et al.* (2003)** identify the main cause of the 'strikingly poor performance records' of megaprojects as 'inadequate deliberation about risk and lack of accountability in the decision making process'.

Nevertheless, most government projects involve (undiversifiable) market risks. The demand for the services of infrastructure projects, for example, is linked to the (future) state of the economy. Less obviously, so are the benefits of regulation.[18] In any case, the assumption that project net returns are statistically independent of each person's disposable income in the absence of the project is very stringent. It is true when people are identical, but when people pay different amounts of tax or if they receive different amounts of taxable benefits from the project, the assumption fails, even when the project's social returns and gross income are uncorrelated. As another counterexample, **Fisher (1973)** pointed out that the Arrow and Lind theorem does not hold in the case of public goods (which are important in many government projects), where the amount of net benefits is the same, whatever the size of the population.

Therefore, dealing with risk may be relevant in many cases and several procedures and techniques have been suggested to tackle this issue. **Haveman (1969)** or **Bailey and Jensen (1972)**, for example, recommended sensitivity tests, calculating *NPV* expected values by developing four or five scenarios keyed to the variables that were most important to a project's success or failure. For each scenario, the analyst should work out the profile of costs and benefit, attach a probability and generate expected values. Other proposals suggest explicitly modelling the probability distribution of the unknown parameters and variables and treat the *NPV* as a random variable itself (**Savvides, 1994**; **de Rus, 2010**). In this case the accept/reject decision becomes a statistical test subject to (controllable) error margins.

Other authors – for example, **Grout (2003)**, **Harrison (2010)**, **Hansen and Lipow (2013) or Hultkrantz *et al*. (2014)** – have finally proposed that the appropriate way to handle this risk is to discount the future periodic (annual) benefits and costs (or net benefits) using a risk-adjusted social discount rate. They claim that the discount rate used to evaluate government projects, the social discount rate, should equal the risk-free discount rate plus a discount rate risk premium. Unfortunately, this view is not definitive since other authors – see **Moore and Viscussi (1990a, 1990b)** and **Moore *et al*. (2004)** – strongly argue that analysts should discount certainty equivalents at a risk-free social discount rate and, for long-run projects, adjust only for the risk to the future growth rate of aggregate consumption.

4. A variable social discount rate: the prescriptive approach

The key issue in determining the *appropriate* social discount rate seems deciding the weights society should apply to costs and benefits that occur in future periods relative to the current

[18] For example, the valuation of 'statistical lives' saved by safety regulations subtly depends on the level of wages.

period. The efficiency criterion that underlies the recommendation of a constant rate in the exponential discounting formula that defines the *NPV* implicitly considers projects with effects that mainly occur within the lifetimes of those currently alive. This does not mean that the *positive* or *descriptive approach* – itself described in **Section 3** – did not take into account equity issues, but instead that these issues were mostly restricted to intra-generational ones, namely, those that arose when individuals in the existing population were allocated costs and/or benefits from a project in an asymmetric fashion, whereas the intergenerational problem (the one that arises when individuals in different generations are allocated costs and/or benefits from a project in an asymmetric fashion) was left aside. The *prescriptive* approach – as we will see below – was progressively emerging in the literature not necessarily as an alternative to the dominant view (in fact, both approaches are still frequent in recent papers), but perhaps as a complementary point of view in order to add more 'ethical contents' to the debate.

4.1. Intergenerational equity and hyperbolic discounting

a. Discounting the far-off future

Implicit in any long-term *CBA* is the idea that costs and benefits can be always compared across long periods of time using appropriate discount rates. Yet positive discount rates in the context of exponential discounting – according to expression **(3)** – lead us to place very little weight on events in the distant future, such as potential calamities arising from global warming. For example, a dollar invested now yields \$51 after 100 years if the social discount rate is 4%. Conversely, a promise to pay someone \$1 in 100 years – even with complete certainty – is worth only 0.02\$ today at a 4% rate of discount. Moreover, a promise to pay someone (or rather, his descendants) \$1 in 200 years is worth only 0.0004\$ today. Intergenerational equity seems relevant in evaluating the far-off future, but (once more) the question is how relevant: does the opportunity cost or the time preference logics that underlie the descriptive approach apply to net benefits in the distant future (decades or centuries away) and to be received mainly by people not alive yet?

To address this issue **Schulze and Brookshire (1982)** considered for example investment in nuclear power by the current generation. Suppose that this project adds utility to the present generation (cheaper energy), but decreases utility of future generations (handling nuclear wastes). If the ethical criterion used for this case is the Pareto efficiency (investment should be undertaken only if some generations would be better off while no generation would be worse off because of this investment), then nuclear investment of this nature should never be undertaken. However, if compensations from the current generation to future generations were possible, then the appropriate discount rate in evaluating this project would be the opportunity cost rate of return for the project (or the marginal rate of time preference, or both). The problem is that the Kaldor-Hicks criterion (see **Note 9**) is hardly justifiable in the (very) long run and the decision may finally depend on such a single figure as the discount rate.[19]

Many advocates of the prescriptive approach usually conclude that ethical obligations require discounting costs and benefits that accrue to future generations at a very low rate (below the marginal return to capital) or even zero, in certain cases that include unforeseeable environmental effects (**Caney, 2008; Dasgupta, 2008**). But not discounting (which means that a benefit to any future generation counts as much as the same benefit now), or using a very low discount rate, is not necessarily the best solution, since it may lead to a 'tyranny of the future generations' (**Pearce *et al*., 2003**; **Harrison, 2010**). Furthermore, using a low or no discount rate may harm future generations for two reasons. First, if the current generation adopts low return projects at the expense of investments with higher returns, it can make future generations worse off because inefficient decisions **(Arrow *et al*., 1995)**. Second, if the current generation sacrifices its welfare it could imply 'lack of savings' for the future (see **Weitzman, 1994, 1998** or **Newell and Pizer, 2005**), something that may be justified only if we knew (with certainty) that our sons and grandsons would be richer than we would.

How much to leave to future generations is an ethical question about how much to bequeath them. As suggested in **Lind (1995)**, once some overall allocation between the present generation and a future generation has been selected, then whatever amount that is to be invested on behalf of the future generation should be invested to maximize efficiency, i.e., giving the greatest benefit to the future generation from the amount invested. There is no case for wasting resources on low return investments when higher returns are available. These considerations lead to the conclusion that project choice should be based both on discounting with an efficiency-based discount rate and on the use of the prescriptive approach to address specific cases where determining the appropriate transfer to future generations is at stake. In these cases, the use of social discount rates that decline as time passes has emerged in the literature as a major contribution to the *SDR* debate.

b. Declining rates and hyperbolic discounting

The use of a declining rate of discount is frequently related to *hyperbolic discounting* (in contrast to conventional *exponential discounting*). Although several models have been suggested to account for this type of discounting, the simplest one was first proposed by the

[19] This was clearly pointed out by **Nordhaus (1999)** and in the well-known *Stern Report*, on climate change policy **(Stern, 2008)**.

psychologist Mazur **(Mazur, 1987)** extending previous works by **Goodin (1982)**, where the *PV* expression becomes very similar to the "simple interest" in mathematical finance,

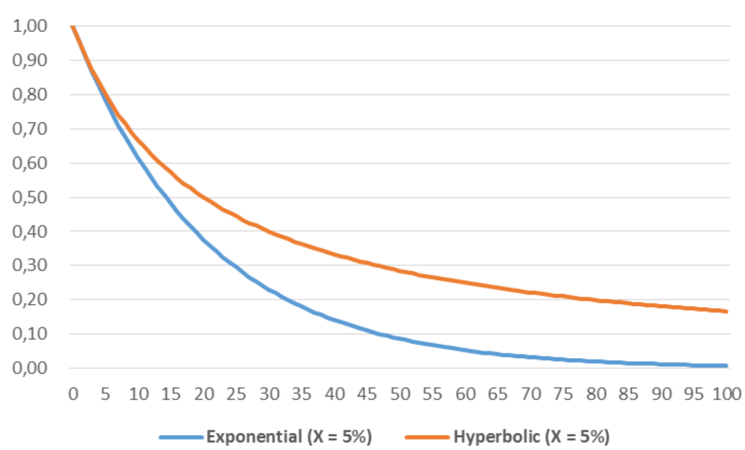
$$PV = \frac{FV}{(1 + X \cdot t)} \quad \textbf{(8)}$$

and the corresponding discount factor of period *t* is respectively given by:

$$\delta(X,t) = \left(\frac{1 + X \cdot (t-1)}{1 + X \cdot t}\right) \quad \textbf{(9)}$$

Note that the discount factor is not constant any more, but an increasing function of time. When objects of choice (for example $1) are distant in the future, deferring consumption one period is not too relevant – for example, δ(0.2, 50) = 0.98, meaning a difference in value of 2% among values in periods 49 and 50. However, deferring consumption one period from the present is much more significant: δ(0.2, 1) = 0.83, meaning a difference in value of 17% among outcomes in periods 0 and 1. **Figure 3** compares the present value of $1 for X = 5% over 100 years and shows that the slope of the exponential discount function declines at a constant rate over the period: that is, the individuals seem to maintain a consistent criterion and use higher discount rates the closer is the decision to them. In the hyperbolic discount function, the slope falls faster at the beginning and much slower for the distant future.

