On the underestimation of the precautionary effect in discounting

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Abstract

Using the extended Ramsey rule, the socially efficient rate is the difference between a wealth effect and a precautionary effect of economic growth. This second effect is increasing in the degree of uncertainty affecting the future. In the literature, it is usually calibrated by estimating the historical volatility of the growth of GDP in a specific country. In this paper, I show that using cross-section data tends to magnify uncertainty, and to reduce the discount rate. Using a data set covering 190 countries over the period 1969-2010, I justify using a much smaller discount rate around 0.7% per year for time horizons exceeding 40 years.

Keywords: Discount rate, prudence, climate change.

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1. Introduction

For many thousands of years, since homo-sapiens emerged as the dominant species on earth, almost all of their consumption was determined by what they collected or produced over the seasonal cycle. Pressured by Malthus' Law, humanity remained at a subsistence level for thousands of generations. The absence of the notion of private property, or the inadequacy of a legal system to guarantee that what an individual saves belongs to them, was a strong incentive to consume everything that was produced year after year. But human beings, contrary to most other species, are conscious of their own future. At the individual level, a trade-off is made between immediate needs and aspirations for a better future. Individual investments can take many forms. When young, individuals invest in their human capital. Later on, they save for their retirement. They invest in their health by doing sport, brushing their teeth, eating healthy food. They plan their own future and those of their offspring to whom they can bequest the capital they have accumulated. In short, individuals sacrifice some of their immediate pleasures for future benefits. Once individual property rights on assets were guaranteed by strong enough governments, the potential of individual investments was unlocked. At the collective level they have generated the enormous accumulation of physical and intellectual capital that the western world has experienced over the last three centuries. New institutions, like corporations, banks, and financial markets, have been created for the governance of these investments. Taken together, this has been a powerful engine for economic growth and prosperity. With a real growth rate of GDP per capita around 2% per year, the western world now consumes 50 times more goods and services than we did 200 years ago.

States and governments also intervened in this process. They invested in public infrastructures like roads, schools, or hospitals. They heavily invested in public research whose scientific discoveries quickly diffused in the economy. At the collective level, these public investments diverted some of the wealth produced in the economy away from the immediate consumption of non-durable goods.

The literature on discounting addresses the difficult question of whether the allocation and the intensity of these sacrifices in favour of the future are socially efficient or not. Ramsey (1928) provides a simple framework to think about this problem. The central piece of the theory is that people have a preference for the smoothing of consumption over time, i.e., they have an aversion to intertemporal inequalities. In the discounted utility framework, this is modelled through a concave utility function, or a decreasing marginal utility. If one believes in the permanency of economic growth, then an intuitive wealth effect prevails in discounting: One should invest in favour of the future only if the return of the project is large enough to compensate for the increasing intertemporal inequality that this project generates. Under the assumption of a relative aversion to intertemporal inequality of 2,[2] the belief in a growth rate of 2% per year implies an efficient discount rate of 4%. If one adds a rate of pure preference for the present between 0 and 2% per year, we obtain the most standard recommendation about the level of the discount rate that exists in the literature (Arrow (1999), Weitzman (2007b), Nordhaus (2008)).

It is intuitive that the uncertainty about the growth rate of the economy should play an important role in the determination of the intensity of our sacrifice in favour of the future, i.e., on the level of the discount rate. The theory states that the uncertain growth generates a precautionary effect that tends to reduce the discount rate. Indeed, prudent agents should invest more when their future incomes become more uncertain (Leland (1968), Drèze and Modigliani (1972), Kimball (1990)). However, extending the Ramsey rule to uncertainty has initially generated disappointing results (Weil (1989), Gollier (2002)). The traditional approach to this problem is to estimate the country-specific risk on growth by the volatility of the growth rate. When performed on U.S. data, one obtains a surprisingly low precautionary effect, which reduces the discount rate by one-tenth of a percent. I show in this paper that a similar observation can be made for most developed countries.

The wealth effect varies much across countries because of the important heterogeneity of the average growth rate observed since World War II. It must also be observed that the volatility of annual growth rates within each country is also very heterogeneous. I show that the mean precautionary effect estimated from the mean volatility of the annual growth rate in 190 countries from 1969 to 2010 is around 1%, which is 10 times larger than in the western world. The stability of growth is a western phenomenon. Calibrating the Ramsey rule on developed countries tends to underestimate the precautionary effect. I show that the average discount rate using the extended Ramsey rule for each of the 190 countries under scrutiny is close to 2.5%. Thus, when faced by a global bad like global warming, the estimation of the present value of damages by using a discount rate of 4% is a mistake, because a large fraction of these damages will be borne by populations that face much more uncertainty about their future than in the western world.

