Social Discount Rates*

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May 6, 2008

Abstract

There is no consensus in the literature on how to discount social investments. In this work, a social time preference methodology derived from Feldstein (1965) is applied to calculate social discount rates across 167 countries and across time from 2005-2050 for a country case (Brazil). This attempt seeks to compute comparable figures from a homogeneous dataset and provides a ready-to-use framework for computing the social discount rate. Social projects are important for stimulating economic development, especially in developing economies. Since social discounting allows for a better allocation of resources, this is a critical issue for the public sector in those economies and the quest for a proper measure of discounting becomes quite relevant.

JEL classification: D61, H43, I10, I31, Q51
Keywords: social discount rate, allocative efficiency, cost-benefit analysis, project evaluation, general welfare, economic evaluation of social programs

1 Introduction

Discounting is the process of weighting values at different points in time. Social discounting refers to the process of weighting costs and benefits of social investments. The relevant question is this: which rate should be used to discount social projects?

Historically, although time preference in economic literature dates mainly to the 1920s with Ramsey's (1928) model on saving, actual debate results from the rise of cost-benefit analysis (CBA) in the 1950s and 1960s (Spackman, 2004). Recently, the discount of social projects has become an important topic of study because of its application to environmental economics (Pindyck, 2007), a field of enormous importance to all societies, which presents

*We are thankful to Kimberly Crawford for editorial assistance. The usual caveat applies.

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many uncertainties for the economic theory to address. For example, a social discount rate (SDR) should be used to discount the future costs and benefits of climate change (Hepburn, 2006; Nordhaus, 2007; Stern Review, 2007; Weitzman, 2007). The SDR may also be applied to other social areas, such as health economics, in which economic evaluation of health care programs also demands discounting (Drummond et al, 2005).

However, there is no consensus in the literature on how to discount social investments (Feldstein, 1964; Sen, 1982; Arrow, 1995; Frederick et al, 2002; Caplin and Leahy, 2004; Spackman, 2004; Nordhaus, 2007; Pindyck 2007; Weitzman, 2007). In the literature, the annual discount rate estimates vary from negative values to infinite (Frederick et al, 2002). The lack of consensus on the appropriate discount rate refers to a conceptual difference about the nature of this rate which is reflected in the multiple methodologies. The main two methods used differentiate the social discount rate as either an ethical or a prescriptive choice (Arrow, 1995). The ethical choice means a moral judgment regarding future generations and the prescriptive choice expresses the private investment replacement by the public investment. In the literature, the ethical choice is known as the social time preference (STP) approach, the prescriptive choice as the social opportunity cost (SOC) approach, with the STP being the most recommended and used (Feldstein, 1964, 1965; Spackman, 1991, 1994; Pearce and Ulph, 1995; Oxera, 2002; Evans, 2005). Although the shadow price procedure (based on the SOC) is theoretically correct, the rationale for not pursuing it is explained by the problems of quantifying participation of investment and consumption in public expenditure (Spackman, 1991). As public investments are funded by distortionary taxes, both private investment and consumption are displaced (Arrow, 1995).

Market imperfections and even ethical issues can cause difficulties in deriving the appropriate discount rate. A lot of issues are at stake. Aggregation of individual discount rates is not recommended, even when social rather than private decisions are considered (Sen, 1982). Furthermore, discount rates for social projects must be carefully chosen in order to consider future generations' interests, not kept by individual discount rates (Sen, 1982).

The inoptimality of market mechanisms to derive the optimal savings and social discount rate can be exemplified by the isolation paradox, derived from prisoner's dilemma by Sen (1967). The paradox says that a social contract which allows a better payoff is only achieved by enforcement, since (isolated) subjects are unwilling to save individually as much as collectively. Along with the isolation argument, there are at least three more arguments to justify the inappropriateness of using market prices (Hepburn, 2006): market imperfections themselves, the "super-responsibility" role of the government and the dual-role of the agents/citizens. Market imperfections, such as externalities, distortionary taxation, imperfect information, market power, sub-optimum distribution of income, among others, call into question the use of market prices to estimate the social discount rate (Dréze and Stern, 1990; Cowen, 2008). The "super-responsibility" role of government refers to the government's responsibility over future generations. Since markets only reveal preferences of current generations, governmental policy should go beyond market information. Finally, related to the previous point, the dual-role implies that, in the political arena, citizens may be more concerned about future generations than their own decisions as agents, which are expressed in the market.

Market interest rates have yet another limitation when being used to evaluate social investments, due to the shortcomings of revealed preferences [1]. Caplin and Leahy (2004) and Farhi and Werning (2007) argue that the social discount factor should be higher than the private one. Their results imply that policy makers should be more patient than private citizens. Caplin and Leahy (2004) arrive at that result in a dynamic framework, while Farhi and Werning (2007) claim that society discounts less since the income of future generations is a public good that all generations may enjoy. However, population growth does not play any role in their analyses.

The recommendation of the STP approach (in opposition to the SOC approach) still does not mean a unified analytical theory. As Feldstein stated in 1964, "the search for a 'perfect' formula to specify the social time preference rate is futile". Cowen (2008) goes further claiming that "the proper discount rate will be context-dependent". Although there is no perfect formula, the Ramsey equation (Ramsey, 1928) has been widely used and accepted (Pearce and Ulph, 1995; Oxera, 2002; Evans, 2005; Spackman, 2004). The equation is composed of the pure time discount rate, the income elasticity of the marginal utility of income, also often described as relative risk aversion, and the rate of growth of per-capita income, the less controversial variable. There are multiple methodologies to estimate the income elasticity of the marginal utility of income and multiple views on the pure rate of time preference. Cowell and Gardiner (1999) present different alternatives to estimate the elasticity of marginal utility (utility as satisfaction; utility and preference analysis, the von-Neumman-Morgenstern approach; the social-welfare function and the Harsanyi lottery), deriving practical estimations from the income tax scheme, as replicated in Evans (2005), assuming the equal sacrifice principle (Young, 1987). In Spackman (2004) the estimation of the elasticity of marginal utility includes factors such as: the moral dimension, the personal savings behavior, the direct evidence on personal risk aversion, income price elasticities and intuition alternatives, along with the impact of a distortionary tax regime.

