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Three Conceptions of Intergenerational Justice

by

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1 Introduction

How should we measure human well-being over time and across generations? In which way ought the interests of people in the distant future be taken into account when we make our own decisions today? In which ethical language should citizens deliberate over the rate at which their society ought to invest for the future? In which assets should that investment be made? What should the balance between private and public investment be in the overall investment that a generation makes for the future?

In his paper of 1928 in the *Economic Journal* ("A Mathematical Theory of Saving"), Frank Ramsey presented a framework in which those questions can be asked in a form that is precise and tractable enough to elicit answers. Although very famous today, the article had no initial impact. In the years following its publication, a period now known as The Great Depression, the central economic conundrum in western industrial countries was to find ways of increasing immediate employment. Factories and machinery lay idle, as did people. The policies that were needed then were those that would help to create incentives for employers to hire workers. This, however, was a short-term problem. With the emergence of post-colonial nations following the Second World War, long-run economic development became a focus of political interest. By the early 1960s, Ramsey's paper came to be acknowledged as the natural point of departure for exploring the normative economics of the long-run. The number of trails the paper laid was remarkable. In academic economics it is probably one of the dozen most influential papers of the 20th century.

I don't recall ever reading Ramsey's article until preparing for the Centennial Conference on Ramsey. Classics typically don't get read by us economists: we come to know them from subsequent developments of the subject and from textbook accounts. The paper has all the hallmarks of a classic and then some more. What has struck me most on reading the work is that it reads as though it could have been written last year. The techniques are thoroughly contemporary. Moreover, there is a self-conscious attempt at identifying a parsimonious body of assumptions that lead to the conclusions: the paper has no fat in it.

Ramsey's conception of intergenerational justice is grounded firmly on the Utilitarian calculus. In what follows, I first present an account of Ramsey's formulation of the problem of optimum saving and sketch its most dramatic implications (Sections 2-4). As we will see, they look odd and are at variance with ethical intuition in plausible worlds. The theory is even incoherent in some worlds. Therefore, in Section 5 I explore one particular interpretation of a dominant alternative ethical theory, that of Rawls (1972), which defines just rates of saving to be the ones that would be "agreed" upon by all generations behind a veil of ignorance - the hypothetical social contract. In keeping with Rawls' reading of what members of a given generation would agree to be a just *intra*generational distribution of resources, I take the Rawlsian principle of just saving to recommend maximizing the well-being of the least well-off generation - the

Difference Principle.[1] I show that, in plausible worlds, the implications of Rawls' theory are very odd and at variance with both ethical intuition and actual, reflective practice.

So, in Section 6, I turn to a formulation of the concept of justice among generations that was developed by a great twentieth century economist, the late Tjalling Koopmans. Koopmans was moved to reformulate the problem of intergenerational justice because of the latent incoherence in Ramsey's conception, mentioned above. Although Ramsey's and Koopmans' conceptions lie at different interpretive ends (Rawls would call the former "teleological", the latter "intuitionist"), Koopmans (1960, 1972) showed that, mathematically, the two are very similar and that Ramsey's techniques for identifying optimum rates of investment are useable in his own formulation (Koopmans, 1965). In Section 6 we confirm that Koopmans' formulation is sufficiently flexible to permit us to derive conclusions that do not jar against considered judgment.

The common mathematical structure of Ramsey's and Koopmans' conceptions has been found to have wide applicability - so wide, that, within modern economics there is no rival formulation for evaluating the intergenerational distribution of benefits and burdens. Today, we economists who work on the concept of justice among the generations refer to that overarching mathematical structure the Ramsey-Koopmans construct, even though the interpretation we give to that mathematical structure is the one advanced by Koopmans.

It is a significant feature of Koopmans' conception that the well-beings of future generations are discounted at a positive rate. This has been regarded by many to be cause for concern. In Section 7 I argue otherwise. In Section 8 I show, more generally, that the obsession in both the philosophy and economics literatures over the question of whether it is ethically justifiable to discount the well-beings of future generations has been misplaced. Koopmans' formulation shows that there are a least two ethical parameters that reflect considerations of intergenerational equity, the discount rate being one. There is, however, another parameter, that is in some sense *dual* to discounting, in that many of the demands made by considerations of intergenerational equity that can be achieved by manipulating the discount rate can also be achieved by manipulating the other parameter. That Koopmans' conception insists on positive discounting would, therefore, seem to be of less moment than it has been taken to be.

For ease of comparison among the formulations of Ramsey, Rawls, and Koopmans, I shall assume, until Section 9, that population is constant and that societies face no uncertainty. So, in Sections 9 and 10, I extend Koopmans' formulation to include population change and uncertainty, respectively. The main conclusions are summarised in Section 11.