Figure 3. Exponential vs. hyperbolic discounting: the present value of $1



This preference pattern may therefore produce dynamic inconsistent choices (**Hansen, 2006**). Thus, **Cooper (1990)** proves this issue by using a hyperbolic function of the form δ(*X*, *t*) = $(1+X \cdot t)^{-\gamma/X}$, that approximately fits most experimental data, where *X* and γ are positive constants. Setting for example *X* = γ = 1, so that δ(t) = $(1+ t)^{-1}$, and given a choice between $1000 in 10 years and $1100 in 11 years, we would take the latter because $1000(1+ 10)^{-1}$<

$1100(1+11)^{-1}$. However, if we could reverse our choice after a lapse of 10 years, we would because $1000 > 1100(1+1)^{-1}$. People are more sensitive to a delay of 1 year when it increases waiting time from zero to 1 year than when it increases waiting time from 10 to 11 years.

Declining discount rates are not only appealing to people concerned about intergenerational equity, but also can be justified on experimental evidence arguments, particularly when valuations relate to an individual's own lifetime versus future generations or health risks (see **Cropper *et al*. 1992; Cropper and Laibson, 1999**, or **Gollier *et al*. 2008**). In these experiments, people typically choose between different rewards (e.g. money, durable goods, relief from noise, saving lives) with different delays, so that an implicit discount function can be constructed. The results seem to confirm that humans employ a higher discount rate for consumption trade-offs in the present than in the future. Although other interpretations, such as similarity relations or sub-additive discounting **(Rubinstein, 2003)**, are also possible, the recent empirical evidence for hyperbolic discounting is relatively strong (see **Hepburn *et al*., 2009**; **Gustman and Steinmer, 2012** or **Freeman *et al*., 2015**).

Building on **Henderson and Bateman (1995)**, **Pearce *et al.* (2003)** considered that if people's preferences counted, and the experimental results truly revealed underlying preferences, then declining discount rates ought to be integrated into social policy formulation, particularly in environmentally related projects. They accepted that the assumptions in this chain of reasoning might be disputed in at least two cases. First, as hyperbolic discounting provides an explanation for procrastination, drug addiction, under saving, and organizational failure, the argument that behavior reflects preferences could be weakened. Second, a careless generalization of these results would lead to the idea that the government should discount the future hyperbolically because individual citizens do, but this 'optimal paternalism' may not be always socially acceptable **(Hepburn and Koundouri, 2007)**.

A second source of foundations for the use of declining rate of discount lies in the limits and bias introduced by economic analysis itself. In a widely cited paper, **Weitzman (2001)** reports the results of a survey conducted over 2,160 PhD level international economists who were asked which social rate of discount would they apply in a long-run project with well-identified, well-measured net benefits (say, $100 million to be received in 300 years). Surprisingly, the resulting empirical distribution was not a Gaussian *normal*, but a *gamma* distribution, with a sample mean at around 4%, a standard deviation of around 3%, a median of 3% and a mode of 2%. The reported rates varied from –3% to 27%.[20]

[20] A gamma distribution concentrates more probability on lower variables of the random variable, thus reflecting more precaution or pessimism about the future. There is a mathematical relationship between gamma and exponential discounting. In fact, an exponential probability distribution is a one-parameter family describing the

One of the most striking consequences of this analysis is the idea that the aggregate distribution of discount rates may be biased. In fact, when there is uncertainty about what discount rate to use, Weitzman argues that the appropriate discount rate to calculate present value is effectively lower the further in the future the payments are received; however, it is uncertainty about the rate to use, not an uncertain interest rate that fluctuates over time. Therefore, he suggests aggregating over discount factors, instead of over *SDR*. A simple example contributes to clarify his point. Suppose just two individuals form the society: for *individual A*, with a reported discount rate of 1%, the resulting *NPV* from the Weitzman question (using exponential discounting) would be more than five million dollars,

$$NPV_A = \frac{100,000,000}{(1+0.01)^{300}} = \$5,053,449\,,$$

whereas for *individual B*, with a reported rate of 10%, the corresponding value would be less than one cent:

$$NPV_B = \frac{100,000,000}{(1+0.1)^{300}} = \$0.00004\,.$$

Averaging both rates of discount ($\bar{X}$ = 5.5%) the resulting *NPV* is \$10.60, which hardly represents this society's extreme preferences. Instead, by averaging the discount factors, the result (NPV_{AB}=\$2,526,724) seems more reasonable, with an implicit discount rate of 1.2%. Thus, it can be concluded that whereas for short-term projects gamma discounting and exponential discounting converge, for long-term projects the (implicit) social discount rate is declining **(Hepburn and Groom, 2007**). In fact, he recommends thinking in terms of a future subdivided into approximately five sub periods. Named in order, these are, roughly: the *Immediate Future* (1 to 5 years hence), the *Near Future* (6 to 25 years hence), the *Medium Future* (26 to 75 years hence), the *Distant Future* (76 to 300 years hence), and the *Far-Distant Future* (more than 300 years hence). The numerical examples suggest using the following approximation of within-period marginal discount rates for long-term public projects: *Immediate Future* about 4% per annum; *Near Future* about 3%; *Medium Future* about 2%; *Distant Future* about 1%; and *Far-Distant Future* about 0%.

Finally, **Gollier (2002a, 2002b)** provides an even more solidly grounded justification for the use of declining discount rates. By specifying an underlying utility function and analyzing an

---

waiting time until breakdown of a single-component system, while the more general gamma probability distribution can be viewed as a two-parameter family representing the waiting time until breakdown of a multiple component system, where the second parameter specifies the number of components in the system.

optimal growth model (with marginal rate of time preferences) where the social discount rate defined in **(6)** explicitly accounts for expectations about future income (*Y^e*),

$$MRTP_t = \xi + \eta(C_t) \cdot g + \beta \,\mathrm{var}(Y^e)\,, \qquad \textbf{(10)}$$

he proves that different investment projects should be ranked according to their expected net future value and we should take a larger interest rate to discount long-term cash-flows with respect to short-term ones. As the time horizon of the project increases, we should be using interest rates from the upper end of the spectrum of possible values (contrary to Weitzman's).

Apparently in contradiction, both results are correct about the effects of uncertainty about the discount rate. The further into the future a payment is received, the lower the discount rate used to calculate expected net present value (Weitzman). The further into the future we evaluate a project, the higher the discount rate used to calculate net future value. The expected net present value and expected net future value criteria can recommend different courses of action. However, this paradox finally disappears if the investment problem is carefully specified and the discount rate is risk-adjusted (**Gollier and Weitzman, 2010**; **Weitzman, 2010,** or more recently, **Fleuerbaey and Zuber, 2015**).

4.2. The prescriptive approach: from theory to practice

To complete the review of this literature, it should be finally mentioned that the lack of consensus within the descriptive/prescriptive approaches about what social discount rate should governments use in social *CBA* moved a number of authors to focus on this problem from an empirical perspective. Thus, instead of arguing in favor of the *social opportunity cost* or the *social time preference* (or a combination of these), they tried to calculate the most adequate social discount rate for real-life examples.[21]

The first attempt to carry out this empirical analysis is found in **Harberger (1969b)**, who uses national income accounts to determine the rate of return to capital in Colombia, as a possible reference for the social discount rate. A similar approach was followed in **Harberger and Wisecarver (1977)** on Uruguay, calculating private and social rates of return. Their results – around 12-14% for Colombia and 7-10% for Uruguay – are taken with care, since they explicitly admit that 'all of our calculations have been emphatically only of the historical returns of past

[21] Interestingly, most of them use a prescriptive approach (in the sense of providing recommendations), but based on the constant discount rates suggested by the descriptive approach literature **(Cruz and Muñoz, 2005)**.

investments, while the appropriate social rate of discount must be a forward-looking concept'.[22]

Using a more detailed approach**, Burgess (1981)** explicitly applied Harberger's approach – as in expression **(7)** – to determine the optimal *SDR* for Canada. He considered that, instead of the 10% official rate used by the government, the appropriate discount rate was a weighted average of the genuine rates of return in the sectors from which resources were withdrawn (namely, displaced private domestic investment, postponed domestic consumption and external funding from abroad). His calculations yielded a 7% figure, with more precise estimates of the corresponding consumption, savings and investment elasticities, although **Jenkins (1981)** discussed these results using different procedures.