There is not a consensus on the pure rate of time preference in the literature either. It

[1] First, the use of revealed preferences is necessary since we do not observe actual private preferences. Second, they claim that revealed preferences may be potentially time-variant.

varies regarding estimates (negative to positive) and definitions (Pearce and Ulph, 1995), and a zero value cannot be disregarded as a reasonable rate, once one considers ethical and temporal issues. According to Ramsey (1928), a positive pure rate of time preference is ethically indefensible. Despite an intention to treat future generations equally, a game-theoretic interpretation of savings behavior showed that the obligation of sacrifice of present generations to benefit future generations may have a similar result as an exponential discounting (Arrow, 1995). Then, an analysis of ethical obligations to the future derived from such a model would allow a positive rate of time preference (Arrow, 1995). Leaving the ethical issue aside, temporal issues affect not only the pure rate of time preference but also the social discount rate. For long time horizons, a SDR close to zero is not implausible. It implies an equally zero rate of time preference (Pindyck, 2007).

The multiplicity of methodologies, the debate about the nature of the rate and the inconclusiveness of SDR estimates show the concern of discounting in economic theory as well as in applied economics. The vast possibilities of application of the SDR and their consequences to societies' future make its study so relevant, indicating the importance of the quest for a standardization of its use.

We take an agnostic view and follow Feldstein (1965) in deriving a micro-founded STP rate, which directly incorporates demographic variables. Thus, we provide a ready-to-use framework for computing the social discount rate that can be easily applied. Using a uniform dataset, we compute the STP rates for 167 countries, both developed and developing economies, for a given year. Finally, we compute the STP rates across time for the period 2005-2050 for a country case (Brazil). For that, we use forecasts of the model parameters required to compute the rate (e.g., population growth, per-capita income growth, marginal utility of income, etc).

The next section derives the discount rate in a micro-founded setting à la Feldstein (1965). Section 3 provides a baseline calibration for the discount rate and some sensitivity of the parameters. The data is presented in section 4, where we compute the social discount rates for 167 countries. In section 6, we shed some light on time-variation aspect of the STP rate, with the calculation of the long-term social discount rate from 2005 until 2050 for Brazil. Finally, discussion and concluding remarks follow in section 7.

2 Model: Feldstein

This section is heavily based on Feldstein (1965). The derivation of the social time preference (STP) rate is made under four assumptions, set by Feldstein (1965). They are:

1. Individual consumption is distributed equally in the population[2], so that $c_{i,t} = c_{j,t}$ for all i, j and t, where $c_{i,t}$ is the consumption of individual i at period t. As a first departure from Feldstein, we consider per-capita income, y_t, instead. This implies that

$$Y_t = N_t y_{i,t} \tag{1}$$

where Y_t is total income (GDP, for example) and N_t is total population at time t. Feldstein's caveat about the distribution of consumption also follows through concerning the distribution of income. This departure may be seen as innocuous theoretically, but it is extremely important quantitatively. Our choice of total income instead of total consumption is related to the fact that total income better reflects the wellbeing of a nation. In many modern economies, governments provide a lot of private goods. Take the case of Sweden, where private consumption is just 48% of GDP, but a large chunk of the government expenditures are indeed publicly provided private goods. While in the United States, for example, a household purchases medical coverage in the private market, in Sweden, this same household can make this purchase indirectly through taxation and public universal health care. Evidence on the substitutability between publicly provided goods and private consumption can be found in Lindbeck and Weibull (1988), Lindbeck and Nandakumar (1990), Evans and Karras (1998), Ho (2001), among others.

2. All individuals have the same utility function u_t over per-capita income[3] with a constant coefficient of relative risk aversion $\sigma > 0$ and marginal utility given by:

$$u_t' = \eta y_t^{-\sigma}, \tag{2}$$

where η is a constant;

3. Social utility U_t is not necessarily the sum of individuals utilities. Since we are in the case with equal distribution of income, Feldstein (1965) and we assume

$$U_t = N_t^{\alpha} u_t, \tag{3}$$

where $\alpha \in [0, 1]$ gives the weight of the population size N_t on the social utility;

[2] Feldstein (1965) has a section on the "Irrelevance of Distribution of Consumption", in which he shows this assumption is made without loss of generality.

[3] Because of the first assumption, we are dropping the subscript i for individuals.

4. Felicity F is the discounted sum of future social utilities:

$$F = \sum_{t=0}^{\infty} \beta^t U_t, \tag{4}$$

where $\beta \in (0, 1)$ is a 'pure' time preference factor[4].

With these assumptions we are ready to derive the STP rate. We refer to Feldstein (1965) for further detailed explanations on the assumptions. The STP rate between years $t-1$ and t (d_t) is defined as:

$$d_t \equiv \text{MRS}_{t,t-1} - 1, \tag{5}$$

where $\text{MRS}_{t,t-1}$ is the marginal rate of substitution of income between $t-1$ and t. By definition:

$$\text{MRS}_{t,t-1} = \frac{\partial F / \partial Y_{t-1}}{\partial F / \partial Y_t}.$$

Using equation (4), we can derive $\partial F / \partial Y_{t-1}$ and $\partial F / \partial Y_t$:

$$\frac{\partial F}{\partial Y_{t-1}} = \beta^{t-1} \frac{\partial U_{t-1}}{\partial Y_{t-1}} \quad \text{and} \quad \frac{\partial F}{\partial Y_t} = \beta^t \frac{\partial U_t}{\partial Y_t}.$$

Hence,

$$\text{MRS}_{t,t-1} = \frac{\beta^{t-1} \partial U_{t-1} / \partial Y_{t-1}}{\beta^t \partial U_t / \partial Y_t} = \frac{\partial U_{t-1} / \partial Y_{t-1}}{\beta \partial U_t / \partial Y_t}.$$

