The debate on discounting: Reconciling positivists and ethicists

Christian Gollier[*]
Toulouse School of Economics
May 1, 2012

Abstract: *Using a simple arbitrage argument, positivists claim that the interest rate provides the right basis to fix the discount rate to evaluate green investment projects. The real interest rate observed in the U.S. during the XXth century has been around 1% and 2%. On the contrary, ethicists estimate the discount rate by the marginal rate of substitution between current and future consumption. From classical estimations of intertemporal inequality aversion and prudence, they recommend a discount rate around 3% and 4%. Ethicists are less prone to investing for the future than positivists. I claim that the positivist approach is right if green investment projects are financed by a reallocation of resources from productive capital in the economy. Ethicists are right if they are financed by a reduction of consumption. I also claim that ethicists should use a rate between 1% and 2% to discount benefits occurring in the distant future. This provides two roads to reconcile the two approaches. A specific risk premium should be added to the discount rate that is proportional to the socio-economic beta of the investment project.*

1. Introduction

In their recent book,[1] Eric Posner and David Weisbach argue that issues related to distributional justice should not prevent us to push forward effective policies to fight climate change. Climate change agreements that are aimed to solve all the world's ills and in particular to redistribute wealth across nations are doomed to fail. One particularly important issue is the problem of intergenerational justice to which is associated the issue of the level of the discount rate. In their chapter 7, Posner and Weisbach present the two classical schools of thought for the determination of the discount rate. The "ethicist position" attempts to reason from basic principles about what the discount rate should be. One of these principles is a preference for the reduction of inequalities. On the contrary, the "positivist position" uses the standard arbitrage argument to claim that the discount rate should equal the interest rate observed on markets. There is no doubt that Posner and Weisbach are inclined to support the positivist approach: "*The positivists are*

[1] Posner, E., and D. Weisbach, (2010), *Climate Change Justice*, Princeton University Press.

correct that choosing any project that has a lower rate of return than the market rate of return throws away resources" (p. 159).

In principle, if markets are frictionless and complete, the competitive allocation of resources is efficient and competitive prices provide the right signals to agents to decentralize this allocation. Applied to credit markets, this means that the allocation of consumption and wealth across time is efficient and that the interest rate should be used to discount cash flows. In particular, at equilibrium, the intertemporal rate of marginal substitution (IRMS) of consumption today and tomorrow is equalized to the rate of return of capital, i.e., to the interest rate. In other words, transferring consumption to the future by investing in capital has no impact on intertemporal welfare at the margin. This equality is perfectly illustrated by the Ramsey rule, which equalizes the interest rate with the IMRS. In this context, Posner and Weisbach are perfectly right to claim that sacrificing current consumption to invest in projects that have a return smaller than the interest rate reduces intertemporal welfare, and throw away resources.

But we know that credit markets do not work particularly well. The recent subprime crisis illustrates the various agency problems that make these markets deeply inefficient. Moreover, recent researches at the frontier between cognitive psychology and economics tend to demonstrate that human beings may have difficulty to behave rationally relative to their consumption planning over their lifetime. Last but not least, credit markets are obviously incomplete. In particular, future generations are unable to write contingent contracts with current generations. These arguments imply that the market allocation of resources over time is inefficient, and that the competitive price of time does not provide the right signal to economic agents about saving and investment. This fact corresponds to the so-called "risk free rate puzzle" (Weil (1989)).[2] It states that the observed interest rate over the last century, which has been approximately equal to 1% in real terms in the U.S., is much smaller than the IRMS, which is usually estimated around 4% in real terms. This puzzle just tells us that positivists value the future much more than the ethicists, contrary to what is suggested by Posner and Weisbach. During the XXth century, we accumulated much more capital than what the ethicists would have recommended from their basic principles. This accumulation of (physical, human and intellectual) capital has indeed generated an extraordinary large growth in developed countries at the cost of very large consumption sacrifices from our poor past generations.