Kula (1984) and, particularly, **Quirk and Terasawa (1987)** identified some practical limitations for the implementation of the *SDR* theories. They focused on the procedures underlying the 1972 recommendation by the US *Office of Management and Budget* (see **Section 5**) that directed most federal agencies to apply a 10% real rate of discount when calculating the present value of the costs and benefits of federal projects. Their analysis confirmed this value but also provide several insights on the practical difficulties in setting any *objective* figure.

The work performed by **Pearce and Ulph (1999)** for the United Kingdom introduced for the first time in the empirical literature the use on no-constant discount rates. In particular, they advocated – on equity grounds – the use of higher values for short-term projects and lower values for the long-run. However, **Evans and Sèzer (2002)** turned back to the efficiency criterion and estimated several social discount rates for the UK based on different time preference measures. A similar procedure was then applied to France **(Evans, 2004)** and other European countries **(Evans and Sèzer, 2004, 2005)**. An approach based on the opportunity cost of capital was used by **Perocco (2008)** for Italy, which resulted into a 4% figure.

The number of recent prescriptive works is also relatively important in Latin American countries. In the case of Peru, for example, it is very interesting the work elaborated by **Fernández-Baca (2012)** for the Ministry of Economics and Finance, where the Harberger methodology is compared with other existing alternatives. This report analyses in detail the specific characteristics of the Peruvian capital markets and estimate the main variables that determine the calculation of the *SDR* in different years. For Chile, **Edwards (2014)** also departs from a previous official report **(Capablanca Limitada, 2013)** for the Ministry of Social

[22] A similar approach was also followed **Canning and Bennathan (2000)** to estimate social rates of return in different sectors thus introducing the idea that *SDR* may vary across projects. In particular, they studied electricity-generating capacity and paved roads in several countries, by examining their effect on aggregate output.

Development and conducts an original survey *à la Weitzman* including both economists and politicians to estimate a declining long-run social discount rate, which is then compared with the Ramsey procedure.[23]

Finally, a special separate mention – which will be immediately expanded in the next section – is deserved by those papers that do not prescribe 'what should be' the optimal discount rate but rather 'what it is' as the current practice by governments and international institutions. Among these surveys and descriptive reviews, the most relevant ones are those conducted by **Percoco and Nijkamp (2006)**, **Evans (2007)**, **Zhuang *et al*. (2007)** and **Harrison (2010)**.

5. International evidence: what it is really done about *SDR*

Since there is no consensus as to which approach is the most appropriate for the choice of the social discount rate to evaluate government projects, it is not surprising that public investment policies significantly vary across different countries around the world. These differences do not only refer to the recommended values for the *SDR*, but also to the underlying methodologies for their calculation and updating. Departing from the literature review carried out in the previous sections and confronting the *descriptive* and *prescriptive* approaches, this section finally surveys some of these policies around the world, used either by developing, developed countries, or by multilateral development banks.

5.1. Different methodologies across countries…

Three major methodological approaches – as discussed above – are currently supported as the main foundations for calculating a constant optimal social discount rate (provided that it exists). The first one, from the point of view of consumers, is related to the marginal rate of time preference (*MRTP*) about present and future consumption. The second, from the point of view of investors, focuses on the social opportunity cost (*SOC*) of capital, taking into account the possible existence of market distortions. The third method is based in Harberger's contributions and suggests the use of a weighted average of the two previous rates. Although each of these methods may include several variations these are the most popular ones, and all derive from the efficiency criterion that stems from the use of net present values. The use of declining

[23] For other countries, **Correa (2008)** calculates a marginal rate of time preference for Colombia, whereas **Ortegón and Pacheco (2004, 2005)** perform the calculations for South America and **Ramírez (2010)** for Mexico. **Cartes *et al*. (2004)** also provide alternative estimates for Chile.

discount rates can be seen as an additional (fourth) approach that tries to introduce some (intergenerational) equity contents.

According to the findings of **Percoco and Nijkamp (2006)** and, particularly, **Zhang *et al*. (2007)**, **Figure 4** shows that the *MRTP* approach dominates in most European countries, although in France the change took place in 2005 (until that moment the rate was chosen 'to keep a balance between public and private sector investment). In the United Kingdom, the *SOC* approach was in use until early 1980s (when it switched to *MRTP*) but different (declining) rates are recommended for long-term projects. The Czech Republic, Norway and Hungary explicitly advocate the use of suitably adjusted (private) market rates.

Figure 4. International evidence: the dominant methodology to calculate the *SDR*

Marginal rate of time preference (MRTP)	Social opportunity cost of capital (SOC)	Other methods
Denmark	Australia	International institutions (*HB*)
France	Canada	
Germany	India	Chile (*HB*)
Italy	Ireland	China (HB)
Portugal	Netherlands	Czech Republic (*MR*)
Slovakia	New Zealand	Norway (*MR*)
Spain	Pakistan	Hungary (*MR*)
Sweden	Philippines	
United Kingdom*	United States**	
United States**		

Source: updated from Zhuang *et al*. (2007).

Notes: * Only from the 1980s. Currently, a declining rate is recommended.

** There are internal discrepancies among agencies.

HB = Harberger method. *MR* = Market rates.

In North America, the Canadian government uses a rate based on the *SOC* approach, while in the United States there are internal divergences. For example, the US *Office of Management and Budget* recommends a discount rate that approximates the marginal pretax rate of return on private investment (the SOC approach), but the US *Congressional Budget Office* and the *General Accounting Office* favor the use of discount rates based on government bond rates **(Lyon 1990)**. They use the interest rate for marketable Treasury debt with maturity comparable to the program being evaluated as a baseline discount rate, thus preferring the SRTP approach, which is also supported by the US *Environmental Protection Agency*.

Interestingly – and perhaps due to the need of internal consensus among their member countries – the use of Harberger approach is explicitly supported by international multilateral organizations (as well as in Chile and China). For example, The World Bank's *Handbook on Economic Analysis of Investment Operations* **(Belli *et al*., 1998)** provides explicit guidance on how to calculate the social discount rate stating that 'it should reflect not only the likely returns of funds in their best relevant alternative use (i.e., the opportunity cost of capital), but also the marginal rate at which savers are willing to save in the country (i.e., the rate at which the value of consumption falls over time)'.[24]

The Inter-American Development Bank (IADB) also favors the Harberger methodology. IADB website includes a project evaluation hub[25] with numerous project examples and research papers on impact evaluation, cost-benefit analysis and cost-effectiveness analysis. It also includes guidelines for designing impact evaluations and for the economic analysis of IADB-funded projects **(IADB, 2012)** and sectoral manuals for *CBA* (such as **de Rus *et al.* 2007** for transport projects or **Adamson and Meirovich, 2013**, for environmental projects), but – to the best of our knowledge – there are no detailed regulations on how to calculate (or even update) the *SDR*.

5.2. …result in different recommended rates for each country…

Provided that the methodologies used everywhere do exhibit significant differences it is no surprise that the recommended discount rates used by governments and international institutions widely differ too. Evidence abounds that the quality of governmental *CBA* varies widely, and that a major reason for this variability is lack of consistency in the use of the *SDR*. Many governmental *CBA*s employ *SDR*s without any well-specified rationale, and some governments, especially at the sub-state level, do not discount at all **(Dively and Zerbe, 1994)**. **Table 3** summarizes the available international evidence on recommended social discount rates in selected countries (ranked from higher to lower rates).[26]

---

[24] There is a specific 'project valuation hub' (www.worldbank.org/projects) that contains an extensive list of resources, examples and research documents. See **Canning and Bennathan (2000)** for a review.

[25] See www.iadb.org/en/topics/development-effectiveness/evaluation-hub/.