2 General Features of Ramsey's Formulation

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[1] Rawls (1972) uses the language of "primary goods", not utility, nor well-being. At this point I am regarding well-being to be an index of Rawlsian primary goods.

In his 1928 paper, Ramsey's goal was practical: "How much of a nation's output should it save for the future?" In answering the question, he adopted a thoroughly Utilitarian posture. (For example, Ramsey used the term "enjoyment" to refer to the content of someone's utility.) The article embodies the sort of ethical deliberation Sen and Williams (1982) somewhat disparagingly called Government House Utilitarianism. But Ramsey's article thrives today because Government Houses need ethical guidance that isn't a prop for paid Officials to act in ways that are self-indulgent, but are, instead, impartial over people's needs and sensitivities. We will see presently that, although Ramsey used the Utilitarian language, a generous reading of his paper suggests that much would be gained if, instead of "utility", we were to work with the broader notion of "well-being".

The raw ingredients of Ramsey's theory are individuals' lifetime well-beings. Now, intergenerational *equity* isn't the primary concern of Ramsey's: the Government House in Ramsey's world maximizes the sum of the well-beings of all who are here today and all who will ever be born. The just distribution of well-being across generations is derived from that maximization exercize.

Of course, the passage of time is not the same as the advance of generations. An individual's lifetime well-being is an aggregate of the flow of well-being she experiences, while intergenerational well-being is an aggregate of the lifetime well-beings of all who appear on the scene. It is doubtful that the two aggregates have the same functional form. On the other hand, I know of no evidence that suggests we would be way off the mark in assuming they do have the same form. As a matter of practical ethics, it helps enormously to approximate by not distinguishing the functional form of someone's well-being through time from that of intergenerational well-being. Ramsey adopted this short-cut and took it, in particular, that the method of aggregation should be *summation*.

We assume that the demographic profile over time is given. The resource allocation problems Ramsey studied are those that arise when we try to strike a balance between the well-beings of present and future generations, keeping in mind that there is a corresponding set of allocation problems arising from the need to strike a balance in every person's lifetime well-being. Parfit (1982) christened allocation problems involving the same demographic profile Same Numbers Problems. The thought is not that population size doesn't change, but that the policies being studied are those that have a negligible effect on reproductive behaviour.

3 Ramsey's Theory of Optimum Saving

Let t denote the date at which the saving problem is being deliberated. I shall use the symbol τ to denote dates not earlier than t (that is, $\tau \geq t$). For notational ease, it helps to interpret the period between adjacent dates as the length of a generation. One can imagine that at the end of each period the existing generation is replaced entirely by its successor. This isn't good demography, but it turns out not to matter. Every ethical consideration that emerges in this model makes an appearance also in worlds where demography is modelled better. Moreover, better models of demography would not raise any ethical issue that doesn't appear here.

Population size is assumed to be constant and the future is taken to be indefinitely long. I first consider a deterministic world. Later I relax these assumptions. In order to focus on intergenerational issues, I ignore matters concerning the distribution of *intra*generational well-being. (If it helps, the reader could without loss of generality imagine that each generation consists of a single person.) So I let U_t denote generation t's level of well-being. We may imagine that t's well-being is an increasing function of t's aggregate consumption, C (which I label as C_t), but that it increases at a diminishing rate. Thus, we write $U_t = U(C_t)$, where the function U(C) satisfies the properties $dU/dC > 0$ (which we may write succinctly as $U'(C) > 0$) and $d^2U/dC^2 < 0$ (which we may write succinctly as $U''(C) < 0$). Being a Utilitarian, Ramsey regarded *intergenerational well-being* to be the sum of each generation's well-being.[2]

From the vantage of generation t, let $(C_t, C_{t+1}, ...)$ be a *consumption stream*, which is a sequence of aggregate consumption from t onward. Denoting intergenerational well-being at t by V_t, Ramsey's theory has it that,

$$V_t = U(C_t) + U(C_{t+1}) + ...,$$

which I write succinctly as,

$$V_t = \sum_{t}^{\infty} U(C_\tau), \text{ for } t \geq 0.^3 \qquad (1)$$

In words, intergenerational well-being at t is the sum of every generation's well-being, starting at t. The theory regards bygones to be bygones.

Let the present generation be t = 0. Generation 0 has inherited from its predecessors a wide range of capital assets, including not only manufactured assets (roads and buildings and machinery) and knowledge and skills (mathematics and the ability to do mathematics), but also natural capital (oil and

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[2] It is an elegant feature of Ramsey's formulation that he avoided specifying a subsistence rate. For technical reasons, he assumed that U has a least upper bound (lub), but that the lub is beyond reach no matter how high is consumption. He called the lub, "bliss"! U is assumed not to depend explictly on time. This looks odd until we ask in which ways it is likely to change. The fact is, we don't know. Certain obvious thoughts - for example, that the baskets of consumption goods and services that are needed today to attain a given level of well-being differ from those needed to attain the same level of well-being a hundred years ago - offer little reason for thinking that U depends explicitly on time. Admittedly, today's necessities are different from necessities a hundred years ago. But the change could have come about because of shifts in the technology of consumption (e.g., if all others communicate over the telephone, one loses out in not using the telephone).