Over the past decade, several colleagues have contributed to reducing the gap between the positions of the positivists and of the ethicists. In my forthcoming book,[3] I survey several of these attempts. Most of them are linked to the role of risk in the toolboxes of the two approaches. From the viewpoint of positivists, because fighting climate change has uncertain cash flows, the risk

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[2] Weil, P., (1989): "The Equity Premium Puzzle and the Risk-Free Rate Puzzle," *Journal of Monetary Economics*, 24, 401–421.

[3] Gollier, C., (2012), *Pricing the planet's future: The economics of discounting in an uncertain world*, Princeton Economic Press, in press (publication in October 2012).

free interest rate is not the correct benchmark return to measure the opportunity cost of capital. Adding a risk premium to the interest rate to determine the rate at which benefits of fighting climate change should be discounted is crucial. However, I don't know any paper that provides estimations of the socio-economic "beta" of investment projects that reduce CO2 emissions. From the viewpoint of ethicists, the recognition of the presence of huge long-term risks affecting economic growth tends to reduce their estimation of the IRMS. Prudent planners should ask for more sacrifices to current generations if future generations bear more risk.

All in all, I believe that a consensus is not out of reach between ethicists and positivists, on the basis of a real discount rate for long term investment projects that are safe around 1.5%. A risk premium should be added to this rate for projects whose future socio-economic benefits are highly correlated to future GDP/cap. Let me explain this in more details. All rates used in the following should be interpreted as real rates.

2. The positivist approach

The interest rate observed on financial markets is the rate of return of risk free capital. Any action that would divert some of this productive capital to finance a safe investment project whose return is smaller than the interest rate would destroy wealth. If asked, future generations would reject this action. This arbitrage argument provides a strong argument for using the interest rate as the rate to discount risk free investment projects.

Dimson, Marsh and Staunton (2002)[4] have computed the annualized return on bonds and equities for different countries during the 20th century. Using extended data from the same authors over the period 1900-2006, the main facts are summarized in Table 1. In the United States, the return on T-Bills, which are probably the safest assets in the world, gave a real return of around *1.0%*, whereas 10-year Treasury bonds and equities delivered an average real return of respectively *1.9%* and *6.6%* per year. The real return of these 3 asset classes varies significantly across different countries during the period. In particular, the real return of fixed income assets was negative in countries which fought a world war on their own soil, including Japan, France and Italy. Observe also that the equity premium varies across countries within the range of *3-7%*. The same exercise has been repeated over the shorter time period of 1971-2006. It is notable that the safe return on government bonds was much larger in this period than over the century as a whole, whereas the return on equities has remained stable. A possible explanation for this is the successful fight against inflation by central banks in recent years.

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4 Dimson, E., P. Marsh and M. Staunton, (2002), *Triumph of the Optimists: 101 Years of Global Investment Returns*, Princeton University Press, Princeton.

	Bills		Bonds 10 years		Equity	
	1900-2006	1971-2006	1900-2006	1971-2006	1900-2006	1971-2006
Australia	0,6%	2,5%	1,3%	2,8%	7,8%	6,3%
Canada	1,6%	2,7%	2,0%	4,5%	6,3%	5,8%
Denmark	2,3%	3,5%	3,0%	7,0%	5,4%	9,0%
France	-2,9%	1,2%	-0,3%	6,6%	3,7%	7,8%
Italy	-3,8%	-0,3%	-1,8%	2,8%	2,6%	3,0%
Japan	-2,0%	0,4%	-1,3%	3,9%	4,5%	5,0%
Netherlands	0,7%	1,8%	1,3%	3,9%	5,4%	8,5%
United Kingdom	1,0%	1,9%	1,3%	3,9%	5,6%	7,1%
Sweden	1,9%	2,4%	2,4%	4,2%	7,9%	11,0%
Switzerland	0,8%	0,4%	2,1%	2,8%	5,3%	6,1%
USA	1,0%	1,3%	1,9%	4,0%	6,6%	6,6%

Table 1 : Real returns of financial assets
Sources: Morningstar and Dimson, Marsh and Staunton, (2002)

If we are interested in very short time horizons, bills are the relevant asset class, and a discount rate not larger than 1% is relevant. Of course, this rate should be flexible along the business cycle to take into account of the cyclicity of the opportunity cost of capital. If we are interested risk free cash flows maturing in 10 years, sovereign bonds maturing at the same date are the relevant benchmark asset to perform the arbitrage argument. A real discount rate around 2% is relevant in that case.