[26] The table has been mostly updated from **Zhuang *et al*. (2007)** and **Harrison (2010)**. In many cases, the available information was fragmented or contradictory. It is important to note that although many countries do have detailed regulations on *CBA* and project appraisals, the most recent documents are not always available for public consultation.

Table 3. International evidence: recommended *SDR* in selected countries

Country	Agency / Program	Recommended *SDR*
Philippines	All public sector	15%
India / Pakistan	Central Government and States	12%
Colombia / Bolivia / Argentina / Uruguay / Costa Rica	Ministry of Finance Ministry of Development	12%
Chile	Ministry for Social Development	6%
Mexico	Federal Government	10% (until 2014 was 12%)
Peru	DGIP	9%
Canada	Treasury Board	10% (until 2007); 8% (since then)
New Zealand	New Zealand Treasury	8%
China	Ministry of Construction	8% (lower for long-term)
South Africa	Selected projects	8%
Australia	Annually reviewed. Varies across states	7%
United States	Varies across agencies	7% (Office of Management and Budget) Lower rates in environmental projects
European Union	European funded projects	5% (3% in certain cases)
Italy	Guidance to Regional Authorities	5%
France	Commissariat Général du Plan	4% (from 1985-2005 used 8%)
Spain	Varies across sectors	6% for transport; 4% for water
Germany	Federal Finance Ministry	Until 1999: 4%. Since 2004: 3%
The Netherlands	Ministry of Finance	4% (risk-free)
Norway	Government borrowing rate	3.5%
United Kingdom	HM Treasury	In 1989: 6%. In 2003: 3.5% Different (declining) rates for long-run

The table suggests that the highest rates are used in developing countries although there are exceptions for geographic areas. An obvious explanation could be that there is a higher opportunity cost in developing countries that are not reflected in the realized returns to capital. However, this not always the case, particularly when the *MRTP* is followed. In fact, recent evidence **(Caselli and Feyrer, 2007)** suggests that the marginal rate of return to capital in developing countries is not always higher than in developed countries.

a. The Asia-Oceania and North-American values

Three Asian countries currently concentrate the higher rates. The Philippines and Pakistan use 15% and 12% as *SDR*, respectively, both based on the SOC approach. India currently uses 12%. In China, according to the Ministry of Construction **(NDRC, 1996)**, the economic cost of capital is a weighted average of social time preference and returns on capital. The former is estimated to be around 4.5-6% and the latter around 9-11%. Thus, the suggested social discount rate is 8% for short- and medium-term projects, although it is also recommended that a lower than 8% discount rate be adopted for projects with a long time horizon.

In Australia, the mandated discount rate was 8% before 1991 and, since then, there has been no prescribed benchmark social discount rate on the basis that the appropriate rate may vary from one year to another, and should be under continuous review. However, some agencies (including the *Commonwealth's Office of Best Practice Regulation*) recommend rates around 7% real, usually justified as being approximately the before-tax rate of return on private investment. For example, the New South Wales Treasury recommends using a real rate of 7% (with sensitivity margins between 4-10%). The New Zealand Treasury had a long-standing rate of 10%, which was reaffirmed in 2005 (**Rose, 2006**), but later reduced to 8% in 2008.

Outside the Pacific region, a similar procedure is applied in other Commonwealth country, Canada where, since 1974 the Canadian Treasury had recommended a 10% rate (see **Treasury Board of Canada Secretariat, 1998)**, which was later reduced to 8% in 2007. In the US, as it has been discussed, the recommended rate varies across agencies. The *Office of Budget Management* explicitly specified a 10% real until 1992, but now uses 7% real (with sensitivity testing for 3%) **(OMB, 1992)**. The *Environmental Protection Agency* recommends that for intra-generational discounting, a rate of 2–3% be used, which is reckoned to be the market interest rate after tax. The EPA further recommends undertaking sensitivity analysis of alternative discount rates in the range of 2-3% as well as at 7% (prescribed by the OMB), as this may provide useful information to decision makers. In addition, all analyses are required to present undiscounted benefit and cost streams. For intergenerational effects, the EPA prescribes that economic analyses should generally include a "no discounting" scenario by displaying undiscounted cost and benefit streams over time. The economic analysis should also present a sensitivity analysis of alternative discount rates, including discounting at 2-3% and 7% as in the intra-generational case, as well as scenarios using rates in the range of 0.5-3% as derived from optimal growth models.

b. The Latin American evidence

Social discount rates are also high in Latin American countries. Many of them still use a 12% rate (which is the IADB recommended rate, see **Table 4** below), although there have been recent reductions in Mexico (10%) and Peru (9%), where the methodologies have been also updated taking into account changes in international capital markets. Chile is the country with a lower rate (6%) and a larger number of studies on this issue and where the institutional design of public investment policies has reached a more advanced stage (see **MIDEPLAN, 2008, 2009**).

The evolution of *SDR*s in the region is closely related to the recent changes experienced by the public investment systems (*Sistemas Nacionales de Inversión*, SNI) in many of them. As pointed out by **Gómez-Lobo (2011)**, the relative strength and politic determination of the public investment institutional framework affects the procedures and regulations that inform CBA in these countries. In the case of Chile, for example, whose SNI is considered the oldest and most consolidated in Latin America,[27] its objective is clearly stated as to provide a coherent framework for identifying, coordinating, evaluating and implementing public investments at national and regional levels. it standardizes project presentation formats, establishes explicit application and evaluation processes for public funds, provides general as well as sector specific methodological guidelines for CBA of projects and programs, and introduces a system of "checks and balances" by separating the institution that evaluates projects from the institutions promoting projects.

A similar institutional approach is followed in Colombia since 1989, although project appraisal competences are more evenly distributed across different departments and ministries. The main role correspond to the National Planning Department (*Departamento Nacional de Planeación*, DNP), who is in charge of the Bank of National Investment Projects (*Banco de Proyectos de Inversión Nacional*, BPIN) a database of projects and the associate normative, including CBA methodologies and SDR determination criteria (12%).

The SNIP in Peru has recently celebrated its first 15 years of experience. At its beginning, it only evaluated investment projects funded with external loans but now it oversees most national and regional projects. It has also produced several manuals and studies and actively promotes a reduction in *SDR*s as a way to encompass the evolution of the economy with an update of CBA procedures. It has also insisted in capacitation at mid and lower administrative levels, particularly in the provinces and municipalities.

With respect to other countries in the region, most of them follow a SNIP scheme based in similar premises to these three examples, although in several cases they are still focused on general planning and development criteria instead of a standard microeconomic cost-benefit analysis (**Ortegón y Pacheco, 2004, 2005**).

---

[27] The different agencies that conform the Chilean SNI and are mostly under the control of the *Ministerio de Desarrollo Social* (www.ministeriodesarrollosocial.gob.cl), the former MIDEPLAN (*Ministerio de Desarrollo and Planificación*).

c. The European approach

In Europe, and due to its peculiar political federalism, the European Union (EU) has been particularly active on the development of clear and transparent common rules for project evaluation. Although *CBA* is explicitly required by the *Structural Funds Regulation* and the *Cohesion Fund Regulation* since 1999, Member States still have the responsibility for a prior appraisal, while the Commission later verifies that the information provided in the appraisal is exhaustive enough to allow an unbiased project selection. Most of the rules are methodically described at the DG Regional Policy website (ec.europa.eu/regional_policy/), where a number of manuals and handbooks are available. The most recent new *CBA* guide, published in December 2014, recommends a general *SDR* of 5%, used for major projects in Cohesion countries and 3% for the other. Member States may even use a different benchmark on the condition that: *(i)* justification is provided for this reference; *(ii)* their consistent application is ensured across similar projects in the same country, region or sector **(European Commission, 2014)**.

With regard to individual European countries, **Evans (2007)** points out that there has been a progressive convergence among official social discount rates, reflecting a trend towards using lower discount rates that, in most cases follow suggestions from the EU. The German Federal Finance Ministry uses 3% real, down from 4% in 1999, based on values of real long-term government bond rates. Norway has been using a 3.5% discount rate after 1998 (also based on real government borrowing rate), down from 7% (used from 1978). France's Commissariat Général du Plan in 2005 lowered its social discount rate from 8% to 4% and has asked for new studies,[28] whereas Italy uses the SRTP approach to derive a 5% discount rate, and Spain adopts 4-6% for different sectors.