[3] $\sum_{t}^{\infty}$ is the summation sign, from t to infinity. Thus, in equation (1), τ signifies dates that go from t to infinity.

natural gas, rivers and lakes, watersheds and wetlands, the atmosphere and the oceans, and ecosystems generally). Given this inheritance, generation 0 is able to identify the set of consumption streams (starting at t = 0) that are feasible. As Ramsey would have it, generation 0's problem is to identify within the set of feasible consumption streams, the one that maximizes V_0. The account in its entirety is as follows:

Generation 0 has inherited from its predecessors a wide array of capital assets. Given this inheritance, it is faced with a feasible set of consumption streams. Call this feasible set Ξ_0. From generation 0's vantage, a typical consumption stream reads as $(C_0, C_1, ..., C_\tau, ...)$. Imagine now that $(\mathbf{C}_0, \mathbf{C}_1, ..., \mathbf{C}_\tau, ...)$ is that member of Ξ_0 which maximizes V_0. Ramsey's theory calls upon generation 0 to consume $\mathbf{C}_0$. This simultaneously yields an investment decision (output minus what is consumed), which adds to, or subtracts from, the various capital assets generation 0 had inherited, which in turn determines the economic possibilities that are open to generation 1. Denote the set of feasible consumption streams for generation 1 to be Ξ_1. A typical member of Ξ_1 can be written as $(C_1, C_2, ..., C_\tau, ...)$.[4] The problem to be faced by generation 1 will be to identify that element of Ξ_1 that maximizes V_1. It is an interesting and important feature of expression (1) that generation 1 would identify the optimum consumption stream to be $(\mathbf{C}_1, \mathbf{C}_2, ..., \mathbf{C}_\tau, ...)$.[5] Plainly, then, generation 1 would consume $\mathbf{C}_1$, invest accordingly, and pass on the optimum stocks of capital assets to generation 2. Denote the set of feasible consumption streams for generation 2 to be Ξ_2. A typical member of Ξ_2 can be written as $(C_2, C_3, ..., C_\tau, ...)$.[6] The problem to be faced by generation 2 will be to identify that element of Ξ_2 that maximizes V_2. It is an interesting and important feature of expression (1) that generation 2 would identify the optimum consumption stream to be $(\mathbf{C}_2, \mathbf{C}_3, ..., \mathbf{C}_\tau, ...)$.[7] Plainly, then, generation 2 would consume $\mathbf{C}_2$, invest accordingly, and pass on the optimum stocks of capital assets to generation 3. And so on. The ethical viewpoints of the succeeding generations are congruent with one another. Each generation chooses its level of consumption and leaves behind capital assets that can sustain the subsequent stream of consumption levels that it deems to be just, aware that succeeding generations will choose in accordance with what it had planned for them. In modern game theoretic parlance, Ramsey's optimum consumption stream is a "non-cooperative" (Nash) equilibrium among the generations. If expression (1) is the coin by which generation t interprets intergenerational well-

[4] Note that the first element of the sequence is generation 1's consumption.

[5] Looking backward, therefore, it would reason that generation 0 had "done the right thing" by consuming $\mathbf{C}_0$. Note too that generation 1 would find it optimum to choose the level of consumption generation 0 had planned for it, namely, $\mathbf{C}_1$.

[6] Note that the first element of the sequence is generation 2's consumption.

[7] Looking backward, therefore, it would reason that generations 0 and 1 had "done the right thing" by consuming $\mathbf{C}_0$ and $\mathbf{C}_1$, respectively. Note too that generation 2 would find it optimum to choose the level of consumption generations 0 and 1 had planned for it, namely, $\mathbf{C}_2$.

being (for all $t \geq 0$), and if every generation can be expected to choose ethically, then there is no need for an intergenerational "contract". That it is not possible for the generations to devise a binding agreement among themselves is of no moment.

4 Problems with Infinite Horizon and No Discounting

Ramsey's assumption that the future is infinite feels odd. We know that the world will cease to exist at some date in the future. So it would seem realistic to stipulate a finite horizon, say T periods, where the chosen T is large. The problem is that no matter how large T is, there is some chance that the world will survive beyond T. So, an alternative to Ramsey suggests itself: specify the capital stocks that are to remain at T for generations still to appear, and regard intergenerational well-being to be the T-period sum of well-beings and the size of the capital base remaining at T.