The first assumption and equation (1) imply that $\partial y_t / \partial Y_t = N_t^{-1}$. Let us define π_t as the rate of population growth between period $t-1$ and t. Using equation (3):

$$\frac{\partial U_t}{\partial Y_t} = N_t^{\alpha} \frac{\partial u_t}{\partial Y_t} = N_t^{\alpha} \frac{\partial u_t}{\partial y_t} \frac{\partial y_t}{\partial Y_t} = N_t^{\alpha} u_t' N_t^{-1} = N_t^{\alpha-1} u_t'.$$

Similarly,

$$\frac{\partial U_{t-1}}{\partial Y_{t-1}} = N_{t-1}^{\alpha-1} u_{t-1}' = N_t^{\alpha-1} \left(1 + \pi_t\right)^{1-\alpha} u_{t-1}'.$$

Then,

$$\text{MRS}_{t,t-1} = \frac{N_t^{\alpha-1} \left(1 + \pi_t\right)^{1-\alpha} u_{t-1}'}{\beta N_t^{\alpha-1} u_t'} = \left(1 + \pi_t\right)^{1-\alpha} \frac{u_{t-1}'}{\beta u_t'}. \tag{6}$$

[4] The notation that we use is a bit different from Feldstein (1965). He uses β for the constant elasticity of utility, P for population size, and τ for the *rate* of discounting. In this paper, we use σ to indicate the constant coefficient of risk aversion and σ is the negative of Feldstein's β. We define β, instead, as the pure time preference *factor*.

Substituting the marginal utility in (2) at (6) and applying the result in (5) deliver the STP rate:

$$d_t = \frac{(1+\pi_t)^{1-\alpha}}{\beta} \left(\frac{y_{t-1}}{y_t} \right)^{-\sigma} - 1. \tag{7}$$

Let us define γ_t as the growth rate of per-capita income between period $t-1$ and t and r as the pure time preference rate, where $\beta(1+r) = 1$. Then, we can rewrite (7) as:

$$d_t = (1+\pi_t)^{1-\alpha} (1+\gamma_t)^{\sigma} (1+r) - 1, \tag{8}$$

which is equivalent to equation (7a) in Feldstein (1965).

3 Baseline calibration

As seen by expression (8), the STP rate depends on a number of parameters: population weight, population growth, per-capita income growth, marginal utility of income (which equals to the coefficient of risk aversion), and pure time preference rate. First, we introduce our baseline parametrization, presented in Table 1. This calibration is not intended to represent any country, but still features values that we consider reasonable for each of the parameters. We proceed to check the sensitivity of the STP rate given changes in each of the parameters holding the others fixed.

Parameter	Economic interpretation	Value
α	population weight	0.5
π	population growth	1%
γ	per-capita income growth	2%
σ	coefficient of risk aversion	1
r	pure time preference rate	1%
d	resulting STP rate	3.53%

Table 1: General baseline calibration

3.1 Population curvature parameter α

The parameter α works both as the curvature of the population growth on the STP rate, and also as the weight put on the size of the population according to (3). It can vary between zero and one. The effect of α on the STP rate is negative. Then, more weight on population will result in a lower rate. Given our parametrization, the effect of increasing α by 0.25 is a reduction in the STP rate of about 0.26 percentage points.

Population weight	0.00	0.25	0.50	0.75	1.00
STP rate (%)	4.05	3.79	3.53	3.28	3.02

Table 2: Population curvature parameter

3.2 Population growth π

The rate of population growth positively affects the STP rate and its curvature is given by α (analyzed above). We consider values of π_t between -0.5% and 2.5%. The following table brings the calculations of the rate for different values of π. For the calibration adopted, an increase of 0.5% in the population growth increases the STP rate by about 0.25 percentage points.

Population growth (%)	-0.5	0.0	0.5	1.0	1.5	2.0	2.5
STP rate (%)	2.76	3.02	3.28	3.53	3.79	4.05	4.30

Table 3: Population growth

3.3 Per-capita income growth γ

We vary the growth rate of income from 0 to 10%. The effect of the income growth rate on the STP rate is positive. An increase of 2 percentage points in the consumption growth rate leads to an increase of a little more than 2 percentage points on the STP rate.

Consumption growth (%)	0.0	2.0	4.0	6.0	8.0	10.0
STP rate (%)	1.50	3.53	5.56	7.59	9.62	11.65

Table 4: Per-capita income growth

3.4 Coefficient of relative risk aversion σ

The coefficient of relative risk aversion or, equivalently, the marginal utility of income, is quite hard to estimate. In macroeconomic models with standard preferences[5], σ usually varies between 1 and 4 (Lucas, 2003). This is the range we consider in the table below. As seen on the following table, an increase of σ of 0.5 leads to an increase of slightly more than 1% in the STP rate.

CRRA	1.0	1.5	2.0	2.5	3.0	3.5	4.0
STP rate (%)	3.53	4.56	5.60	6.66	7.72	8.79	9.87

Table 5: Coefficient of relative risk aversion

[5] As the utility function assumed in the model (CRRA utility function). Using that specification, $\sigma = 1$ corresponds to the log-utility case.

3.5 Pure time preference rate r

The pure time preference rate is related to the pure discounting of the social utilities, as in (4). There is no consensus value. We consider values between 0% and 1.5%. The effect of r on the STP rate is intuitively positive. For our calibration, increasing r by 0.25% leads to an increase of similar 0.26% in the STP rate. In this case the derivative of d with respect to r is very straightforward:

$$\frac{\partial d}{\partial r} = (1+\pi)^{1-\alpha} (1+\gamma)^{\sigma} ,$$

and, for our parametrization, this equals to about 1.

Pure time preference rate (%)	0.00	0.25	0.50	0.75	1.00	1.25	1.50
STP rate (%)	2.51	2.77	3.02	3.28	3.53	3.79	4.05

Table 6: Pure time preference rate

4 Data and choice of parameters

Our objective now is to compute the STP rate in (8) by adequately choosing the parameters π, γ, α, σ, and r for 168 countries in which we have available data. We discuss the choice of the parameters (one at a time) in the following five subsections. The computed rates and selected bounds are presented in table 7 below (subsection 4.6).