In Gollier (2008), I have shown that the presence of positive serial correlation in the growth rate of the economy tends to magnify the long term uncertainty. Weitzman (2007a) provides an example of this effect in which the uncertainty yields an infinite precautionary effect. In this

[2] This implies that an increase in consumption by 1% reduces the marginal utility of consumption by 2%.

paper, I attack the problem from a different angle. Following Barro (2006), I believe that the history of shocks on country-specific economic growth rates provides information about the long term uncertainty faced within each country. What has been observed over the last few decades in China, Argentina or Russia for example may affect our beliefs about the uncertain growth in our own economies. The slow-growing economies of today may become the fast-growing economies of tomorrow. In this paper, I use brute statistical force to estimate the uncertainty affecting growth by the standard deviation of the growth rate of consumption between 1969 and 2010 among 190 countries. Because of the important heterogeneity of economic fate across these countries over the period under scrutiny, I obtain a much larger precautionary effect than by the standard time-series analysis in developed countries. In my calibration, the wealth effect and the precautionary effect amount respectively to 4.5% and to -3.8%, yielding a discount rate of 0.7%.

The paper is organized as follows. In section 2, I present the classical Lucas-tree model that generates the extended Ramsey rule. Section 3 is devoted to the calibration of this rule by using country-specific time-series data. In section 4, I develop the main idea of the paper by considering a cross-section analysis of the degree of uncertainty affecting the economic growth process. I provide a few concluding remarks in section 5.

2. The model

I consider an economy with n agents indexed by $i=1,\ldots,n$. Agent i consumes c_{i0} at date 0 and c_{it} at date t. The growth rate of consumption of agent i in this period is denoted $x_{it} = \log(c_{it} / c_{i0})$. Agents evaluate their intertemporal welfare V_i by the discounted flow of expected utility, with an increasing and concave utility function u, and with a rate of pure preference for the present δ:

$$V_i = u(c_{i0}) + e^{-\delta} Eu(c_{it}). \tag{1}$$

We assume that the allocation of consumption across time and states of nature is Pareto-efficient. This means that there exists a vector of positive Pareto weights $(\lambda_1,...,\lambda_n)$ so that this allocation maximizes the utilitarian social welfare $W = \sum_i \lambda_i V_i$ subject to feasibility constraints. Equivalently, this means that the following necessary and sufficient conditions are satisfied:[3]

$$\lambda_i u'(c_{i\tau}) = \lambda_1 u'(c_{1\tau}) \quad i = 2,...,n, \quad \tau = 0,t. \tag{2}$$

Agent *i=1* is hereafter identified as the representative agent in this economy. All other agents have a marginal utility that is proportional to the representative agent's marginal utility, in all states of nature and at all dates.

At the collective level, agents contemplate the possibility to transfer consumption through time via a safe investment project that reduces all agents' consumption by ε at date *0* and that increases all agents' consumption by $\varepsilon \exp \rho$ at date *t*. Observe that ρ is the rate of return of the project. This project is socially desirable if it raises social welfare

$$W = \sum_{i=1}^{n} \lambda_i \left(u(c_{i0}) + e^{-\delta} Eu(c_{it}) \right) \tag{3}$$

at the margin. This is the case if and only if

$$\sum_{i=1}^{n} \lambda_i \left(u'(c_{i0}) - e^{\rho-\delta} Eu'(c_{it}) \right) \geq 0. \tag{4}$$

Equivalently, the investment project is socially desirable if its rate of return ρ is larger than the discount rate *r* defined by the following equation:

$$r = \delta - \log \frac{\sum_{i=1}^{n} \lambda_i Eu'(c_{it})}{\sum_{i=1}^{n} \lambda_i u'(c_{i0})}. \tag{5}$$

Efficient risk sharing implies that this equation can be rewritten as follows:

$$r = \delta - \log \frac{Eu'(c_{1t})}{u'(c_{10}).}. \tag{6}$$

This is the classical asset pricing formula in the finance literature (see for example Cochrane (2001)). Equation (6) is the discount rate that agent *i=1* should use to evaluate safe investment projects. Because of efficient risk sharing, it is also the discount rate that should be used by all other agents in the economy.

[3] For more details, see Borch (1962), Wilson (1968) and Gollier (2001).