Notice that we don't observe the return of assets whose risk free cash flows mature in time horizons exceeding 30 years. The positivist approach fails to provide any clear answer to the determination of the arbitrage-free discount rate for those horizons. The arbitrage argument entails a reinvestment risk in that case. If we consider a project yielding risk free cash flows in 60 years, the natural arbitrage strategy would be to invest in a bond yielding a risk free return in 30 years, and then to reinvest in another 30-year bond at that time. The problem is that we don't know today what will be the risk free rate in 30 years. How should we treat this source of uncertainty related to the opportunity cost of capital? Posner and Weisbach (p. 152) follow a proposal made by Weitzman in 1998 to answer this question.[5][6] They claim that when the interest rate is uncertain, a risk free investment project should be implemented if and only if its expected NPV is positive. Because the NPV is decreasing and convex in the discount rate, this is equivalent to using a decision rule based on a "certainty equivalent" discount rate that is smaller than the expected interest rate. I have shown elsewhere[7] that this argument to reduce the discount

[5] Weitzman, M. L., (1998a), Why the Far-Distant Future Should Be Discounted at Its Lowest Possible Rate, *Journal of Environmental Economics and Management* 36 (3): 201-208.
[6] Weitzman, M.L., (1998b), Gamma discounting, *American Economic Review*, 91, 260-271.
[7] Gollier, C., (2004), Maximizing the expected net future value as an alternative strategy to gamma discounting, *Finance Research Letters*, 1, 85-89.

rate has no scientific basis. Even a risk-neutral investor would not use the expected NPV criterion to evaluate risk free projects when the interest rate is random. For example, such an investor could use the alternative expected Net Future Value criterion, which would yield the opposite policy recommendation to raise the certainty equivalent discount rate under uncertainty. The bottom line is that even the positivist needs to rely on ethical principles when prices are not observable or when markets are incomplete. I will come back to this point in the next section.

The point here is that positivists are weak to provide an answer to the choice of a discount rate corresponding to time horizons expressed in decades and centuries, which are outside the scope of liquid financial markets.

To sum up, we see that the positivist position, which implies a discount rate between 1% and 2% depending upon the maturity and the position in the business cycle, is limited by the problem of incomplete markets. We just don't observe traded assets whose risk and time profiles fit those of climate change. This implies that positivists need to complement their analysis with ethical principles and economic models.

3. The ethicist approach

The ethicists consider another road to estimate the socially efficient discount rate. Remember that the positivist's arbitrage argument relies on the assumption that the investment project under scrutiny is financed through a reallocation of productive capital. No additional sacrifice is requested on the side of current generations for which this reallocation is neutral to their welfare. Only future generations are impacted by this reallocation. The ethicist approach is based on the alternative assumption that the new project entails a reallocation of consumption through time, because the initial implementation cost is financed by a corresponding reduction in current consumption. Ethicists must thus compare the benefit for the future generation to the cost borne by the current one, i.e., it entails interpersonal comparisons of welfare. Their estimation of the discount rate is based on the measurement of the intertemporal rate of marginal substitution (IRMS) between current and future consumption.

Together with Posner and Weisbach and most ethicists, I reject the possibility to weight differently utility changes of different generations. In other words, there is no preference for the present. We value a transfer of consumption by its impact of a social welfare function (SWF). I assume that this SWF takes the form of the undiscounted sum of the flow of utility of the different generations. There are several ways to interpret this SWF. The simplest approach consists in assuming that the current generation is altruistic and values the flow of future consumption as if it would be its own consumption. Under that interpretation, the characteristics of the utility function are those of the preferences of the current generation with respect to intertemporal inequality. This interpretation is of course particularly relevant for short time horizons. An alternative interpretation of the SWF is that it represents our collective attitude towards de distribution of wellbeings across generations. The concavity of the utility function expresses the aversion to intergenerational inequality in that case. I will hereafter refer to this interpretation of the SWF for long time horizons. In any case, the concavity expresses an aversion to consumption inequality.