There is a problem even with this formulation. If T and the capital base that remains at T are chosen arbitrarily, the consumption stream deemed the best could be sensitive to that choice. This means that T and the capital stocks at T should not be chosen arbitrarily, but should be based on our understanding of what lies beyond T (for example, the needs of those who may appear after T). But then, why not include their claims in the ethical exercise to begin with; why truncate the future into two bits? The route Ramsey followed, of regarding the future to be indefinitely long, is logically unavoidable; for, although we know that the world will not exist for ever, we don't know when it will cease to exist.

I want to leave aside for the moment the question whether V_t in expression (1) is well defined. (The infinite sum may not, after all, exist; see below.) The point to which I want now to draw attention is that in Ramsey's formulation, as reflected in expression (1), future values of U are *undiscounted*. (Formally, V_t is symmetric in its arguments.) More than any other feature of his theory, it is this that has provoked debate among economists and philosophers. Ramsey himself wrote (1928: 261) that to discount later Us in comparison with earlier ones is "... ethically indefensible and arises merely from the weakness of the imagination." Harrod (1948: 40) followed suit by calling the practice a "... polite expression for rapacity and the conquest of reason by passion."[8]

What would Utilitarianism with positive discounting of future well-beings look like? Let δ (> 0) be the rate at which it is deemed desirable to discount future well-beings. Then, in place of expression (1), intergenerational well-being at t would be

$$V_t = \sum_{t}^{\infty} U_\tau \beta^{(\tau-t)}, \text{ for } t \geq 0, \text{ where } \beta \equiv 1/(1+\delta) < 1, \tag{2}$$

[8] Their position has been re-examined and endorsed by a number of modern philosophers; see Feinberg (1980) and Broome (1992). For wide-ranging discussions among economists on this question, see Lind (1982) and Portney and Weyant (1999).

In expression (2), δ the *discount rate* and β the resulting *discount factor*.[9]

To some economists, Ramsey's stricture, forbiding the discounting of future well-beings, reads like a Sunday pronouncement. Solow (1974a: 9) expressed this feeling when he wrote, "In solemn conclave assembled, so to speak, we ought to act as if the [discount rate on future well-beings] were zero." But there is a deeper problem with the stance. In such complex exercises as those involving the use of resources over a very long time horizon, in a world where investment in capital has a *positive* return (the latter reflecting an in-built bias in favour of future generations), it is *foolhardy* to regard any ethical judgement as sacrosanct. This is because one can never know in advance what it may run up against. A more judicious tactic than Ramsey's would be to play off one set of ethical assumptions against another in not-implausible worlds, see what their implications are for the distribution of well-being across generations, and then appeal to our intuitive senses before arguing over policy. The well-being discount rate may well be too blunt an instrument to settle questions of intergenerational equity.

Consider, for example, the following ethical tension:

A. Low rates of consumption by generations sufficiently far into the future would not be seen to be a bad thing by the current generation if future well-beings were discounted at a positive rate. It could then be that, by applying positive discount rates, the present generation finds it acceptable to save very little for the future - it may even find disinvestment to be justifiable. But if that were to happen, the demands of intergenerational equity would not be met. This suggests that we should follow Ramsey and *not* discount future well-beings.

B. As there are to be a lot of future generations in a world that faces an indefinite future and where the return on investment is positive, not to discount future well-beings could mean that the present generation would be required to do too much for the future; that is, they would have to save at too high a rate. But if that stricture were to be obeyed, the demands of intergenerational equity would not be met. This suggests that we should abandon Ramsey and discount future well-beings at a positive rate.

The force of each consideration has been demonstrated in the economics literature. It has been shown that in an economy with exhaustible resources and "low" productive potentials for manufactured capital assets, optimum consumption declines to zero in the long run if the future well-beings are discounted at a positive rate, no matter how low the chosen rate is (Dasgupta and Heal, 1974), but increases indefinitely if we follow Ramsey in not discounting future well-beings (Solow, 1974b). This

[9] The discount rate in expression (2) is constant. Arrow (1999) has appealed to agent-relative ethics to explore the consequences of using a variable discount rate. The variation he explored arises from the idea that each generation should award equal weight to the well-beings of all subsequent generations, but should award its own well-being a higher weight relative to that awarded to the subsequent generations. In this paper I am exploring the concept of intergenerational well-being, an essential ingredient in Government House Ethics. It is doubtful that agent-relative ethics would be appropriate for such exercises as Government House would be required to conduct.

finding was the substance of Solow's remark (Solow, 1974a), that, in the economics of exhaustible resources, whether future well-beings are discounted can be a matter of considerable moment. In recent years, environmental and resource economists writing on *sustainable* development have taken this possibility as their starting point (e.g., Bromley, 1995).