4.1 Population curvature parameter α

The curvature parameter α refers to the population weight in the social utility. There is no calculation of this parameter that we are aware of. We take the same stand as Feldstein (1965) and consider values over the entire admissible range of α (from 0 to 1). In lieu of a better estimate, we consider the mid-point $\alpha = 0.5$ as benchmark. In table 7, we provide bounds considering the two extreme values for α (0 and 1) so that we cover all the range of admissible values. In this way we are providing the upper and lower bounds for the STP rate. Our benchmark is about the mean value.

4.2 Rate of population growth π

We use the population growth rate from the World Development Indicators (WDI) available at World Bank (2007). The figures are for 2006. Ukraine has the lowest rate of population growth of -1.1% and Burundi has the highest of about 3.8%. The average growth rate in the sample is 1.21% and the standard deviation is 1.09%. The distribution of rates is double-picked with the first pick between 0 and 0.5% and at about 1.5%.

4.3 Rate of per-capita income growth γ

We use real per capita GDP growth figures for 2006 from the WDI (World Bank, 2007). The growth rates vary between -7% (Equatorial Guinea) and 13.7% (Armenia). The average per-capita GDP growth rate in the sample is 4% and the standard deviation is 3.14%. The distribution of rates is single-picked. Very few countries display negative growth (11 out of 168) and most countries have growth rates between 2% and 3%.

4.4 Coefficient of relative risk aversion σ

There is no consensus on the parameter σ. Feldstein (1965) argues that higher values of σ would seem less relevant for policy purposes and suggests values between 1 and 2. Stern (1977 apud Pearce and Ulph, 1995) is widely quoted for estimates of value of σ in the range of 1-10 based on three approaches: analysis of complete demand systems, von-Neumann-Morgenstern utility functions, and savings behavior. Estimates based on choice under uncertainty range from 0 to 10 or even higher (Lanot et al, 2006) while estimates based on intertemporal choice vary less (Blundell et al, 1994). Based on the structure of personal income tax rates, a study on 20 OECD countries suggests that, on average, for developed countries σ is close to 1.4 (Evans, 2005).

Layard et al (2008) use data on different countries and time periods to estimate the marginal utility of income from direct measurement of experienced happiness in six major surveys instead of inferences from behavior[6]. Results were very similar among surveys, with a narrow range of 1.19-1.34. They note that the similarity occurs "in spite of the great differences between the countries, cultures, and languages in the surveys" they use. Their best overall estimate is 1.26, and this is the one we use for all countries in our computations.

4.5 Pure time preference rate r

Arrow (2005) indicates 1% as a tentatively pure discount rate. OXERA (2002) stipulated 1% for UK. Stern Review (2007) uses 0.1% per year. Nordhaus (2007), which he calls time

[6] Although the results from Layard et al (2008) are valid across different countries and time periods, their evidence "shed no light on the source of inter-country variability or stability of reported happiness across time". That is a result of marginal utility of income estimation based on happiness surveys which yield single estimate consistent with different data sets.

discount rate, suggests 1.5%. We choose 1% as a mid-point for all the countries. In this way, we limit the cross-country variation in the STP rates due to the pure time preference rate.

4.6 STP rates for 167 countries

Our calculations of the STP rates for 168 countries (presented in table 7) varied from -6.8% for Equatorial Guinea to 18.6% for Armenia. The average computed STP is 6.8% and the standard deviation is 3.9%. Differences among countries result mainly from per-capita income and population growth variations. Gollier (2002) states that the main argument for using a positive discount rate is the fact that income per head is expected to grow over time, making the per-capita income growth an important variable in the determination of the SDR.

[TABLE 7 GOES HERE]

5 Long-term social discount rate: the case of Brazil

The estimates for population growth come from the projected population done by IBGE (2004). It indicates that Brazil's population growth is steadily decreasing from 1.43% in 2005 to 0.24% in 2050, when the population will reach about 260 million people (from about 184 million in 2005). The per capita GDP growth is computed by considering the forecasts of GDP growth. We use data from the World Economic Outlook published in IMF (2007). Brazil's GDP growth is 2.9% for 2005, 3.7% for 2006, the forecast is 4.4% for 2007, and 4% for 2008. These numbers imply per-capita income growth between 2.3% and 3%. For the first 4 years (2005-2008) we display the actual per-capita GDP growths provided by IMF (2007). From 2009 onward, we assume a constant per-capita GDP growth of 2.6% (average of the subperiod 2006-2008 and about the same rate of 2008). Since we expect income to evolve in cycles, we believe that the true STP rates for each year will be fluctuating around our estimates, which better reflect the trend for per-capita income[7]. Finally, we hold the population weight α, the marginal utility of income σ, and the pure time preference rate r fixed at the values described in the previous section, 0.5, 1.26, and 1%, respectively. Table 8 shows the estimates and figure 1 displays the profile of Brazil's social discount rates from 2005 to 2050. The rate initially increases from 3.6% in 2005 to 5.5% in 2007. From there,

[7] The average per-capita income growth for Brazil in the period 1947-2006 is 2.75% according to data from IPEA (the Applied Economic Research Institute of the Brazilian Government; data available at http://www.ipeadata.gov.br). This figure is quite close to the number we use (2.6%), providing more evidence that we are capturing the long-term trend on per-capita income growth.

the STP rate is decreasing over time, reaching a level of slightly below 4.5% in 2050. The average for the entire period is 4.7%.

Under various conditions on preferences and considering decreasing relative and absolute risk aversion, Gollier (2002) shows that growth uncertainty reduces the efficient discount rate at any horizon, and that this discount rate should be smaller for more distant futures. Moreover, the declining discount rate assumption is not only a result of the STP approach. Using the SOC approach (shadow discount rate), Hepburn (2006) concludes that the discount rate should be declining over time to reflect certainty-equivalent path. Other suggestions of discount rates according to time horizons have been done (Gollier, 2002; Oxera, 2002).