Ethicists using this SWF usually recommend a positive discount rate on the basis of the following wealth argument: In a growing economy, future generations will be wealthier than us. Because marginal utility of wealth is decreasing, one more unit of consumption in the future has a smaller impact on the SWF than one more unit of consumption today. Thus, one should depreciate changes in consumption that occur later in time. The positive discount rate expresses this wealth effect. It is the minimum rate of return of a safe investment project that compensates the fact that implementing it transfers consumption from the current poors to the future riches, i.e., to compensate for the increased intertemporal inequality that it generates.

The Ramsey rule tells us that the intensity of this wealth effect is equal to the product of the growth rate *g* of consumption by the degree γ of relative inequality aversion. This parameter is ethical. I hereafter use $\gamma = 2$. This means that one is ready to sacrifice as much as 4 dollars from the riches to increase consumption of the poors by 1 dollar, when the consumption of the riches is twice the consumption of the poors. If one assumes that the average growth rate of consumption in the future will be close to the one that has been observed in the western world since the industrial revolution, one should use *g*=2%. This implies a socially efficient discount rate around $2 \times 2\% = 4\%$. Of course, this estimation is sensitive to the selection of the parameters present in the Ramsey rule. The lowest rate existing in the literature is obtained by Stern (2007)[8] who takes *g*=1.3% and $\gamma = 1$, yielding a discount rate of 1.3%.

In reality, the Ramsey rule is useless because we don't know what the growth rate of consumption will be in the future. Estimating the growth rate of consumption for the coming year is already a difficult task. Any estimate of growth for the next decade is subject to potentially very large errors. Over a century estimation errors could be enormous. When the growth rate of consumption is unknown, the intensity of the wealth effect cannot be estimated, and the Ramsey rule is unable to produce a precise prescription for the choice of the discount rate. Uncertainty over how wealthy the future will be at least casts some doubt on the relevance of the wealth effect to justify the use of a large discount rate.

How should the Ramsey rule be adapted in an uncertain world? Determining the optimal level of savings requires an estimate of the future utility gain of this transfer of wealth in a context in which little is known about future incomes. This problem is at the core of the question of what should be done for the future. It is commonly accepted that individuals are ready to sacrifice more in the present for the future when this future becomes more uncertain. Keynes was the first

[8] Stern, N., (2007), *The Economics of Climate Change: The Stern Review,* Cambridge University Press, Cambridge.

to mention this idea by pointing out the precautionary motive for saving. What is desirable at the individual level is also desirable at the collective one. A Society which wants to reinforce the incentive to invest for the future should select a smaller discount rate to evaluate the set of all possible investment projects. Thus ethicists should reduce their estimation of the discount rate in the face of an uncertain economic growth.

What is the intensity of this precautionary effect? If we assume that the growth rate of consumption follows a random walk, Gollier (2002)[9] has shown that the discount rate should be uniformly reduced by $0.5\gamma(1+\gamma)\sigma^2$, where σ is the volatility of the growth rate of consumption. The observed volatility of economic growth in the XXth century in western economies was around 4%. This yields a precautionary effect that reduces the discount rate by 0.48%. Combining the wealth effect and the precautionary effect yields a discount rate of 3.5%.

However, various authors have argued that modelling uncertainty by a random walk for the growth rate of consumption may be reasonable for short term horizons, but this potentially vastly underestimates the long term uncertainty that our planet faces. See for example Weitzman (2007)[10] and Gollier (2012). The history of the western world before the industrial revolution is full of significant economic slumps, such as those which occurred following the collapse of the Roman Empire in the Vth century, or the Black Death epidemic in the mid XIVth century. Some argue that the effects of improvements in information technology have yet to be realized and that the world is entering a period of more rapid growth. By contrast, those who emphasize the effects of natural resource scarcity, or the inability of financial markets to allocate capital efficiently, predict lower growth rates in the future. Some even suggest a negative growth of GDP per head, owing to a deterioration of the environment, population growth and decreasing returns to scale. The implication of this last position is that the wealth effect on the discount rate is negative rather than positive as supposed by most experts. Under these plausible beliefs, the future is poorer than the present so we should make more sacrifices today to improve the future. This short discussion tells us that our civilization faces uncertain future shocks that are likely to be persistent. When shocks exhibit some degree of persistence, assuming a random walk for the growth rate of consumption underestimates the uncertainty affecting the level of consumption enjoyed by generations living in a distant future. Thus, this underestimates the precautionary effect affecting the discount rate to be used for those very long maturities.