The UK government **(HM Treasury 2003)** is the most advanced in terms of declining rates, considering that an SRTP of 3.5% should be used to discount future benefits and costs of public projects with a lifespan below 30 years. This figure is calculated on the basis of the estimates of the following three parameters: (i) the rate of pure time preference at 1.5%; (ii) the elasticity of the marginal utility of consumption at around 1%; and (iii) the output growth per capita over the period 1950–1998 in the UK at 2.1%. For projects with very long-term impacts (over 30 years), the discount rate will depend on the length of their lifespan: 3.0% for projects with a lifespan of 31-75 years; 2.5% with 76-125 years; 2.0% with 126-200 years; 1.5% with 201-300 years; and 1.0% with 301 years and beyond (curiously in line with **Weitzman, 2001**).

[28] See **CGDD (2011)** and **Meunier *et al*. (2014)**. Similarly, for the Netherland, see **Mouter *et al.* (2011)**.

5.3. …and international institutions

Finally, with respect to international institutions, **Table 4** shows that the degree of variability is narrower when compared to the individual countries. The World Bank, for example, traditionally has not calculated a discount rate but has used 10–12% as a notional figure for all its cost-benefit analysis. The handbook **(Belli et al. 1998)** further advises that task managers may use a different discount rate as long as departures from the 10–12% rate are justified in the Country Assistance Strategy. Similarly, in the case of the Inter-American Development Bank, a 12% discount rate is being used as a weighted measure of the economic opportunity cost of capital and the marginal rate of time preference but, again, it is not clear why this figure has been chosen.

Table 4. International evidence: recommended *SDR* by multilateral institutions

Institution	Recommended *SDR*
The World Bank	10-12%
Inter-American Development Bank	12%
Asian Development Bank	10-12%
African Development Bank	10-12%
European Bank for Reconstruction and Development	10%

The Asian Development Bank's policy on the social discount rate, specified in its Guidelines for the Economic Analysis of Projects **(ADB, 1997),** follows The World Bank approach. Although the Guidelines state that "economic rates of return differ considerably between sectors and countries", and "from time to time, an appropriate discount rate for economic analysis should be calculated for each country to compare with the existing practice", in practice, a single minimum rate of 10-12% has been always used to calculate the net present value of a project, or to compare with the internal rate of return. Similar procedures are followed by other international institutions.[29]

[29] The *European Investment Bank* (not reported in **Table 4**) advocates a sector-by-sector approach with *SDR* closely following the trends of private market rates.

6. Conclusion: is a constant *SDR* (still) reasonable?

This paper has attempted to provide a critical revision of the economic literature underlying the determination of the social discount rate (*SDR*), as well as an updated review of current international practices on this issue. Departing from the basic principles of discounting, it has been shown that the choice of the discount rate remains as a critical decision in cost-benefit analysis (*CBA*) and public project evaluation, particularly when the net present value (*NPV*) of future benefits and costs is used as the main accept/reject or ranking criterion.

During the last decades, the academic debate in the literature on this topic has been intense, but economists have not yet reached a consensus as how to finally close it. In principle, there is a theoretical agreement that, in a perfectly competitive world without distortions, the market interest rate would be the appropriate social discount rate. However, in the real world where markets are distorted by taxes, uncertainty or externalities, this private rate may not represent the social preferences. Two major approaches have emerged in the way in which most authors have addressed this issue. The first one – the *descriptive* approach – is mostly based on the efficiency criterion that stems from the simple use of the *NPV*. It is generally associated to the mechanics of exponential discounting, whereby the future is less (and less) valuable than the present. Authors in this approach favor the use of a fixed or **constant *SDR***, calculated using one of three dominant methodologies: the marginal rate of time preference (which represents the view of the consumers), the social cost of capital (representing the investors' positions), or a weighted average of both (as advocated by Harberger). There are many other alternatives (such as the use of the shadow price of capital), but are less popular and/or difficult to implement.

The second branch of the literature follows a *prescriptive* approach that explicitly focuses on the equity considerations (in particular intergenerational ones). It is based (although not always) on hyperbolic discounting, where the rate at which the future is discounted declines slower (and slower). Authors on this current tend to favor a **declining *SDR*** to give more relevance to future values, which may be relevant for environmental and other (very) long-term projects. There is no specific methodology for calculating the social discount rate thus becoming a complementary (rather than a substitute) of the descriptive approach.

The differences among all these approaches are not only vested in their primary focus, but also reflect the different views on how public projects affect the economy: whether public investment displaces current consumption, or private investment, or both, and whether benefits of projects are consumed immediately, or reinvested to generate more future consumption. In cases of very long-term projects, the debate has centered on whether or not one should assume a constant pure time preference on the grounds that individuals are 'impatient', but they do not know (today) how rich (or poor) will be his descendants.

From an empirical point of view, the review of the existing evidence and current practices around the world confirms that there are significant differences in the underlying *SDR* methodologies, although – in most cases – a single, constant discount rate is still recommended by governments for project evaluation. International institutions – such as The World Bank, the Inter-American Development Bank or the Asian Development Bank – also use an *administrative* constant rate in the range of 10%-12%, not always with adequate background justification. In general, developed countries tend to apply lower rates (3%-7%) than the developing countries (8%-15%), although in most cases the rates have been reduced in recent years. It is possible that these variations do not only reflect different theoretical approaches, but also differences in the perceived marginal social opportunity cost of public funds that the *SDR* tries to measure in order to ensure efficient allocation of resources, or differences in the extent to which the issue of intergenerational equity is considered. However, there is no enough detailed evidence on this issue and it demands more research.

On the other hand, the advantages and disadvantages of using constant versus declining discount rates are not yet definitive. The use of standard and well-understood NPV mechanisms, based on exponential discounting with a constant discount rate still seems fundamental in *CBA*. It is not only easy to calculate but also transparent and uniform, which facilitates social and political acceptability. When investment funds are scarce, a constant discount rate can also be defended on equity grounds, since it treats (and ranks) different projects with the same (objective) criteria, regardless its geographical location or the social groups it may benefit. However, this does not imply that any discount rate is valid. It is required that a clear (and transparent) methodology support the chosen *SDR*, in order to allow external reviews and/or updates. An adequate institutional design and more information (for example, through an international database of case studies) is highly recommended.

The advantages of declining discount rates are clear, in the sense that they explicitly introduce equity concerns in social *CBA*. It seems that they are very appropriate for (very) long-term projects or those in sectors with long-run consequences (environment, energy, transport infrastructure, etc.), but do not solve methodological question on the ultimate determination which rate(s) to choose. Declining rates also require solid (and transparent) economic foundations to avoid or reduce the risk of manipulation or discretional usage. Again, better institutional design and shared information seem recommendable.

In any case, specifying the rate(s) at which society is willing to trade present for future consumption is always bound to be a controversial issue. 'Society' is not a decision maker (not even the government controls the whole of society). Inevitably, the analyst seeks to impose one (or several) specific discount rate(s), yet economists have no particular expertise about how the future should count. For that reason, it is not surprising that there is little agreement about the appropriate approach or the optimal methodology, and it is difficult that this debate can be closed in the near future. In the meantime, more empirical work could contribute to this research, either by analyzing how the institutional settings on this issue work around the world, or by analyzing in detail real case studies where the choice of the social discount rate may play a significant role. That is possibly the main work that remains to be done.

References

Adamson, M. and H. Meirovich (2013): *Fundamento y práctica del análisis beneficio costo de la inversión en adaptación de infraestructura al cambio climático*, Inter-American Development Bank. Climate Change Division. Washington DC.

ADB (1997): *Guidelines for the Economic Analysis of Projects*. Asian Development Bank. Manila.

Almansa, C. and J. Calatrava (2007): "Reconciling Sustainability and Discounting in Cost–Benefit Analysis: A Methodological Proposal", *Ecological Economics*, 60: 712-725.

Arrow, K. and R. Lind (1970): "Uncertainty and the Evaluation of Public Investment Decisions", *American Economic Review*, 60(3): 364–78.

Arrow, K. J. (1966): "Discounting and Public Investment Criteria", in A.V. Kneese and S. C. Smith (eds.), *Water Research*, Baltimore.

Arrow, K.J., W. Cline, K. Maler, M. Munasinghe, R. Squitieri, and J.E. Stiglitz (1995): *Intertemporal equity, discounting and economic efficiency*, in: J.P. Bruce, H. Lee, E.F. Haites (eds.), *Climate Change – Economic and Social Dimensions of Climate Change*, Cambridge University Press, Cambridge.