To calibrate formula (6), I specify the utility function of the representative agent and the uncertain growth rate of consumption. I assume that relative risk aversion is constant and equal to $\gamma > 0$, so that

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma}. \tag{7}$$

I also assume that the growth rate of consumption x_{1t} is normally distributed with mean μ and variance σ^2. It implies that

$$Eu'(c_{1t}) = c_{10}^{-\gamma} Ee^{-\gamma x_{1t}} = c_{10}^{-\gamma} e^{-\gamma(\mu - 0.5\gamma\sigma^2)}. \tag{8}$$

The last equality comes from the well-known fact that the Arrow-Pratt approximation is exact when the function is exponential and the risk is normal (see Gollier (2001) for example). Combining conditions (6) and (8) yields

$$r = \delta + \gamma\mu - 0.5\gamma^2\sigma^2. \tag{9}$$

It is easier to rewrite this equation as

$$r = \delta + \gamma g - 0.5\gamma(\gamma+1)\sigma^2 \tag{10}$$

where $g = \log Ec_{1t} / c_{10} = \mu + 0.5\sigma^2$ is the growth rate of expected consumption. Equation (10) is often referred to as the “extended Ramsey rule”. It is the cornerstone of most recent papers on the discount rate.[4]

Equation (10) shows that the discount rate has three components, expressed by the three terms in the right-hand side of this equation. The first component is the rate δ of pure preference for the present, or the rate of impatience. There is no convergence among experts toward an agreed, or unique, rate of impatience. Frederick, Loewenstein and O'Donoghue (2002) conducted a meta-analysis of the literature on the estimation of the rate of impatience. Rates differ dramatically across studies and within studies across individuals. For example, Warner and Pleeter (2001), who examined actual households’ decisions between an immediate down-payment and a rental payment, found that individual discount rates vary between 0% and 70% per year! However, the general view is that a small or zero discount rate should be used when the flow of utility over time is related to different generations. The fact that I discount my own felicity next year by *2%* does

[4] See for example Gollier (2002), Weitzman (2007a, b), and Gollier and Weitzman (2010).

not mean that I should discount my children's felicity next year by *2%*. In fact, there is no moral reason to value the utility of future generations less than the utility of the current ones. As explained by Broome (1992), good at one time should not be treated differently from good at another, and the impartiality about time is a universal point of view. The normative doctrine is that the rate of time preference is zero. In later sections, this book takes a *normative* stand to set δ at zero. This is justified because the dominant role of the discount rate over the longer term is to allocate utility across different generations rather than within an individual's lifetime.

The second component is the wealth effect. In a growing economy, the marginal utility of consumption will be smaller in the future. This justifies using a positive discount rate. One should invest for the future only if the rate of return of the project is large enough to compensate for the increased intertemporal inequality that this investment generates. The wealth effect γg is increasing in the growth rate of consumption and in the speed at which marginal utility decreases when consumption increases. The sum of the impatience effect and the wealth effect is the discount rate under certainty that has been derived by Ramsey (1928).

There is no consensus on the intensity γ of relative aversion to intertemporal inequality. Using estimates of demand systems, Stern (1977) found a concentration of estimates of γ around *2* with a range of roughly *0-10*. Hall (1988) found an γ around *10*, whereas Epstein and Zin (1991) found a value ranging from *1.25* to *5*. Pearce and Ulph (1995) estimate a range from 0.7 to 1.5. Following Stern (1977) and the author's own introspection, we will hereafter consider γ *=2* as a reasonable value, together with a rate of impatience $\delta = 0\%$.

The third component of the social discount rate is the precautionary effect, which is given by the last term in the right-hand side of equation (10). It characterizes the potentially important role of uncertainty in the determination of the optimal effort to improve that future. As suggested by the intuition, it is negative: the precautionary effect tends to reduce the discount rate, thereby inducing the community to invest more for the future. This is the collective parallel to the old Keynesian concept of the precautionary saving motive: the uncertainty surrounding future incomes induces consumers to save more. Leland (1968) and Drèze and Modigliani (1972) have shown that this is true in the classical discounted expected utility model if and only if marginal utility is convex in consumption, i.e., if u''' is positive. Indeed, under this condition of prudence (Kimball (1990)), $Eu'(c_{1t})$ is increased by the uncertainty, thereby reducing r in equation (6). Kimball (1990) shows that the precautionary effect is equivalent to a sure reduction of consumption that is approximately equal to half the variance of future risk times the index of convexity of marginal utility. In this multiplicative context with a power utility function, this index of relative prudence is equal to relative risk aversion plus one, or $\gamma+1$. Equation (10) shows that the effect of uncertainty is indeed equivalent to reducing the growth rate of expected consumption g by the precautionary premium $0.5(\gamma+1)\sigma^2$.