In Gollier (2008),[11] I model economic growth by considering various stochastic processes with persistent shocks: mean reversion processes, Markov regime-switches, and brownian processes with parametric uncertainty. These models support a decreasing term structure for the discount

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[9] Gollier, C., (2002b), Time horizon and the discount rate, *Journal of Economic Theory*, 107, 463-473.
[10] Weitzman, M. L., (2007), Subjective expectations and asset-return puzzle, *American Economic Review*, 97, 1102-1130.
[11] Gollier, C., (2008), Discounting with fat-tailed economic growth, Journal of Risk and Uncertainty, 37, 171-186.

rate, with a short term rate around 3.5%, and a discount rate for time horizons exceeding 1 or 2 centuries between 1% and 2%. This decreasing structure biases the evaluation of safe investment projects in favour of those which generates benefits in the distant future.

To sum up, the ethicists base their evaluation of the discount rate on collective preferences characterized by inequality aversion and prudence. Inequality aversion justifies using a discount rate around 4% per year. The precautionary effect justifies reducing this rate by around 0.5% for short maturities and by as much as 3% for much longer maturities.

4. The risk free rate puzzle

Weil (1989) was the first to observe that the positivist and the ethicist positions are difficult to reconcile in the sense that the observed interest rates are much smaller than the IMRS. Indeed, the real interest rate has been between 1% and 2%, whereas the IRMS for time horizons treated by financial markets (less than 30 years) has been estimated above around 3.5%. In other words, economists have hard time to explain why people have sacrificed some much of their past consumption to accumulate capital in a context of low interest rate and of bright economic prospect. From the ethicist viewpoint, this intertemporal allocation of consumption over the last century or so has been vastly inefficient, asking too much sacrifice from poor old generations for the benefit of the current riches. For them, this could have been justified only by the presence of a sequence of extremely profitable short term investment projects with a sure return of at least 3.5%. This is contradicted by the positivist observation that the interest rate, which reflects the rate of return of safe capital, has been much smaller, around 1 or 2%. Ethicists would consider that one has invested too much in the past, and that one should have abstained from investing in all projects whose return were between 2% and 3.5%. This sheds some light on the debate about the short-termism of financial markets. In fact, financial markets have been more long-termist than one would have liked from the viewpoint of intergenerational welfare.

Interestingly enough, observe the reversal of attitude towards the discount rate of the two approaches. Because positivists recommend a lower discount rate than the ethicists, the first are more favourable to sustainable development than the second, at least in the context of the evaluation of projects maturing in less than 30 years. Who is right? To answer this question, consider an investment project with such a relatively short maturity that exhibits a sure real rate of return of 3%. Under the positivist approach, one should implement it, whereas ethicists would go against this implementation. My position on this is contingent to the mode in which this project is funded. If it is financed by a reallocation of productive capital from a sector producing a return of 2% to this project, there is no doubt that this should be done. If it is financed by a reduction in consumption of current generations, I would strongly reject this proposal.

This discussion is not really relevant for climate change, because our actions to fight it will mature only in a distant future for which there is no corresponding risk free asset traded on markets. As said before, the positivists are not in a situation to make a recommendation for the rate at which long benefits should be discounted. On their side, ethicists recommend a discount rate that is smaller than the 3.5%, and that is close to the 1-2% recommended by the positivists for short horizons. It is not clear whether anything more than that can be said to compare the two positions, given the non-applicability of the arbitrage argument used by the positivists in this context.