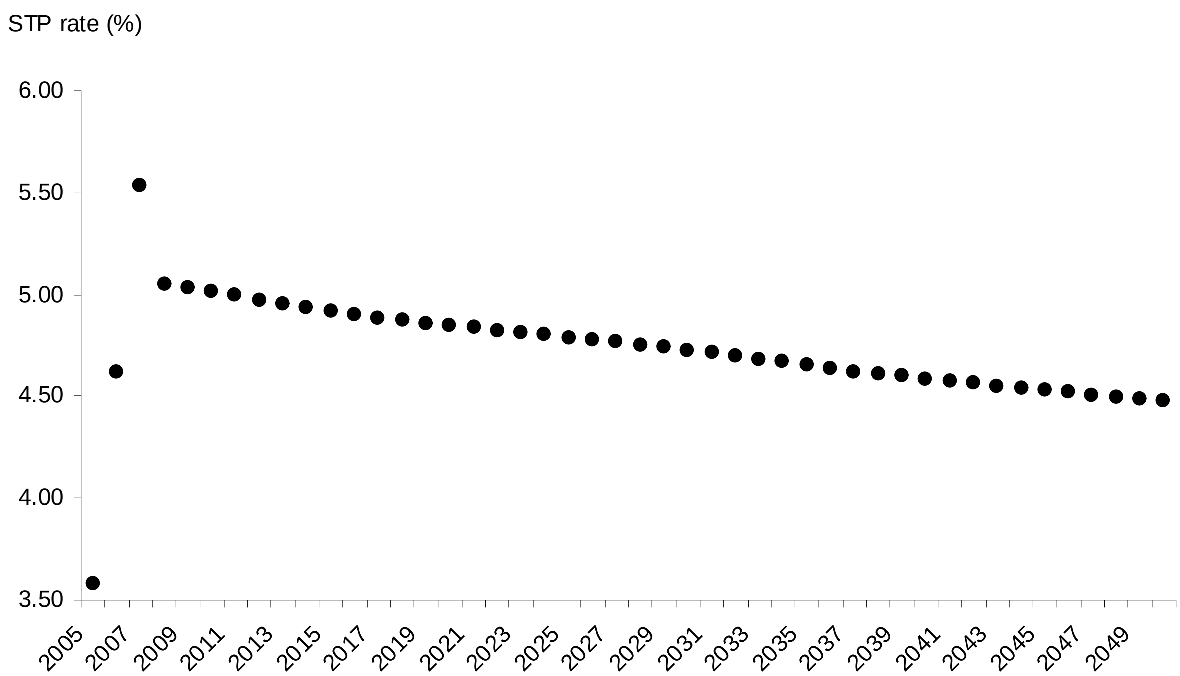

Figure 1: STP rate for Brazil, 2005-2050

[TABLE 8 GOES HERE]

6 Concluding remarks

We provide a ready-to-use framework for computing the social discount rate, based on Feldstein (1965), which can be easily applied. Using an uniform dataset, we compute the STP rates for 167 countries, both developed and developing economies, for a given year (2006). Exploring the time-varying component of STP rates, we compute them for the period 2005-2050 for Brazil, a country case. Our computed values vary across countries and across time. The average STP rate for the 167 countries in the sample is 6.8%. The figures ranged from -6.8% for Equatorial Guinea to 18.6% for Armenia. For Brazil, STP rates display a decreasing profile across time, with an average rate of 4.7%. Computed figures vary from 3.6% and 5.5%.

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Table 7: Social time preference rates for various countries, 2006

Country	π	γ	α	σ	r	d	min d	max d
Albania	0.25	4.7	0.5	1.26	1.0	7.2	7.1	7.3
Algeria	1.50	1.5	0.5	1.26	1.0	3.6	2.9	4.4
Angola	2.82	11.4	0.5	1.26	1.0	17.4	15.7	19.0
Antigua and Barbuda	1.00	6.9	0.5	1.26	1.0	10.4	9.9	11.0
Argentina	0.96	7.4	0.5	1.26	1.0	11.1	10.5	11.6
Armenia	-0.30	13.7	0.5	1.26	1.0	18.6	18.8	18.4
Australia	0.94	1.4	0.5	1.26	1.0	3.3	2.8	3.8
Austria	0.08	3.0	0.5	1.26	1.0	4.9	4.9	4.9
Bangladesh	1.78	4.8	0.5	1.26	1.0	8.2	7.2	9.1
Belarus	-0.61	10.8	0.5	1.26	1.0	14.6	15.0	14.2
Belgium	0.07	3.1	0.5	1.26	1.0	5.0	5.0	5.1
Belize	1.86	2.1	0.5	1.26	1.0	4.6	3.7	5.6
Benin	3.01	1.1	0.5	1.26	1.0	3.9	2.3	5.4
Bhutan	1.57	6.1	0.5	1.26	1.0	9.7	8.8	10.5
Bolivia	1.77	2.8	0.5	1.26	1.0	5.5	4.6	6.4
Bosnia and Herzegovina	0.04	5.7	0.5	1.26	1.0	8.3	8.3	8.3
Botswana	-0.40	4.6	0.5	1.26	1.0	6.7	6.9	6.5
Brazil	1.23	2.4	0.5	1.26	1.0	4.8	4.1	5.4
Bulgaria	-0.53	6.7	0.5	1.26	1.0	9.3	9.5	9.0
Burkina Faso	2.71	2.9	0.5	1.26	1.0	6.1	4.6	7.5
Burundi	3.78	1.3	0.5	1.26	1.0	4.6	2.7	6.5
Cambodia	1.99	8.3	0.5	1.26	1.0	12.8	11.7	14.0
Cameroon	2.21	1.6	0.5	1.26	1.0	4.2	3.1	5.4
Canada	0.80	2.0	0.5	1.26	1.0	3.9	3.5	4.4
Cape Verde	2.27	3.7	0.5	1.26	1.0	7.0	5.8	8.2
Central African Republic	1.42	2.0	0.5	1.26	1.0	4.3	3.6	5.1
Chad	2.44	-1.1	0.5	1.26	1.0	0.8	-0.4	2.0
Chile	0.96	3.0	0.5	1.26	1.0	5.3	4.8	5.8
China	0.56	10.1	0.5	1.26	1.0	14.3	14.0	14.6
Colombia	1.36	5.4	0.5	1.26	1.0	8.6	7.9	9.3
Comoros	2.18	-1.6	0.5	1.26	1.0	0.0	-1.1	1.1
Congo, Dem. Rep.	3.11	1.9	0.5	1.26	1.0	5.0	3.4	6.7
Congo, Rep.	2.66	3.6	0.5	1.26	1.0	7.1	5.7	8.5
Costa Rica	1.40	6.4	0.5	1.26	1.0	10.0	9.2	10.7
Cote d'Ivoire	1.73	2.3	0.5	1.26	1.0	4.8	3.9	5.7