Notice that the discount rate *r* characterized by equation (10) is the minimum total return over period *[0,t]*, exactly as g is the expected rate of growth of consumption in that period, and σ^2 is the variance of this random variable. If one is interested in annualized rates, one should divide *r* by *t*, if the unit of time is the year. Observe that this discount rate will be invariant to the time horizon *t* if we assume that the annual growth rate of consumption has no serial correlation. Indeed, in that case, the first two moments of $x_{it} = \log(c_{it} / c_{i0})$ are proportional to *t*, so that *r* is independent of *t*. This illustrates the fact that the term structure of the discount rate is flat when the growth rate of consumption is a random walk and the relative risk aversion is constant (Gollier, 2002).

3. Calibration using time series of specific countries

Kocherlakota (1996), using United States annual data over the period 1889-1978, estimated the mean g and the standard deviation σ of the growth of consumption per capita to be respectively 1.8% and 3.6% per year. Assuming normality, this means that there is a *95%* probability that the actual growth rate of consumption next year will be between *-5%* and *+9%*. It yields a wealth effect of 3.6% and a precautionary effect of -0.39%, implying a discount rate of 3.21%.

In the remainder of this paper, we use a data set of real historical GDP per capita extracted from the Economic Research Service (ERS) International Macroeconomic Data Set provided by the United States Department of Agriculture (USDA). This set contains the real GDP/cap expressed in dollars of 2005 for 190 countries for each year from 1969 to 2010. If we limit the analysis to the United States, the first two moment of the growth rate of GDP/cap over the period has been respectively *g=1.74%* and $\sigma = 2.11\%$. It yields a wealth effect of 3.48% and a precautionary effect of -0.13%, implying a discount rate of 3.35%. The U.S. economy has been less unstable during the last four decades than during the period examined by Kocherlakota, thereby reducing the intensity of the precautionary effect. This has a positive impact on the estimated discount rate. We have performed the same exercise for other countries. Our results are summarized in Table 1.

INSERT TABLE 1 HERE

We see that we obtain the same order of magnitude for the wealth effect and the precautionary effect for other developed countries like France, Germany, and the United Kingdom. For Japan, the mean growth rate and the volatility have been larger, yielding a net positive effect with a discount rate around 4.5%. The picture is quite different for emerging countries, which by definition experienced a much larger growth rate of consumption. The most striking example is China, with a mean annual growth rate of around 7.5% per year, and a relatively large volatility around 4%. The calibration of the extended Ramsey rule (10) with these parameter values yields a discount rate as large as 14.82%. If one believes that this growth is sustainable, intertemporal inequality aversion and the associated wealth effect should induce the Chinese authorities to limit their safe investments to projects having a rate of return above this large discount rate.

At the other extreme of the spectrum is the set of countries which have experienced low growth rates. The worst example is Zaire (RDC), with an awful mean growth rate of -2.76% per year over the last 4 decades. If one believes that this negative growth trend is persistent, a negative discount rate of -6.38% should be used to evaluate safe projects in that country. Liberia provides another example of a country with a negative discount rate. In this country, the volatility of the growth rate has been extremely large, with σ equalling 19.58%. This implies a precautionary effect around -11.5%. Combining that with a wealth effect of -3.8%, I obtain a socially efficient discount rate for Liberia around -15%.

The important differences in growth outcomes among the 190 countries present in the ERS/USDA data set over the last 4 decades make it difficult to draw general conclusions about the discount rate. In Table 2, I summarize the calibration of the extended Ramsey rule on the basis of the mean wealth and precautionary effects among the 1990 countries of the data set.

Mean wealth effect	3.54% per year
Mean precautionary effect	-1.00% per year
Mean discount rate	2.54% per year

Table 2: The mean discount rate among the time series of the 190 countries

In Figure 1, we draw the frequency graph for the wealth effect and the discount rate. It is noteworthy that the precautionary effect tends to be much smaller in developed countries, because of the more efficient stabilizing policies put in place in these countries. This is an important reason for the relatively larger discount rates that are efficient in the western world. Precautionary investment is a substitute to macroeconomic stabilizing policies.