5. Discounting risky project

Most real collective projects are not safe, and indeed many of them are very risky. This is particularly the case for those yielding cash flows in the distant future. For example, the size of the damages associated to climate change is vastly uncertain. How should this affect the way in which we discount the reduction of these damages obtained from our green investments? In a highly uncertain distant future, how do we value R&D yielding uncertain distant benefits and costs, as is the case for genetically manipulated organisms, or for space exploration? In a less abstract fashion, how do we compare merits of various investment projects that differ not only in their maturities but also in their degrees of riskiness? For example, should we invest in fighting malaria, whose benefits are immediate and almost certain, or in new education and transportation infrastructures in developing countries, whose benefits are more distant and more uncertain?

The positivists and the ethicists have different strategies to answer these questions. Let us first examine the solution provided by the positivists, for relatively short time horizons. Extending the arbitrage argument presented in section 2 to the case of risky projects, one should discount the flow of future expected benefit at the market rate of return of an asset whose risk profile is identical that the one of the investment project under evaluation. Those assets may not be easy to identify. Let us consider a simple application of this arbitrage argument by considering a project whose risk profile is identical to the one of a diversified portfolio of U.S. stocks, for example the SP500. If we rely on Table 1, the expected benefits of this risky project should be discounted at a rate around 6.6%. This discount rate contains the risk free interest rate around 2%, and a risk premium of 4.6%. This gives an order of magnitude of the impact of the riskiness of the project itself on the rate at which it should be discounted when using the positivist approach.

The Capital Asset Pricing Model (CAPM) predicts that the risk premium observed on financial markets for a specific risk profile should be proportional to its financial beta (β), which measures the expected percentage increase in the value of the project when the market value of the SP500 increases by 1%. In particular, marginal projects whose risks can be diversified away in individual portfolios should not get any risk premium.[12] They are actuarially priced, i.e., they should be implemented as soon as the discounted value (with a rate of 2%) of their expected cash flows is non-negative. A project with a risk profile β should be discounted at a rate equalling $2\% + \beta \times 4.6\%$.

The ethicist approach is based on the estimation of the impact of the additional risk generated by the project on the wellbeing of future generations. Adding risk to consumption is bad for future generations because they are risk-averse. This risk aversion comes from the concavity of the utility function, which implies that a given reduction in consumption has a larger impact on utility than its equivalent increase. Consider for example an investment project whose risk profile is identical to the uncertainty affecting aggregate consumption growth: When it increases by 1%, so does the socio-economic benefit of the project. It is easy to check (Gollier (2012)) that such a marginal investment project raises intergenerational welfare if and only if the net present value of its flow of expected benefits is positive, where the discount rate is adapted to the riskiness of the project by adding a risk premium to the risk free rate examined in section 3. This risk premium is equal to $\gamma\sigma^2$, where σ is the volatility of the growth rate of consumption. Using $\sigma = 4\%$ as before, this yields a risk premium associated to the macroeconomic risk around 0.32%. Using a risk free discount rate of 3.5%, this computation supports a discount rate around 3.82%. The Consumption-based Capital Asset Pricing Model (CCAPM) extends this methodology for other risk profiles. Under the CCAPM, the risk profile of an investment is summarized by its socio-economic beta (β^{se}), which measures the expected percentage increase in the socio-economic value of the project when aggregate consumption increases by 1%. The socially efficient discount rate to be used for a project with risk profile β^{se} is equal to $3.5\% + \beta^{se} \times 0.32\%$. In particular, a risky project whose benefits are not correlated to aggregate consumption should be discounted at the risk free rate discussed in section 3.

In order to compare the two positions, let us see how an ethicist would evaluate a project whose risk profile is similar to the diversified portfolio of U.S. equities. We estimate the socio-economic beta of the SP500 at $\beta^{se} = 1.72$. Thus, ethicists should use a discount rate of $3.5\% + 1.72 \times 0.32\% = 4.05\%$. This should be compared to the 6.6% proposed by the positivists to discount this project. Because the equity premium of 4.6 observed during the XXth century is much smaller than the equity premium of 0.55% estimated by the ethicists, we obtain a new reversal of the two positions with respect to the valuation of the future: ethicists are more investment-prone than the positivists when projects are risky. This corresponds to the well-known "equity premium puzzle" first discovered by Mehra and Prescott (1985).[13] During the XXth century, markets have compensated risk-taking much more than what would have been socially

[12] Arrow, K.J., and R.C. Lind, (1970), Uncertainty and the evaluation of public investment decision, *American Economic Review*, 60, 364-378.