On the other hand, if the Ramsey requirement, that future well-beings are *not* discounted, is put to work in a close variant of the model economy Ramsey himself studied in his paper, it recommends that every generation should save at a very high rate. For classroom parametrizations, the optimum saving rate has been calculated to be in excess of 60 percent of gross national product. In a poor country, such a figure would be unacceptably high, requiring the present generation to sacrifice beyond the call of duty.[10] The real problem is that no one, not even Ramsey, could be expected to know in advance how to capture the right balance between the claims of the present generation and those of future ones. The issues are far too complex, especially in infinite horizon models. Unaided intuition is suspect. Rushing to Utilitarianism with no discounting can be treacherous. What the quantitative exercises in Dasgupta and Heal (1974) and Solow (1974b) tell us is that the long-run features of optimum saving policies depend on the relative magnitudes of the rate at which future well-beings are discounted and the long-term productivity of capital assets.

In fact there is a deeper problem with Ramsey's stricture that future well-beings should not be discounted. Koopmans (1965) showed that consideration B can even overwhelm the stricture and render expression (1) incoherent. Zero discounting can imply that there is no best policy; that, no matter how high is the rate of saving, saving a bit more would be better. To see how and why, imagine a world where goods are completely perishable. Consider an economic programme where consumption is the same at every date. Now imagine that an investment opportunity presents itself in which, if the present generation were to forgo a unit of consumption, a perpetual stream of additional consumption μ (> 0) would be generated.[11] Suppose intergenerational well-being is represented by expression (1). Then, no matter how small is μ, future generations, taken together, would experience an infinite increase in well-being as a consequence of the investment, the reason being that μ "multiplied" by infinity is infinity. So, for any level of consumption, no matter how low, a further reduction in consumption (possibly short of a reduction that brings consumption down to zero) would be desirable. As a piece of ethics, this is clearly uncceptable. Ramsey's conception simply does not do.

5 Rawlsian Saving

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[10] As a matter of comparison, it should be noted that saving rates in the United Kingdom and the United States are in the range 10-15 percent of their gross national products. Interestingly, the fast growing poor countries of the world in the 1970s (Taiwan, South Korea, and Singapore) routinely saved at rates in the range 40-45 percent of their gross national products.

[11] This means that the rate of return on investment is μ. The example has been taken from Arrow (1999).

In the philosophical literature, the only rival to Ramsey's Utilitarian principle of optimum saving is probably the principle of just saving in Rawls (1972). In fact, though, Rawls doesn't have much of a theory of just saving. The first half of his second principle of justice, emanating from choice behind the veil of ignorance (the "original position"), alludes to a just saving principle (Rawls, 1972: 302), but he gets nowhere with it (Arrow, 1973; Dasgupta, 1974, 1994). For example, he writes (Rawls, 1972: 284-95): "The parties do not know to which generation they belong ... Thus the persons in the original position are to ask themselves how much they would be willing to save ... at any given phase of civilization with the understanding that the rates they propose are to regulate the whole span of accumulation... Since no one knows to which generation he belongs, the question is viewed from the standpoint of each and a fair accommodation is expressed by the principle adopted."

But this says nothing of import, it is merely a requirement of intergenerational *consistency*, namely, that each generation should find it reasonable to save at the rate that was agreed upon in the original position. But we are not told what could be expected to be agreed upon. If Rawls' Difference Principle, which is all-important in the rest of his book, were applied to the saving problem, then for all consumption streams $\{C_0, C_1, C_2, ..., C_t, ...\}$, the Rawlsian V_t would be

$$V_t = \inf \{U(C_t), U(C_{t+1}), ...\}. \quad (3)$$

The problem with this conception is that if savings yielded a positive return, there would be no ethical motivation *to* save: a positive rate of saving, no matter how low, would mean that the present generation would be worse off than all future generations, an inequity that it could prevent by not saving at all!

Rawls recognised the problem. So he altered the motivation assumption of individuals and wrote:

"The process of accumulation, once it is begun, and carried through, is to the good of all subsequent generations. Each passes on to the next a fair equivalent in real capital as defined by a just savings principle... Only those in the first generation do not benefit ... for while they begin the whole process, they do not share in the fruits of their provision. Nevertheless, since it is assumed that a generation cares for its immediate descendents, *as fathers say care for their sons,* a just savings principle ... would be acknowledged." (Emphasis added.)

One could take Rawls to mean by this that generation t's well-being depends not only on its own consumption level, but also on its descendents' consumption levels. Arrow (1973) and Dasgupta (1974) proved that if parental concerns extend only to a finite number of descendents, the Difference Principle either implies that no generation should do any saving (this would be so if the natural concern for descendents is "small"), or recommends a programme of savings and dissavings that would be revoked by the generation following any that were to pursue it (this would be so if the natural concern for descendents is not "small"). The latter would mean that Rawlsian saving policies are intergenerationally inconsistent.