This exercise in which we apply the extended Ramsey rule (10) to each individual country relies on the assumption that risks are efficiently shared within each country, so that the volatility of the growth of GDP/cap is the right measure of uncertainty born by all citizens within that country. By the power of imagination, suppose that risks are efficiently shared at the level of the entire world, so that the growth of world GDP/cap is the right measure of consumption growth of all human beings on the earth. Expectations about the future can be inferred from the first two moments of the growth of world GDP/cap over the last three decades. Using the same data set, we obtain by pure chance that the mean and the volatility of the real growth rate of world GDP/cap are equal to 1.41%. This yields a wealth effect and a precautionary effect of respectively 2.82% and -0.06%, implying a discount rate of 2.76%. Because country-specific risks are washed out through international diversification, the small precautionary effect reflects the low systematic risk at the aggregate level.

However, this exercise has no economic meaning because it is clear that credit and risk-sharing markets do not work efficiently at the international level. Except in a few integrated economic unions like in Europe, there is little international solidarity across borders. Thus, condition (2) does not hold when agents are identified as countries. For example, a necessary condition for (2) is that consumption levels for different agents are comonotone. This excludes the possibility that one country be in recession and another country be in expansion at the same time. In fact, efficient markets would imply the law of one price, or the existence of a single discount rate at the world level. Table 1 and Figure 1 clearly demonstrate that this property of a single discount rate does not hold.

To sum up our results in this section based on a time series analysis of country-specific economic growth, one must admit that the precautionary effect remains a marginal component in the estimation of the socially efficient discount rate. For the western world, the precautionary effect is generally smaller than a quarter of a percent, and is close to 0.1% for countries like the United States, France, the United Kingdom and Germany. This is because of the low volatility of their economic growth observed during the last 4 decades. This precautionary effect is marginal compared to the usually much larger wealth effect equalling two times the anticipated growth rate. However, this conclusion of the limited role of uncertainty to determine the intensity of our sacrifices in favour of the future does not hold for developing countries. Many of them have experienced a huge volatility of their growth rate during the same period. This suggests that the discount rate that should be used in these countries should be smaller than in the western world, even in the case of similar expectations on the trend of economic growth.

4. Calibration using cross-section data

In the previous section, we made the assumption that each country faces its own stochastic growth process characterized by a random walk for the annual growth rate of consumption with known country-specific mean and volatility. This implies a flat term structure of the country-specific discount rate at a level defined by equation (10).

If we take a more long term perspective, one must recognize that growth processes undergo persistent shocks, or that they are subject to long-lasting cycles covering several decades. Contrary to what is implicitly assumed in the above computations, it is indeed hard to believe that China will be able to stay permanently with a trend of growth around 8% per year, or that Zaire will permanently face an expected growth rate of -2.7% per year. Based on this idea, I propose to consider an alternative modeling of growth risk than the one that is classically considered in the literature, as illustrated in the previous section. In the spirit of Kondratiev waves ranging from forty to sixty years in length, let us consider the abstract stochastic growth process in which each country-specific growth rate is reset every 41 years, as was the case in early 1969 and early 2011. To be more precise, let us assume that each country-specific change in log consumption x_{i41} is drawn from the same worldwide "urn" which is normally distributed with mean $\mu = g - 0.5\sigma^2$ and volatility σ. This allows us to use again equation (10) to estimate the socially efficient rate r at which cash flows occurring in 2052 should be discounted at the end of 2010.[5] In this framework, all countries should use the same discount rate ex ante.

The observation of the change in log consumption between 1969 and 2010 in the 190 countries of the ERS/USDA data set allows us to estimate the first two moments of random variable x_{i41}. In Figure 2, we draw the frequency graph of $x_{i41} = \log(c_{2010} / c_{1969})$. The mean and the volatility of x_{i41} are respectively equal to $\mu = 65.74\%$ and $\sigma = 72.18\%$. It yields a growth rate of expected

[5] Observe that in this model, the term structure of the discount rate will be decreasing, as shown by Gollier and Weitzman (2010). This is due to the important persistence of country-specific shocks to consumption growth that we assume in this stochastic model.

consumption equalling $g = \mu + 0.5\sigma^2$ =91.79%, or 2.24% per year. The calibration of the extended Ramsey rule in this cross-sectional analysis is summarized in Table 3.

Wealth effect	183.59%	4.48% per year
Precautionary effect	-156.30%	-3.81% per year
Discount rate	27.29%	0.67% per year

Table 3: The discount rate using the cross-section approach over period 1969-2010

Focusing on the annualized rates, two conclusions should be drawn from these results when tables 2 and 3 are compared. First, the relatively large growth rate of expected consumption in this model implies a large wealth effect in the Ramsey rule. But the precautionary effect is also large, amounting to almost 4% per year. Remember that the mean level of the precautionary effect that we documented in the previous section was only 1%. This huge difference in the precautionary effect when using a cross-sectional approach rather than the traditional time-series approach comes from the important heterogeneity in the country-specific growth rates observed during the last 4 decades. In other words, there is more volatility across countries than through time.