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Table 7 (continued)

Country	π	γ	α	σ	r	d	min d	max d
Croatia	-0.13	4.7	0.5	1.26	1.0	7.0	7.1	6.9
Czech Republic	-0.15	6.2	0.5	1.26	1.0	8.9	9.0	8.8
Denmark	0.23	3.0	0.5	1.26	1.0	4.9	4.8	5.0
Djibouti	1.59	3.2	0.5	1.26	1.0	5.9	5.0	6.7
Dominica	0.55	3.5	0.5	1.26	1.0	5.8	5.5	6.1
Dominican Republic	1.52	9.0	0.5	1.26	1.0	13.5	12.6	14.4
Ecuador	1.39	3.1	0.5	1.26	1.0	5.6	4.9	6.4
Egypt, Arab Rep.	1.84	4.9	0.5	1.26	1.0	8.2	7.2	9.2
El Salvador	1.61	2.2	0.5	1.26	1.0	4.6	3.8	5.4
Equatorial Guinea	2.26	-7.0	0.5	1.26	1.0	-6.8	-7.8	-5.8
Eritrea	3.11	-4.0	0.5	1.26	1.0	-2.5	-4.0	-1.0
Estonia	-0.38	11.8	0.5	1.26	1.0	16.0	16.3	15.8
Ethiopia	2.04	6.8	0.5	1.26	1.0	10.8	9.7	12.0
Fiji	0.68	2.7	0.5	1.26	1.0	4.8	4.4	5.2
Finland	0.17	5.3	0.5	1.26	1.0	7.9	7.8	8.0
France	0.27	1.7	0.5	1.26	1.0	3.3	3.2	3.5
Gabon	1.58	-0.4	0.5	1.26	1.0	1.3	0.5	2.1
Gambia, The	2.35	2.1	0.5	1.26	1.0	4.9	3.7	6.1
Georgia	-0.85	10.3	0.5	1.26	1.0	13.8	14.3	13.4
Germany	-0.07	2.9	0.5	1.26	1.0	4.6	4.7	4.6
Ghana	1.90	4.2	0.5	1.26	1.0	7.4	6.4	8.4
Greece	0.08	4.2	0.5	1.26	1.0	6.4	6.4	6.5
Grenada	1.55	4.9	0.5	1.26	1.0	8.1	7.2	8.9
Guatemala	2.41	2.1	0.5	1.26	1.0	4.9	3.7	6.2
Guinea	2.18	0.6	0.5	1.26	1.0	2.9	1.8	4.0
Guinea-Bissau	2.93	1.2	0.5	1.26	1.0	4.1	2.6	5.6
Guyana	-0.01	4.8	0.5	1.26	1.0	7.2	7.2	7.1
Haiti	1.40	0.9	0.5	1.26	1.0	2.8	2.1	3.6
Honduras	2.09	3.9	0.5	1.26	1.0	7.1	6.0	8.2
Hong Kong, China	0.97	5.9	0.5	1.26	1.0	9.1	8.6	9.6
Hungary	-0.31	4.2	0.5	1.26	1.0	6.2	6.4	6.1
Iceland	0.75	1.8	0.5	1.26	1.0	3.7	3.3	4.1
India	1.39	7.7	0.5	1.26	1.0	11.7	10.9	12.4
Indonesia	1.13	4.3	0.5	1.26	1.0	7.1	6.5	7.7

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Table 7 (continued)

Country	π	γ	α	σ	r	d	min d	max d
Iran, Islamic Rep.	1.32	4.4	0.5	1.26	1.0	7.4	6.7	8.1
Ireland	1.21	4.7	0.5	1.26	1.0	7.7	7.1	8.4
Italy	-0.06	2.0	0.5	1.26	1.0	3.5	3.5	3.4
Jamaica	0.35	2.3	0.5	1.26	1.0	4.1	4.0	4.3
Japan	-0.16	2.4	0.5	1.26	1.0	3.9	4.0	3.9
Jordan	3.22	3.1	0.5	1.26	1.0	6.7	5.0	8.4
Kazakhstan	1.06	9.4	0.5	1.26	1.0	13.8	13.2	14.4
Kenya	2.59	3.1	0.5	1.26	1.0	6.3	4.9	7.6
Kiribati	1.57	4.2	0.5	1.26	1.0	7.2	6.3	8.0
Korea, Rep.	0.26	4.7	0.5	1.26	1.0	7.2	7.0	7.3
Kyrgyz Republic	1.09	1.6	0.5	1.26	1.0	3.6	3.0	4.1
Lao PDR	1.78	5.7	0.5	1.26	1.0	9.2	8.3	10.2
Latvia	-0.60	12.6	0.5	1.26	1.0	16.9	17.3	16.6
Lebanon	1.10	-1.1	0.5	1.26	1.0	0.2	-0.4	0.7
Lesotho	-0.32	3.1	0.5	1.26	1.0	4.8	5.0	4.7
Liberia	2.95	4.7	0.5	1.26	1.0	8.6	7.0	10.2
Libya	1.91	3.6	0.5	1.26	1.0	6.6	5.6	7.6
Lithuania	-0.51	8.1	0.5	1.26	1.0	11.1	11.4	10.8
Luxembourg	1.17	5.0	0.5	1.26	1.0	8.0	7.4	8.6
Macedonia, FYR	0.19	2.9	0.5	1.26	1.0	4.8	4.7	4.9
Madagascar	2.58	2.2	0.5	1.26	1.0	5.2	3.9	6.6
Malawi	2.17	6.1	0.5	1.26	1.0	10.1	8.9	11.2
Malaysia	1.65	4.2	0.5	1.26	1.0	7.2	6.4	8.1
Mali	2.90	2.5	0.5	1.26	1.0	5.6	4.1	7.2
Marshall Islands	3.35	0.6	0.5	1.26	1.0	3.5	1.8	5.2
Mauritania	2.77	8.7	0.5	1.26	1.0	13.7	12.2	15.3
Mauritius	0.82	2.7	0.5	1.26	1.0	4.9	4.4	5.3
Mexico	1.10	3.6	0.5	1.26	1.0	6.2	5.6	6.8
Micronesia, Fed. Sts.	0.45	-1.1	0.5	1.26	1.0	-0.2	-0.5	0.0
Moldova	-0.87	4.9	0.5	1.26	1.0	6.8	7.3	6.4
Mongolia	1.20	7.1	0.5	1.26	1.0	10.8	10.1	11.4
Montenegro	-0.32	6.8	0.5	1.26	1.0	9.6	9.8	9.4
Morocco	1.17	6.0	0.5	1.26	1.0	9.4	8.7	10.0
Mozambique	1.78	6.6	0.5	1.26	1.0	10.4	9.5	11.4