Bailey, M. and M.C. Jensen (1972): "Risk and the Discount Rate for Public Investment", in M.C. Jensen (ed.): *Studies in the Theory of Capital Markets*, New York, Praeger: 269–93.

Baum, S.D. (2009): "Description, Prescription and the Choice of Discount Rates", *Ecological Economics*, 69: 197-205

Baumol, W.J. (1968): "On the Social Rate of Discount", *American Economic Review*, 58(4): 788–802.

Bazerlon, C. and K. Smetters (1999): "Discounting inside the beltway", *Journal of Economic Perspectives*, 13: 213–228.

Belli P., J. Anderson, H. Barnum, J. Dixon, and J. Tan (1998): *Handbook on Economic Analysis of Investment Operations*. The World Bank, Washington, DC.

Boadway, R. (2006): "Principles of Cost-Benefit Analysis", *Public Policy Review*, 2(1): 1-44.

Boardman, E.A., Greenberg, D.H.; Vining, A.R., and D.L. Weimer (2006): Cost–Benefit Analysis: Concepts and Practice, 3rd edition, Pearson Prentice Hall, New Jersey.

Bradford, D. (1975): "Constraints on Government Investment Opportunities and the Choice of Discount Rate", *American Economic Review*, 65(5): 887–889.

Broome, J. (1994): "Discounting the future", *Philosophy and Public Affairs*, 23 (2), 128–156.

Burgess, D.F. (1981): “The Social Discount Rate for Canada: Theory and Evidence”, *Canadian Public Policy / Analyse de Politiques*, 7(3): 383–394.

Burgess, D.F. (2013): “Reconciling Alternative Views about the Appropriate Social Discount Rate”, *Journal of Public Economics*, 97, 9-17.

Burgess, D.F. and R.O. Zerbe (2011): “Appropriate Discounting for Benefit-Cost Analysis”, *Journal of Benefit-Cost Analysis*, 2(2): 1–20.

Burgess, D.F. and R.O. Zerbe (2013): “The Most Appropriate Discount Rate”, *Journal of Benefit-Cost Analysis*, 4(3): 391-400.

Caney, S. (2008): “Human Rights, Climate Change, and Discounting”, *Environmental Politics*, 17(4), 536–555.

Canning, D. and E. Bennathan (2000): “The Social Rate of Return on Infrastructure Investments”, *World Bank Policy Research Working Paper* No. 2390, The World Bank, Washington DC.

Capablanca Limitada (2013): *Estudio de Actualización del Modelo de Estimación de la Tasa Social de Descuento en el Marco del Sistema Nacional de Inversiones de Chile*. Ministerio de Desarrollo Social de Chile.

Cartes, F., E. Contreras and J.M. Cruz (2004): “La Tasa Social de Descuento en Chile”, Santiago de Chile, Centro de Gestión de la Universidad de Chile (CEGES). Mimeo.

Caselli, F. and J. Feyrer (2007): “The Marginal Product of Capital”, *Quarterly Journal of Economics*, May: 535-68.

CGDD (2011): *Evaluation Globale du Projet de Schéma National des Infrastructures de Transport*. Commissariat Général au Développement Durable, Paris.

Chen, J. (2012): “The Nature of Discounting”, *Structural Change and Dynamics*, 23: 313-324.

Cooper, I. (1996): “Arithmetic versus Geometric Mean Estimators: Setting Discount Rates for Capital Budgeting”, *European Financial Management*, 2(2): 157-67.

Correa, F. (2008): “Tasa de descuento ambiental Gamma: una aplicación para Colombia”, *Lecturas de Economía*, 69: 141-162, Universidad de Antioquia, Colombia.

Cowen, T. and D. Parfit (1992): “Against the Social Discount Rate”, in Laslett, P. and J.S. Fishkin (eds.), *Justice Between Age Groups and Generations*. Yale University Press, New Haven, 144–161.

Cropper, M. and D. Laibson (1999): *The implications of hyperbolic discounting for project evaluation*, in: P.R. Portney, J.P. Weyant (Eds.), *Discounting and Intergenerational Equity, Resources for the Future*, Washington.

Cropper, M.L., Aydede, S.K. and P.R. Portney (1992): "Rate of time preference for saving lives", American Economic Review (Papers and Proceedings) 82(2):469-472.

Cruz, S. and M.J. Muñoz (2005): "Some Considerations on the Social Discount Rate", *Environmental Science and Policy*, 8, 343-355.

Dasgupta, P. (2008): "Discounting Climate Change", *Journal of Risk and Uncertainty*, 37, 141-169.

de Rus, G. (2010): *Introduction to Cost-Benefit Analysis: Looking for Reasonable Shortcuts*. Edward Elgar. Cheltenham.

de Rus, G., O. Betancor and J. Campos (2007): *Manual de Evaluación Económica de Proyectos de Transporte*. Banco Interamericano de Desarrollo. Washington DC.

Diveli, D. and R.O. Zerbe (1994): *Benefit-Cost Analysis: in Theory and Practice.* New York.

Drèze, J. (1974): "Discount Rates and Public Investment: A Post-Scriptum", *Economica*, 41(161): 52-61.

Eckstein, O. (1957): "Investment Criteria for Economic Development and the Theory of Intertemporal Welfare Economics". *Quarterly Journal of Economics*, 71(1): 56-85.

Eckstein, O. (1958): *Water Resource Development: The Economics of Project Evaluation*. Harvard University Press, Cambridge.

Eckstein, O. (1961): "A Survey of the Theory of Public Expenditure Criteria", in J.M. Buchanan (ed.): *Public Finances: Needs, Sources and Utilization*. Princeton University Press. Princeton: 439-95.

Edwards, G. (2014): *Estimación de la Tasa Social de Descuento en el Largo Plazo en el Marco del Sistema Nacional de Inversiones*. División de Evaluación de Inversiones. Ministerio de Desarrollo Social de Chile.

European Commission (2014): *Guide to Cost-benefit Analysis of Investment Projects. Economic appraisal tool for Cohesion Policy 2014-2020*. DG REGIO. Brussels

Evans, D. (2004): "A Social Discount Rate for France", *Applied Economics Letters*, 11: 803–808.

Evans, D. (2007): "Social Discount Rates for the European Union", in M. Florio (ed.): *Cost-Benefit Analysis and Incentives in Evaluation: The Structural Funds of the European Union*. Edward Elgar. Cheltenham.

Evans, D. and H. Sèzer (2002): "A Time Preference Measure of the Social Discount Rate for the UK", *Applied Economics*, 34: 1925–34.

Evans, D. and H. Sèzer (2004): "Social Discount Rates for Six Major Countries", *Applied Economics Letters*, 11: 557–60.

Evans, D. and H. Sèzer (2005): “Social Discount Rates for Member Countries of the European Union”, *Journal of Economic Studies*, 32: 47–59.

Feldstein, M.S. (1964): “The Social Time Preference Discount Rate in Cost Benefit Analysis”, *Economic Journal*, 74(294): 360–379.

Feldstein, M.S. (1972): “The Inadequacy of Weighted Discount Rates”, in R. Layard (ed.): *Cost Benefit Analysis*, Harmondsworth UK, Penguin Books: 311-331.

Fernández-Baca, F. (2012): *Actualización de la Tasa Social de Descuento.* Dirección General de Inversión Pública. Ministerio de Economía y Finanzas. Lima, Perú.

Fisher, A. (1973): “A Paradox in the Theory of Public Investment”, *Journal of Public Economics*, 2: 405-407.

Fleurbaey, M. and S. Zuber (2015): “Discounting, Risk and Inequality: A General Approach”, *Journal of Public Economics*, 128, 34-49.

Flyvbjerg, B., Bruzelius, N. and W. Rothengatter (2003): *Megaprojects and Risk: An Anatomy of Ambition*, Cambridge University Press.

Frederick, S., G. Loewenstein and T. O’Donoghue (2002): “Time Discounting and Time Preference: A Critical Review”, *Journal of Economic Literature*, XL: 351-401.

Freeman, M., B. Groom, E. Panopoulou and T. Pantelidis (2015): “Declining discount rates and the ‘Fisher Effect: Inflated past, discounted future?, *Journal of Environmental Economics and Management,* forthcoming.

Gollier, C. (2002a): “Discounting an uncertain future”, *Journal of Public Economics*, 85: 149–166.

Gollier, C. (2002b): “Time Horizon and the Discount Rate”, *Journal of Economic Theory*, 107: 463–473.