On the other hand, if parental concern were to extend to all descendents, the Rawlsian formulation would look similar to Ramsey's (expression (1)), albeit with possible discounting (expression (2)).

However, the infinite sum would now represent a generation's well-being, not intergenerational well-being. Given that the Difference Principle is to apply, the Rawlsian recommendation would be that the rate of saving should be zero: any saving, whether positive or negative, would create inequity across the generations.

In short, what Rawls has offered us is either mean spirited (no saving at all) or intergenerationally inconsistent. So we must look elsewhere for a theory of just saving.

6 The Koopmans Construct

In a classic article, Koopmans (1960) adopted a different research tactic from that of Ramsey.[12] Intergenerational well-being in Ramsey's theory is the sum of well-beings (expression (1)). The ethical comparisons of infinite consumption streams in Ramsey's theory is derived from the sum of well-beings. In constrast, the primitive concept in Koopmans's formulation is that of an *ordering* of infinite well-being streams.[13] Koopmans's tactic was to impose ethical conditions on such orderings and to determine, if possible, the form of their numerical representations. Intergenerational well-being in Koopmans's theory is a numerical representation of an ordering of infinite well-being streams.[14]

An ordering is said to be *continuous* if, in an appropriate mathematical sense, well-being streams that don't differ much are close to one another in the ordering. For an ordering to be *monotonic*, it is meant that a given stream of well-beings is regarded as being more just than another if *no* generation experiences less well-being along the former than along the latter and if there is at least one generation that enjoys greater well-being in the former than it does in the latter. Continuity is a compelling assumption. But even monotonicity is compelling, since it says that a just distribution of well-beings should not be an inefficient distribution of well-beings.[15]

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[12] See also Koopmans, Diamond, and Williamson (1964) and Diamond (1965).

[13] In a subsequent work (Koopmans, 1972), the primitive was a consumption stream. But for ease of exposition, I report his earlier formulation. In order to avoid technicalities, I also cut corners in the account that I offer; nothing of moment will be lost by my so doing. To remind the reader, by an *ordering* on a set of objects, X, we mean a binary relation, R (interpreted as, say, "at least as good as", or "no less just than") among the objects that is reflexive (for all x in X, xRx), transitive (for all x,y, and z in X, if xRy and yRz, then xRz) and complete (for all x and y in X, either xRy or yRx). The idea of building the concept of social welfare from the more fundamental notion, that of a social ordering (a sort of ground-up approach), was not Koopmans' creation. It was the basis of the new welfare economics of (Bergson) Burke (1938) and Samuelson (1947). But it was Koopmans who used the apparatus to develop the concept of intergenerational justice.

[14] Let R be an ordering of the elements of a set X. Let V be a numerical function on X. This means that V awards a numerical value to each element of X. We say that V is a *numerical representation* of R if, for all x and y in X, $V(x) \geq V(y)$ if and only if xRy.

[15] Even Rawlsian justice is efficient in the production and distribution of what Rawls called primary goods.

Imagine that the problem of intergenerational justice is being deliberated by generation 0. To see what the term "discounting" means when the primitive concept is an ordering of well-being streams, consider two streams, $\{U_0, U_1, U_2, ..., U_\tau, ...\}$ and $\{U_1, U_0, U_2, ..., U_\tau, ...\}$, that are identical except for the well-beings of generations 0 and 1, which are interchanged. Now suppose that $U_1 > U_0$. Positive discounting of future well-beings means that $\{U_1, U_0, U_2, ..., U_\tau, ...\}$ should be judged to be more just than $\{U_0, U_1, U_2, ..., U_\tau, ...\}$. Diamond (1965) proved that if an ordering of infinite streams of well-being satisfies continuity and monotonicity, it must involve a positive discounting of future well-beings.

If you think this result is stunning, you will find the following no less so. To motivate it, consider two further ethical assumptions, which Koopmans (1960, 1972) christened *separability* and *stationarity*, respectively. The former is familiar from expected utility theory, where it is applied to states of nature, rather than time. In the present context, it says that the ethically permissible tradeoff between the well-beings of any pair of generations is independent of the well-beings of all other generations. The stationarity axiom, however, may be novel to philosophers; but it is merely a strong rendering of the idea that ethical principles should be universalizable. The axiom states that the ordering of a set of infinite well-being streams should be the same no matter which generation ranks the elements of that set. Generations should assume the same ethical perspective as and when they come on the scene: their time of arrival should not matter.[16] Koopmans (1972) showed that if, in addition to continuity and monotonicity, an ordering on well-being streams satisfies separability and stationarity, its numerical representations is of the form,

$$V_t = \sum_{t}^{\infty} G(U_\tau)\beta^{(\tau-t)}, \quad \text{for } t \geq 0, \text{ where } \beta \equiv 1/(1+\delta), \text{ with } \delta > 0, \text{ where G is a monotonically increasing function of U.} \qquad (4)$$