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Table 7 (continued)

Country	π	γ	α	σ	r	d	min d	max d
Namibia	0.96	3.6	0.5	1.26	1.0	6.1	5.6	6.7
Nepal	1.94	-0.1	0.5	1.26	1.0	1.9	0.9	2.9
Netherlands	0.32	2.6	0.5	1.26	1.0	4.5	4.3	4.6
New Zealand	0.65	1.0	0.5	1.26	1.0	2.7	2.3	3.0
Nicaragua	1.95	1.7	0.5	1.26	1.0	4.2	3.2	5.2
Niger	3.29	0.1	0.5	1.26	1.0	2.8	1.1	4.5
Nigeria	2.40	3.4	0.5	1.26	1.0	6.6	5.4	7.9
Norway	0.44	2.4	0.5	1.26	1.0	4.4	4.1	4.6
Pakistan	2.07	4.1	0.5	1.26	1.0	7.3	6.2	8.4
Palau	0.50	5.2	0.5	1.26	1.0	7.9	7.6	8.2
Panama	1.64	6.4	0.5	1.26	1.0	10.1	9.2	11.0
Papua New Guinea	1.84	1.8	0.5	1.26	1.0	4.3	3.3	5.2
Paraguay	1.99	1.9	0.5	1.26	1.0	4.4	3.4	5.5
Peru	1.43	6.5	0.5	1.26	1.0	10.1	9.4	10.9
Philippines	1.85	3.5	0.5	1.26	1.0	6.4	5.4	7.4
Poland	-0.14	5.9	0.5	1.26	1.0	8.5	8.6	8.4
Portugal	0.38	0.9	0.5	1.26	1.0	2.4	2.2	2.6
Romania	-0.43	8.2	0.5	1.26	1.0	11.3	11.5	11.0
Russian Federation	-0.52	7.3	0.5	1.26	1.0	10.0	10.3	9.7
Rwanda	2.29	2.9	0.5	1.26	1.0	6.0	4.8	7.2
Samoa	0.32	2.0	0.5	1.26	1.0	3.7	3.5	3.8
Sao Tome and Principe	2.26	4.6	0.5	1.26	1.0	8.1	6.9	9.4
Senegal	2.32	0.9	0.5	1.26	1.0	3.4	2.2	4.6
Serbia	-0.02	5.8	0.5	1.26	1.0	8.5	8.5	8.4
Serbia and Montenegro	-0.11	6.2	0.5	1.26	1.0	8.9	9.0	8.9
Seychelles	1.49	3.0	0.5	1.26	1.0	5.6	4.8	6.3
Sierra Leone	2.09	4.9	0.5	1.26	1.0	8.4	7.3	9.5
Singapore	1.18	6.6	0.5	1.26	1.0	10.1	9.5	10.8
Slovak Republic	-0.04	8.3	0.5	1.26	1.0	11.7	11.7	11.6
Slovenia	-0.15	5.4	0.5	1.26	1.0	7.8	7.9	7.7
Solomon Islands	2.40	2.8	0.5	1.26	1.0	5.9	4.6	7.1

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Table 7 (continued)