Gollier, C., and M.L. Weitzman (2010): “How Should the Distant Future be Discounted When Discount Rates are Uncertain?” *Economic Letters*, 107(3): 350-353.

Gollier, C., Koundouri, P., and T. Pantelidis, (2008): “Declining Discount Rates: Economic Justifications and Implications for Long-run Policy”, *Economic Policy*, 23: 759–795.

Gómez-Lobo, A. (2011): “Institutional Safeguards for Cost Benefit Analysis: Lessons from the Chilean National Investment System”, *Journal of Benefit-Cost Analysis*, 3(1).

Goodin, R.E. (1982): “Discounting Discounting”. *Journal of Public Policy* 2(1): 53-72.

Grout, P. (2003): “Public and private sector discount rates in public–private partnerships”, *Economic Journal*, 113: 62–68.

Gustman, A. and T. Steinmer (2012): "Policy Effects in Hyperbolic vs. Exponential Models of Consumption and Retirement", *Journal of Public Economics*, 96: 465–473

Hanke, S.E. and J.B. Anwyll (1980): "On the Discount Rate Controversy", *Public Policy*, 28(2)*:* 171–183.

Hansen, A.C. (2006): "Do Declining Discount Rates lead to Time Inconsistent Economic Advice?", *Ecological Economics*, 60 (1), 138-144.

Hansen, J. and J. Lipow (2013): "Accounting for Systematic Risk in Benefit-Cost Analysis: A Practical Approach", *Journal of Benefit-Cost Analysis*, 4(3): 361-373

Harberger, A.C and G. Jenkins (2002): *Cost-Benefit Analysis for Investment Decisions*. Queen's University, Canada.

Harberger, A.C. (1969a): "The Discount Rate in Public Investment Evaluation". *Conference Proceedings of the Committee on the Economics of Water Resource Development*, Report No. 17. Denver, CO: Western Agricultural Economics Research Council.

Harberger, A.C. (1969b): "On Estimating the Rate of Return to Capital in Colombia", *Revista de Planeación y Desarrollo*. Colombia, Departamento Nacional de Planeación.

Harberger, A.C. (1972): "On Measuring the Social Opportunity Cost of Public Funds". In: *Project evaluation: Collected papers*. Chicago: University of Chicago Press.

Harberger, A.C. (1976): *Project Evaluation: Collected Papers*. The University of Chicago Press. Chicago.

Harberger, A.C. (1978): "On the Use of Distributional Weights in Social Cost-Benefit Analysis", *Journal of Political Economy*, 86 (2): S87-S120

Harberger, A.C. (1984): "Basic Needs versus Distributional Weights in Social Cost-Benefit Analysis", *Economic Development and Cultural Change*, 32(3): 55-474.

Harberger, A.C. and D. Wisecarver (1977): "Private and Social Rates of Return to Capital in Uruguay", *Economic Development and Cultural Change*, 25(3): 411-445.

Harrison, M. (2010): "Valuing the Future: the Social Discount Rate in Cost-Benefit Analysis". *Visiting Researcher Paper*, Australian Government Productivity Commission, Canberra.

Hartman, J.C. and I.C. Schafrick (2004): 'The Relevant Internal Rate of Return', *The Engineering Economist*, 49(2), 139–158.

Harvey, C.M. (1994): "The Reasonableness of non-Constant Discounting", *Journal of Public Economics*, 53: 31-51.

Haveman, R.H. (1969): "The Opportunity Cost of Displaced Private Spending and the Social Discount Rate". *Water Resources Research*, 5(5), 947–957.

Henderson, N. and Bateman, I. (1995): "Empirical and Public Choice Evidence for Hyperbolic Social Discount Rates and the Implications for Intergenerational Discounting", *Environmental and Resource Economics*, 5: 413–423.

Hepburn, C., and B. Groom (2007): "Gamma Discounting and Expected net Future Value", *Journal of Environmental Economics and Management*, (53): 99-109.

Hepburn, C., and P. Koundouri (2007): "Recent Advances in Discounting: Implications for Forest Economics". *Journal of Forest Economics*, 13(2–3): 169–189.

Hepburn, C., Koundouri, P., Pasnopoulou, E. and T. Pantelidis (2009): "Social Discounting under Uncertainty: a Cross-country Comparison", *Journal of Environmental Economics and Management*, 57: 140–150.

Hirshleifer, J., DeHaven, J.C. and J.W. Milliman (1960): *Water Supply: Economics, Technology, and Policy*. The University of Chicago Press. Chicago.

HM Treasury (2003): *The Green Book. Appraisal and Evaluation in Central Government*. Online available at www.hm-treasury.gov.uk/economic_data_and_tools/greenbook/.

Hultkrantz, L., N.A. Krüger and P. Mantalos (2014): "Risk-adjusted long-term Social Rates of Discount for Transportation Infrastructure Investment", *Research in Transportation Economics*, 47: 70-81.

IADB (2012): *Guidelines for the Economic Analysis of IADB-Funded Projects*. Inter-American Development Bank. Washington DC.

Jenkins, G.P. (1981): "The Public Sector Discount Rate for Canada: Some Further Observations", *Canadian Public Policy*, 7(3): 399–407.

Johansson, P.O. (1993): *Cost-Benefit Analysis of Environmental Change*. Cambridge University Press, Cambridge.

Kaldor, N. (1939): "Welfare Propositions in Economics". *Economic Journal,* 49(195):549-52.

Kula, E. (1984): "Derivation of Social Time Preference Rates for the United States and Canada", *Quarterly Journal of Economics*, 99(4): 873–882.

Layard, R. and S. Glaister (1994): *Cost-Benefit Analysis*. Cambridge University Press. Cambridge.

Levy, N. and A. Pauzner (2014): "Government's Credit-rating Concerns and the Evaluation of Public Projects", *Journal of Public Economics*, 115: 117-130

Lind, R.C. (1982): "A Primer on the Major Issues Relating to the Discount Rate for Evaluating National Energy Options", in Lind, R. C. (ed.) *Discounting for Time and Risk in Energy Policy*, Washington, DC: Resources for the Future: 21-94.

Lind, R.C. (1995): “Intergenerational Equity, Discounting, and the Role of Cost–Benefit Analysis in Evaluating Global Climate Policy”, *Energy Policy*, 23(4–5): 379-89.

Little, I.M.D. and J.A. Mirrlees (1974): *Project Appraisal and Planning for Developing Countries.* Heinemann. London.

Liu, L. (2003): “A Marginal Cost of Funds Approach to Multi-period Public Project Evaluation: Implications for the Social Discount Rate”, *Journal of Public Economics*, 87: 1707-1718.

Lyon, R. (1990): “Federal Discount Rate Policy, the Shadow Price of Capital, and Challenges for Reforms”, *Journal of Environmental Economics and Management*, 18: S29–S50.

Marglin, S.A. (1963a): “The Social Rate of Discount and the Optimal Rate of Investment”, *Quarterly Journal of Economics*, 77: 95–112.

Marglin, S.A. (1963b): “The Opportunity Cost of Public Investment”, *Quarterly Journal of Economics*, 77: 274-289.

Marglin, S.A. (1963c): *Approaches to Dynamic Investment Planning.* North-Holland. Amsterdam.

Mazur, J.E. (1984): “Tests of an Equivalence Rule for Fixed and Variable Delays”, *Journal of Experimental Psychology: Animal Behavior Processes*, 10: 426-436.

Meunier, D., E. Quinet and Q. Roquigny (2014): “An assessment of present state and possible improvements of cost-benefit analysis in France”. Transport Research Arena 2014, Paris.

MIDEPLAN (2008). *Metodología General de Preparación y Evaluación de Proyectos*. Ministerio de Planificación y Cooperación. Chile

MIDEPLAN (2009): *Manual de Procedimientos*, Sistema Nacional de Inversiones, Subsistema Análisis Técnico-Económico, Ministerio de Planificación y Cooperación, División Planificación, Estudios e Inversión. Chile.

Mikesell, R.F. (1977): *The Rate of Discount for Evaluating Public Projects*. American Enterprise Institute for Public Policy Research. Washington DC.

Moore, M.A and V.K. Viscussi (1990b): “Models for estimating discount rates for long-term health risks using labor market data”, *Journal of Risk and Uncertainty*, 3(4): 381–401.

Moore, M.A. and V.K. Viscussi (1990a): “Discounting environmental health risks: new evidence and policy implications”, *Journal of Environmental Economics and Management*, 18(2), (Supplement): S51–S62.