The bottom line is a small discount rate at 0.67% per year. If one believes in the existence of random persistent shocks to growth, which is what the data set suggests, then the existing literature on discounting is misleading in recommending a discount rate around 3-6%. My punchline here is that this literature based on relatively short time series data tends to vastly underestimate the risk of regime switches in country-specific economic growth. This implies that this literature largely overestimates the rate at which distant cash flows should be discounted.

One can test the robustness of this analysis by performing two different sensitivity analyses. I first consider the shortening of the data set to period 1969-1990. The first two empirical moments of $\log(c_{1990} / c_{1969})$ are $\mu = 32.03\%$ and $\sigma = 48.94\%$. Table 4 summarizes the calibration of the extended Ramsey rule in this case.

Wealth effect	88.01%	4.19% per year
Precautionary effect	-71.85%	-3.42% per year
Discount rate	16.15%	0.77% per year

Table 4: The discount rate using the cross-section approach over period 1969-1990

The differences with respect to the analysis covering the entire data set are not significant.

In this model, I treat all countries symmetrically, from China to Samoa. One may want to provide a larger probability weight to the elements of the 1969-2010 sample corresponding more heavily populated countries. I hereafter report the calibration of the Ramsey rule in which the outcome $\log(c_{it}/c_{i0})$ receives a probability weight $p_{i1990}/\sum_j p_{j1990}$, where p_{i1990} is the population in country i in year 1990. Under this assumption, we obtain $\mu = 137.39\%$ and $\sigma = 102.37\%$. The calibration of the extended Ramsey rule in this case is summarized in Table 5.

Wealth effect	379.58%	9.26% per year
Precautionary effect	-314.42%	-7.67% per year
Discount rate	65.16%	1.59% per year

Table 5: The discount rate using the population-weighted cross-section approach over period 1969-2010

Because of the presence of China in the sample, the population-weighted cross-sectional calibration of the extended Ramsey rule has a large wealth effect and a large precautionary effect. When comparing these results to Table 3, the net effect of the weighting of the country-specific growth of consumption by the population is to raise the annualized discount rate from 0.67% to 1.59%.

5. Concluding remarks

The recent literature on discounting is based on the extended Ramsey rule, which combines a wealth effect and a negative precautionary effect. The wealth effect is proportional to the expected growth rate of consumption, whereas the precautionary effect is quadratic in its volatility. The standard calibration of the Ramsey rule relies on the estimation of past mean and volatility of economic growth, in general using U.S. data. I have shown that using this approach for most developed countries yields a discount rate around 3.5% per year. The effect of uncertainty is small, with a precautionary effect usually smaller than 0.25% for this set of countries.

However, if we consider the entire sample of 190 countries, we obtain that the precautionary effect is much larger in absolute value in many other countries. The extreme case is Liberia, for which the precautionary effect reduces the discount rate by as much as 11.5%. The average precautionary effect among the 190 countries of the sample is 1%. The average discount rate among the 190 countries is 2.5%

An alternative approach to calibrate the Ramsey rule is to assume that the economic growth of each country observed between 1969 and 2010 represents one independent draw from the same distribution. I have shown that using this cross-section approach à la Barro yields a much larger precautionary effect due to the important heterogeneity of growth rates across countries. Under this approach, the wealth effect amounts to 4.5%, but the precautionary effect reduces this by 3.8%, yielding a socially efficient discount rate of 0.7% per year. Thus, the existing literature tends to vastly overestimate the socially efficient discount rate.

I conclude this paper by providing a few remarks about this result. First, it provides an alternative solution to the so-called risk-free rate puzzle (Weil, 1989). This puzzle is based on the observation that the classical consumption-based pricing model à la Lucas yields an interest rate around 4%, which is much larger than the average real interest rate around 1% observed in the United States during the last century. American consumers may establish their beliefs about the growth of incomes in the United States not only by observing past growth rates in the country, but also by taking account of experiences in other countries around the world. Barro (2006) made a similar point, but by focusing on extreme events only.