Notice that the numerical representation of the ordering is not unique, because G is unique only

[16] Formally, the axioms are:
Intergenerational Separability:
If $\{U_0, U_1^*, U_2^*, ..., U_\tau^*, ...\}$ is judged to be ethically at least as good as $\{U_0', U_1^*, U_2^*, ..., U_\tau^*, ...\}$, then this judgement is independent of the reference stream $(U_1^*, U_2^*, ..., U_\tau^*, ...)$, where the reference stream awards U_1^* to generation 0, U_2^* to generation 1, and so on.
Stationarity:
For all $\{U_0^*, U_1^*, U_2^*, ..., U_\tau^*, ...\}$, if $\{U_0^*, U_1^*, U_2^*, ..., U_\tau^*, U_{\tau+1}, U_{\tau+2}, ...\}$ is judged to be ethically at least as good as $\{U_0^*, U_1^*, U_2^*, ..., U_\tau^*, \underline{U}_{\tau+1}, \underline{U}_{\tau+2}, ...\}$, then $\{U_{\tau+1}, U_{\tau+2}, ...\}$ should be judged to be ethically "at least as good as" $\{\underline{U}_{\tau+1}, \underline{U}_{\tau+2}, ...\}$. In other words, the ranking of a pair of streams that are identical over the first $\tau+1$ generations should be the same as the ranking of the pair that is constructed by deleting the first $\tau+1$ periods' well-beings from both and by bringing forward the subsequent well-beings by $\tau+1$ periods. But this can be shown to amount to saying that the perspective that ought to be adopted by generation $\tau+1$ is the same as the one that ought to be adopted by generation 0.

upto a positive affine transformation.[17] In expression (4), δ is the well-being *discount rate*.

While expression (4) looks identical to Classical Utilitarianism with discounting (expression (2)), it is not. Even if U were to be interpreted as "utility", G(U) should not be so interpreted: G is a monotonically increasing function of U. If instead, U were to be interpreted more widely as well-being (as we are interpreting it here), the function G would reflect the manner in which different levels of well-being are traded off against one another in the ethical reckoning. This means that G is a measure of the extent to which intergenerational equity in well-beings is accommodated in the ordering, a matter to which I return in Section 8.

It will be noticed that Koopmans' axioms, on their own, are unable to determine the numerical value of δ; nor are they able to specify the functional form of G (barring the fact that it is monotonically increasing). This open-endedness makes Koopmans' formulation particularly attractive. The formulation ties down the concept of intergenerational well-being, but it doesn't tie it down unduly; it leaves open the door for further ethical deliberations. In practical applications, Koopmans' formulation allows us to conduct conceptual experiments. It possesses sufficient degrees of ethical freedom (in the choice of the number δ and the function G) to iterate between the possible and the desirable to arrive at what Rawls (1972) called a "reflective equilibrium".

It is an agreeable feature of Koopmans's theory that, as in Ramsey's theory, the ethical viewpoints of succeeding generations are congruent with one another. Each generation chooses that policy it deems just, aware that succeeding generations will choose in accordance with what it had planned for them.

7 A Possible Weakness in Koopmans' Formulation

But there is a seeming problem with (4) as an expression of intergenerational well-being: it is vulnerable to what we earlier called consideration A. It is easy to construct possible worlds where Koopmans's ethical axioms regard as most desirable a consumption stream that declines to zero in the long run (Dasgupta and Heal, 1974).

The question is whether we should find this troubling. I argue that we should not. Imagine that we adopted Koopmans's formulation of intergenerational well-being (expression (4)), applied it to a deterministic model of production and consumption possibilities and discovered that if the discount rate δ is positive, the just consumption level will decline to zero in the long run, no matter how small δ happens to be. Suppose it is also discovered that if δ is sufficiently small (but not zero), the decline in consumption will begin only in the distant future - the smaller is δ, the farther is the generation that will experience a

[17] Thus, if expression (4) is a numerical representation of the ordering, then it would remain so if G were replaced by (aG + b), where a and b are constants and a > 0.

lowering of consumption.[18] Should Koopmans's formulation be rejected on the ground that it recommends an eventual decline in consumption?