Moore, M.A., A.E. Boardman and A.R. Vining (2015a): “More appropriate discounting: the rate of social time preference and the value of the social discount rate”, *Journal of Benefit-Cost Analysis*; 4(1): 1–16.

Moore, M.A., A.E. Boardman and A.R. Vining (2015b): "The choice of the social discount rate and the opportunity cost of public funds", *Journal of Benefit-Cost Analysis*; 4(3): 401–409.

Moore, M.A., Boardman, A.E., Vining, A.R., Weimer, D.W. and D.H. Greenberg (2004): "Just give me a number!: practical values for the social discount rate", *Journal of Policy Analysis and Management*, 23(4): 789–812.

Mouter N., J.A. Annema and B. van Wee (2011): "Current issues in the Dutch CBA practice", *CTS Workshop on Contemporary Issues in CBA in the Transport Sector*, Stockholm.

National Development and Reform Commission (NDRC) of the People's Republic of China (2006). *The Economic Analysis of Construction Projects: Methods and Parameters*, 3rd version. Ministry of Construction. Unpublished. As cited by Zhuang *et al*. (2007).

Newell, R.G. and W.A. Pizer (2003): "Discounting the distant future: how much do uncertain rates increase valuations?", *Journal of Environmental Economics and Management*, 46: 52–71.

Nordhaus, W.D. (1999): "Discounting and public policies that affect the distant future", in: P.R. Portney and J. P. Weyant (eds.), *Discounting and intergenerational equity*. Washington, DC: Resources for the Future: 145–162

Olson, M. and M.J. Bailey (1981): "Positive Time Preference", *Journal of Political Economy* 89(1): 1-25.

OMB. Office of Management and Budget (1992): *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*. The White House. Washington DC. Online available at: http://www.whitehouse.gov/omb/circulars/

Ortegón, E. and J.F. Pacheco (2004): "Los sistemas nacionales de inversión pública en Centroamérica: marco teórico y análisis comparativo multivariado", Serie Manuales Nº 34, *Instituto Latinoamericano y del Caribe de Planificación Económica y Social (ILPES)*, Área de proyectos y programación de Inversiones, CEPAL.

Ortegón, E. and J.F. Pacheco (2005): "Los sistemas nacionales de inversión pública en Argentina, Brasil, México, Venezuela, y España como caso de referencia (cuadros comparativos)", Serie Manuales Nº 40, *Instituto Latinoamericano y del Caribe de Planificación Económica y Social (ILPES)*, Área de proyectos y programación de Inversiones, CEPAL.

Osborne, M.J. (2010): "A resolution to the NPV-IRR debate?", *The Quarterly Review of Economics and Finance*, 50: 234–239.

Palacios-Huerta, I. (2003): "Time-Inconsistent Preferences in Adam Smith and David Hume", *History of Political Economy*, 35(2): 241-268.

Parker, R.H. (1968): “Discounting Cash Flow in Historical Perspective”, *Journal of Accounting Research*, 6(1): 58-71.

Pearce, D. and D. Ulph (1999): “A social discount rate for the United Kingdom”, in D.W. Pearce (ed.), *Environmental Economics: Essays in Ecological Economics and Sustainable Development*, Cheltenham: Edward Elgar: 268–285.

Pearce, D., B. Groom, C. Hepburn and P. Koundouri (2003): “Valuing the Future. Recent advances in social discounting”, *World Economics*, 4(2): 121–141.

Percoco, M. (2008): “A social discount rate for Italy”, *Applied Economics Letters*, 15(1): 73–77.

Percoco, M. and P. Nijkamp (2006): “Individual Time Preferences and Social Discounting: A Survey and a Meta-Analysis”, *ERSA Conference Papers*, European Regional Science Association.

Priemus, H., B. Flyvbjerg, and B. van Wee (2008): *Decision-Making on Mega-Projects, Cost-Benefit Analysis Planning and Innovation*. Edward Elgar Publishing Limited, Glos, UK.

Promislow, S.D. and D. Spring (1996): “Postulates for the internal rate of return of an investment project”, *Journal of Mathematical Economics*, 26: 325–361.

Quirk, J.P. and K.L. Terasawa (1987): *The Choice of Discount Rate Applicable to Government Resource Use. Theory and Limitations*. RAND National Defense Research Institute. Washington.

Ramírez, V. (2010): “The Practice of Cost-Benefit Analysis in the Transport Sector: A México Perspective”, *ITF-OECD Round Table on Improving the Practice of Cost-Benefit Analysis in Transport*, Instituto Mexicano de Transporte, Querétaro, México.

Ramsey, D.D. (1969): “On the Social Rate of Discount: Comment”, *American Economic Review*, 59(5): 919–924.

Ramsey, D.D. (1970): “The Marginal Efficiency of Capital, the Internal Rate of Return, and Net Present Value: An Analysis of Investment Criteria”, *Journal of Political Economy*, 78 (5): 1017-1027.

Ramsey, F.P. (1928): “A mathematical theory of saving”, *Economic Journal*, 38: 543–559.

Robinson, J.C. (1990): “Philosophical Origins of the Social Rate of Discount in Cost-Benefit Analysis”, *The Milbank Quarterly*, 68 (2): 245–265.

Rose, D. (2006): “The Public Sector Discount Rate”. Paper presented at the New Zealand *Association of Economists Annual Conference*, 26 June, Christchurch, New Zealand.

Rubinstein, A. (2003): “Is it economics and psychology? The case of hyperbolic discounting”, *International Economic Review*, 44: 1207-1216.

Sandmo, A. and J.H. Drèze (1971): "Discount Rates for Public Investment in Closed and Open Economies", *Economica*, 38(152): 395–412.

Savvides, S. (1994): "Risk Analysis in Investment Appraisal", *Project Appraisal*, 9(1): 3–8.

Schulze, W. and D. Brookshire (1982): "Intergenerational Ethics and Depletion of Fossil Fuels" in J. Quirk *et al*. (eds.), *Coal Models and Their Use in Government Planning*, Praeger Publishers, New York, Chap. 10.

Seagraves, A.J. (1970): "More on the Social Rate of Discount", *Quarterly Journal of Economics*, 84(3): 430–450.

Sen, A. (1961): "On Optimizing the Rate of Saving", *Economic Journal*, 71: 74-84.

Sen, A.K. (1967): "Isolation, Assurance and the Social Rate of Discount", *Quarterly Journal of Economics*, 81: 112-124.

Spackman, M. (2004): "Time Discounting and the Cost of Capital in Government", *Fiscal Studies* 25(4): 467–518.

Steiner, P.O. (1959): "Choosing Among Alternative Public Investments in the Water Resource Field", *American Economic Review*, 49: 893-916.

Stern, N. (2008): "The Economics of Climate Change", *American Economic Review: Papers & Proceedings*, 98(2): 1–37.

Stiglitz, J. (1982): "The Rate of Discount for Benefit–Cost Analysis and the Theory of the Second Best', in R.C. Lind (ed.) *Discounting for Time and Risk in Energy Policy*, Washington, DC: Resources for the Future: 21-94.

Treasury Board of Canada Secretariat (1998): *Benefit Cost Analysis Guide*. Canada. Online available at www.tbs-sct.gc.ca/fin/sigs/Revolving_Funds/bcag/BCA2_E.asp

Tullock, G. (1964): "The Social Rate of Discount and the Optimal Rate of Investment: Comment", *Quarterly Journal of Economics*, 78: 331-336.

Usher, D. (1970): "On the Social Rate of Discount: Comment", *American Economic Review*, 60: 925-929.

Weitzman, M.L. (1994): "On the *environmental* discount rate", *Journal of Environmental Economics and Management*, 26 (1): 200–209.

Weitzman, M.L. (1998): "Why the far-distant future should be discounted at its lowest possible rate", *Journal of Environmental Economics and Management*, 36: 201–208.

Weitzman, M.L. (2001): "Gamma discounting", *American Economic Review*, 91: 260–271.

Weitzman, M.L. (2010): "Risk-adjusted Gamma Discounting", *Journal of Environmental Economics and Management*, 60: 1-13.

Zhuang, J., Liang, Z. Lin, T. and F. De Guzmán (2007): "Theory and Practice in the Choice of Social Discount Rate for Cost–Benefit Analysis: A Survey", *ERD Working Paper* No. 94, Asia Development Bank.

Zuber, S. and G.B. Asheim (2012): "Justifying Social Discount: the rank-discounted Utilitarian Approach", *Journal of Economic Theory*, 147: 1572-1601.