Second, it must be noticed that the discount rate derived from the Ramsey rule is independent of the initial level of development. This is due to the assumptions of constant relative risk aversion, and of the absence of serial correlation in growth rates. Our conclusion would be different if any of these two conditions would be relaxed. In Gollier (2011), I examine the role of economic convergence in determining the discount rate. I show that economic convergence, i.e., the negative correlation between the level of development and the trend of growth, tends to raise the efficient discount rate. Indeed, under the veil of ignorance, economic convergence reduces the uncertainty affecting consumption in the long term. Mostly due the recent emergence of China, our data set clearly exhibits such negative correlation.

Third, my model governing country-specific grow rates is an over-simplification of the real world. It is based on the idea that economic growth is affected periodically by long-lasting shocks that are not correctly taken into account by using a time series approach. Still, it is too extreme by assuming that the dates at which growth rates are reset are deterministic. In Gollier (2008), I examine a two-regime Markov switching model that shares the basic idea with the one examined in this paper. But I limit the econometric analysis in this other paper to the United States. A more in-depth econometric analysis combining country and time effects remains to be performed.

Finally, it must be mentioned that the discount rate should be used to discount real cash flows of safe projects. In the real world, most investment projects have uncertain impacts, in particular in the distant future. If these impacts are positively correlated to economic growth, the discount rate should include a positive risk premium.

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	Country	g *(wealth effect)*	σ *(precautionary effect)*	*Discount rate*
Developed countries	United States	1.74% *(3.48%)*	2.11% *(-0.13%)*	*3.35%*
	France	1.75% *(3.50%)*	1.57% *(-0.07%)*	*3.43%*
	Germany	1.76% *(3.52%)*	1.83% *(-0.10%)*	*3.42%*
	United Kingdom	1.86% *(3.71%)*	2.18% *(-0.14%)*	*3.57%*
	Japan	2.34% *(4.67%)*	2.61% *(-0.20%)*	*4.47%*
Emerging countries	China	7.60% *(15.20%)*	3.53% *(-0.37%)*	*14.82%*
	South Korea	5.38% *(10.75%)*	3.40% *(-0.35%)*	*10.41%*
	Taiwan	5.41% *(10.82%)*	5.29% *(-0.84%)*	*9.98%*
	India	3.34% *(6.88%)*	3.03% *(-0.28%)*	*6.61%*
	Russia	1.54% *(3.08%)*	5.59% *(-0.94%)*	*2.14%*
Africa	Gabon	1.29% *(2.58%)*	9.63% *(-2.78%)*	*-0.20%*
	Liberia	-1.90% *(-3.79%)*	19.58% *(-11.50%)*	*-15.30%*
	Zaire (RDC)	-2.76% *(-5.53%)*	5.31% *(-0.85%)*	*-6.38%*
	Zambia	-0.69% *(-1.38%)*	4.01% *(-0.48%)*	*-1.86%*
	Zimbabwe	-0.26% *(-0.53%)*	6.50% *(-1.27%)*	*-1.79%*

Table 1: Country-specific discount rate computed from the extended Ramsey rule using the historical mean g and standard deviation σ of growth rates of real GDP/cap 1969-2010.