Country	π	γ	α	σ	r	d	min d	max d
South Africa	1.07	3.9	0.5	1.26	1.0	6.5	6.0	7.1
Spain	0.34	3.5	0.5	1.26	1.0	5.7	5.5	5.9
Sri Lanka	0.74	6.6	0.5	1.26	1.0	9.8	9.4	10.2
St. Kitts and Nevis	0.82	3.7	0.5	1.26	1.0	6.2	5.8	6.7
St. Lucia	0.74	4.1	0.5	1.26	1.0	6.7	6.3	7.1
St. Vincent and the Grenadines	0.49	3.6	0.5	1.26	1.0	5.9	5.6	6.1
Sudan	2.13	10.6	0.5	1.26	1.0	15.9	14.7	17.2
Suriname	0.52	5.3	0.5	1.26	1.0	8.0	7.7	8.3
Swaziland	-0.43	2.5	0.5	1.26	1.0	4.0	4.2	3.8
Sweden	0.24	4.1	0.5	1.26	1.0	6.4	6.3	6.6
Switzerland	0.06	2.6	0.5	1.26	1.0	4.4	4.4	4.4
Syrian Arab Republic	2.38	2.6	0.5	1.26	1.0	5.5	4.3	6.7
Tajikistan	1.55	5.4	0.5	1.26	1.0	8.7	7.9	9.5
Tanzania	2.60	3.3	0.5	1.26	1.0	6.5	5.2	7.9
Thailand	0.77	4.2	0.5	1.26	1.0	6.8	6.4	7.2
Togo	2.56	-1.0	0.5	1.26	1.0	1.0	-0.3	2.3
Tonga	0.13	1.8	0.5	1.26	1.0	3.3	3.3	3.4
Trinidad and Tobago	0.27	12.2	0.5	1.26	1.0	16.9	16.8	17.1
Tunisia	1.03	4.1	0.5	1.26	1.0	6.8	6.3	7.4
Turkey	1.21	4.8	0.5	1.26	1.0	7.8	7.2	8.5
Uganda	3.67	1.5	0.5	1.26	1.0	4.8	2.9	6.7
Ukraine	-1.07	8.3	0.5	1.26	1.0	11.0	11.6	10.4
United Kingdom	0.22	2.6	0.5	1.26	1.0	4.4	4.3	4.5
United States	0.87	2.4	0.5	1.26	1.0	4.5	4.1	5.0
Uruguay	0.22	6.8	0.5	1.26	1.0	9.9	9.8	10.0
Uzbekistan	1.43	5.8	0.5	1.26	1.0	9.2	8.4	10.0
Vanuatu	1.88	3.6	0.5	1.26	1.0	6.5	5.5	7.5
Venezuela, RB	1.67	8.5	0.5	1.26	1.0	12.9	12.0	13.8
Vietnam	1.21	6.9	0.5	1.26	1.0	10.5	9.8	11.2
West Bank and Gaza	3.17	-1.7	0.5	1.26	1.0	0.4	-1.2	1.9
Yemen, Rep.	3.14	0.2	0.5	1.26	1.0	2.8	1.2	4.4
Zambia	1.66	4.3	0.5	1.26	1.0	7.3	6.5	8.2
Zimbabwe	0.59	-5.4	0.5	1.26	1.0	-5.5	-5.8	-5.2

Sources: World Bank (2007), Layard et al (2008), and our own calculations.

Table 8: STP rate for Brazil, 2005-2050

year	π	γ	α	σ	r	d
2005	1.43 %	1.4 %	0.5	1.26	1.0 %	3.58 %
2006	1.40 %	2.3 %	0.5	1.26	1.0 %	4.62 %
2007	1.37 %	3.0 %	0.5	1.26	1.0 %	5.53 %
2008	1.34 %	2.6 %	0.5	1.26	1.0 %	5.05 %
2009	1.30 %	2.6 %	0.5	1.26	1.0 %	5.03 %
2010	1.27 %	2.6 %	0.5	1.26	1.0 %	5.01 %
2011	1.23 %	2.6 %	0.5	1.26	1.0 %	4.99 %
2012	1.19 %	2.6 %	0.5	1.26	1.0 %	4.97 %
2013	1.15 %	2.6 %	0.5	1.26	1.0 %	4.95 %
2014	1.12 %	2.6 %	0.5	1.26	1.0 %	4.94 %
2015	1.08 %	2.6 %	0.5	1.26	1.0 %	4.92 %
2016	1.05 %	2.6 %	0.5	1.26	1.0 %	4.90 %
2017	1.02 %	2.6 %	0.5	1.26	1.0 %	4.89 %
2018	1.00 %	2.6 %	0.5	1.26	1.0 %	4.87 %
2019	0.97 %	2.6 %	0.5	1.26	1.0 %	4.86 %
2020	0.95 %	2.6 %	0.5	1.26	1.0 %	4.85 %
2021	0.92 %	2.6 %	0.5	1.26	1.0 %	4.83 %
2022	0.90 %	2.6 %	0.5	1.26	1.0 %	4.82 %
2023	0.88 %	2.6 %	0.5	1.26	1.0 %	4.81 %
2024	0.86 %	2.6 %	0.5	1.26	1.0 %	4.80 %
2025	0.83 %	2.6 %	0.5	1.26	1.0 %	4.79 %
2026	0.81 %	2.6 %	0.5	1.26	1.0 %	4.78 %
2027	0.79 %	2.6 %	0.5	1.26	1.0 %	4.76 %
2028	0.76 %	2.6 %	0.5	1.26	1.0 %	4.75 %
2029	0.74 %	2.6 %	0.5	1.26	1.0 %	4.74 %
2030	0.71 %	2.6 %	0.5	1.26	1.0 %	4.73 %
2031	0.69 %	2.6 %	0.5	1.26	1.0 %	4.71 %
2032	0.66 %	2.6 %	0.5	1.26	1.0 %	4.70 %
2033	0.63 %	2.6 %	0.5	1.26	1.0 %	4.68 %
2034	0.60 %	2.6 %	0.5	1.26	1.0 %	4.67 %
2035	0.57 %	2.6 %	0.5	1.26	1.0 %	4.65 %

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Table 8 (continued)

year	π	γ	α	σ	r	d
2036	0.54 %	2.6 %	0.5	1.26	1.0 %	4.64 %
2037	0.51 %	2.6 %	0.5	1.26	1.0 %	4.62 %
2038	0.49 %	2.6 %	0.5	1.26	1.0 %	4.61 %
2039	0.47 %	2.6 %	0.5	1.26	1.0 %	4.60 %
2040	0.44 %	2.6 %	0.5	1.26	1.0 %	4.59 %
2041	0.42 %	2.6 %	0.5	1.26	1.0 %	4.57 %
2042	0.40 %	2.6 %	0.5	1.26	1.0 %	4.56 %
2043	0.38 %	2.6 %	0.5	1.26	1.0 %	4.55 %
2044	0.36 %	2.6 %	0.5	1.26	1.0 %	4.54 %
2045	0.33 %	2.6 %	0.5	1.26	1.0 %	4.53 %
2046	0.32 %	2.6 %	0.5	1.26	1.0 %	4.52 %
2047	0.30 %	2.6 %	0.5	1.26	1.0 %	4.51 %
2048	0.28 %	2.6 %	0.5	1.26	1.0 %	4.50 %
2049	0.26 %	2.6 %	0.5	1.26	1.0 %	4.49 %
2050	0.24 %	2.6 %	0.5	1.26	1.0 %	4.48 %

Sources: IBGE (2004), IMF (2007), Layard et al (2008), and our own calculations.