[13] Mehra, R. and E. Prescott, (1985), The Equity Premium: A Puzzle, *Journal of Monetary Economics*, 10, 335-339.

efficient. Shareholding companies that undertook risky projects incurred much larger costs of capital than safer firms. It implies that much less risk have been undertaken during the period than what would have been desirable from the viewpoint of intergenerational welfare.

These observations hold for risky projects with relatively short maturities. For larger maturities, both the risk free discount rate and the macro-economic risk premium should be adapted. When the macroeconomic risk is subject to persistent shocks, the term structure of the risk premium will be increasing. Gollier (2012) recommends a macro-economic risk premium in the range of 1.5% and 3% for long horizons.

Another important question is thus to determine the beta of investment projects whose main benefits come from the reduction of emissions of CO2. Estimating this parameter from market data is problematic, because these benefits have not been materialized yet, and they will not do so before long. We must thus again rely on a model. Some may believe that the benefits from reducing emissions will be the largest when economic growth will be large, i.e., when a large number of accumulated assets will be under the peril of climate change. Some other may believe the opposite. For them, the benefits from reducing emissions will be the largest in scenarii where our civilization will go back to Stone Age, i.e., when the marginal utility of these benefits will be large, potentially maintaining many people just above the minimum level of subsistence. The first should use a large discount rate for climate change (because of the large beta), whereas the second should use a much smaller discount rate for climate change, potentially smaller than the interest rate (because of the negative beta).

6. Conclusion

Do we do enough for the future? If we consider the near future, we can answer this question by examining the level of the interest rate on financial markets, which represents the opportunity cost of capital. Positivists are perfectly right to oppose the idea to transfer resources from productive capital in the economy to green investment projects whose socio-economic return would be less than the interest rate. That would be bad news for future generations. But ethicists are concerned by the question of whether the level of the interest rate is compatible with intertemporal welfare. There are indeed many reasons to believe that financial markets do not allocate resources efficiently through time. This implies that there may exist at equilibrium unexploited transfers of consumption that increase intertemporal welfare. Paradoxically, the so-called risk free rate puzzle tells us that the ethicists are less prone to sacrifices for the future than positivists. Ethicists using the Ramsey rule claim that the sacrifices made by poor old generations in terms of accumulating capital have been much too large compared to what have been desirable in terms of intertemporal justice. They would recommend using a discount rate *larger* than the interest rate observed on markets.

The problem of incomplete and inefficient financial markets is particularly acute when considering longer time horizons. In particular, future generations cannot trade on these markets, thereby raising more concerns about the efficiency of the intertemporal allocation of resources. Moreover, one does not observe liquid safe assets with maturities larger than 30 years. This implies that the positivist arbitrage argument cannot be used to determine the efficient rate at which long investment projects should be discounted. The determination of the efficient long discount rate should then rely on the kind of models used by ethicists. The existence of large uncertainties associated to the wellbeing of distant generations justifies using a decreasing term structure of the discount rate. I recommend using a real discount rate between 1% and 2% for time horizons exceeding a century. This shows that we are not so far from reconciling ethicists and positivists.

Finally, it is crucial to be clear on the fact that we are talking about the discount rate for safe projects. Because green investment projects have highly uncertain distant socio-economic benefits, a risk premium should be added to the discount rate. This risk premium should be proportional to the socio-economic beta of these green projects. It is a shame that the economic literature on climate change has not yet addressed this question.

* This research has received funding from the European Research Council under the European Community's Seventh Framework Programme (FP7/2007-2013) *Grant Agreement* no. 230589. This project was also supported by the partners of the Chair "Sustainable Finance and Responsible Investment", and the French reinsurance company SCOR which funded the Chair "Risk Markets and Value Creation" at IDEI.