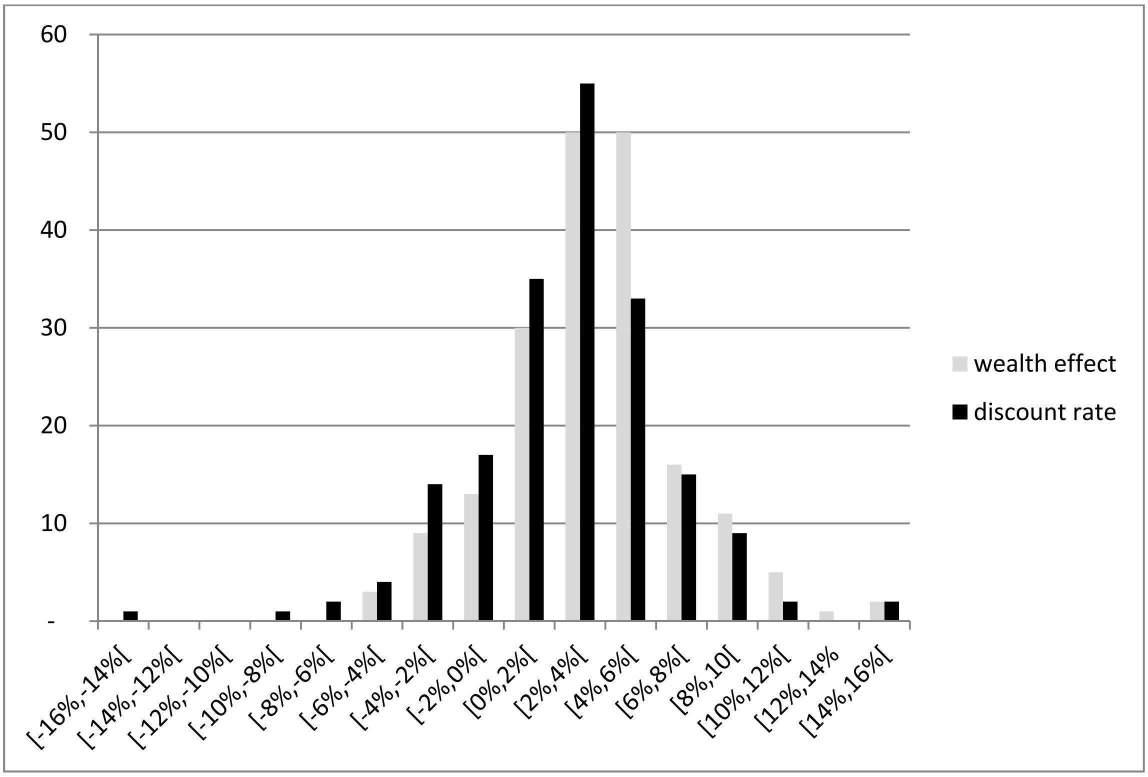

Figure 1: Frequency for the wealth effect and the discount rate among the 190 countries, using the extended Ramsey rule.

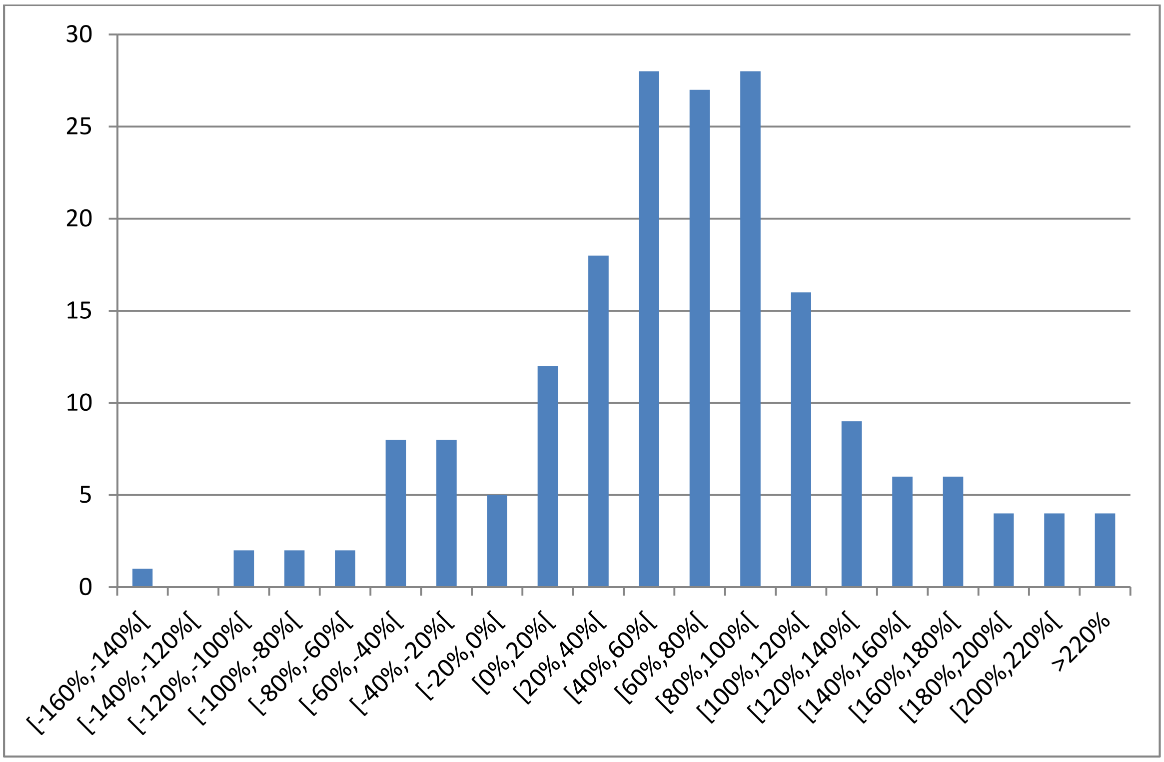

Figure 2: Frequency of $\log(c_{2010} / c_{1969})$ among the 190 countries of the ERS data set.