Many would reject it on that very ground,[19] but I have never understood why. Models of a deterministic world with an infinite horizon are mathematical artifacts. They are meant to train our intuitions about economic possibilities in a world with a long, but finite, horizon, when we are loath to specify the termination date, and are also loath to acknowledge that it as an uncertain date. The models must not be taken literally, because Earth will not last forever. We cannot, of course, know now when Earth will cease to exist, but we do know that it will cease to exist *by* some date, say, 10^{12} years. (That's 1 trillion years; and Earth is a bit over a mere 4 billion years old.) Suppose, for example, that we were to set δ equal to 10^{-n} per generation and were to choose n sufficiently large, so that the just consumption level in the kind of deterministic model I have been considering would have a turning point for, say, generation 10^{30} (that's a billion billion trillion generations). Should we care that consumption in the model will decline for generations 10^{30} onward? I know of no reason why we should. On the contrary, justice would be ill-served if all generations were asked to save for a posterity that won't appear. As an articulation of the concept of intergenerational well-being, Koopmans's theory would seem to be compelling.

8 Ethical Duality

We noted in Section 6 that δ is not the only free parameter in Koopmans' formulation: the function G(U) is another. The two together determine the rates at which the well-beings of different generations are traded off against one another in expression (4). Now G is an increasing function of U, meaning that $G'(U) > 0$. It can be shown that if equity in the intergenerational distribution of well-beings is taken to be a commendable feature of such distributions, then $G''(U)$ must be negative, which is to say that G must be a strictly concave function (Kolm, 1969; Atkinson, 1970). It is also easy to prove that, other things being equal, the greater is the concavity of G, the greater is equity favoured in the ethical theory underlying expression (4). I demonstrate below that there is a sense in which δ and G are dual to each other, that aspects of the concept of equity among the generations that can be captured in the number δ can also be caught in the function G(U).

To see this, consider a world where the rate of return on investment is a constant, μ, per generation. We imagine that capital assets are productive. Therefore, $\mu > 0$. As in Section 3, I assume that generation t's well-being is an increasing function of its consumption level (C_t), but that it increases at a diminishing rate, meaning that $U'(C)$ is positive and U(C) is a strictly concave function ($U''(C) < 0$). Define $H(C) = G(U(C))$. Since G(U) is an increasing and strictly concave function also, it must be that H

[18] As noted earlier, this has been shown to be the case in simple economic models involving exhaustible resources. See Dasgupta and Heal (1979: ch. 10).

[19] For example, Heal (1998). Earlier, I called it consideration A.

is an increasing and strictly concave function of C. Thus, $H'(C) > 0$ and $H''(C) < 0$. For expositional ease, I now focus on the question of equity among the generations in the distribution of *consumption*, rather than well-being.

The theory of inequality measures has taught us that the correct index of the degree of concavity of H with respect to C is the absolute value of the percentage rate of change in $H'(C)$. Let α be that measure. Then we have

$$\alpha(C) = -CH''(C)/H'(C) > 0. \tag{5}$$

$\alpha(C)$ is called the *elasticity* of $H'(C)$. The theory of inequality measures has taught us that the larger is $\alpha(C)$, the more equality-regarding is the concept of intergenerational well-being in expression (4). Since α is defined at each value of C, α is a local measure, which means that in general α is a function of C.

Now consider generation 0's ethical problem. It has inherited from its predecessors a wide array of capital assets. Given this inheritance and the fact that the rate of return on capital investment is μ, it is faced with a feasible set of consumption streams, which, as in Section 3, I label as Ξ_0. From generation 0's vantage, a typical consumption stream reads as $(C_0, C_1, ..., C_\tau, ...)$. Imagine now that $(\mathbf{C}_0, \mathbf{C}_1, ..., \mathbf{C}_\tau, ...)$ is that member of Ξ_0 which maximizes V_0, where V_0 is given by expression (4), with $t = 0$. Ramsey (1928), Koopmans (1965) and others have shown that the optimum consumption stream $(\mathbf{C}_0, \mathbf{C}_1, ..., \mathbf{C}_\tau, ...)$ must be a solution of the equation

$$\mu = \delta + \alpha(C_t)g(C_t), \tag{6}$$

where $g(C_t)$ is the percentage rate of change in consumption between the consumption levels enjoyed by generations t and t+1.

Equation (6) is fundamental to intergenerational ethics. It has a simple interpretation. μ is the rate of return on investment, meaning that it is, at the margin, the percentage rate at which consumption can *feasibly* be exchanged among successive generations, t and t+1 ($t \geq 0$). The right hand side of equation (6) can be shown to be the percentage rate at which, at the margin, it is ethically *permissible* to exchange consumption among the successive generations t and t+1 (see, e.g., Arrow and Kurz, 1970; Dasgupta and Heal, 1979). If the two expressions were not equal, an appropriate reallocation of consumption between t and t+1 would increase V_0. Therefore, the consumption stream deemed just must satisfy equation (6), and it must satisfy the equation for every $t \geq 0$. In the language of social cost-benefit analysis, the right hand side of equation (6) is the social rate at which future *consumption* ought to be discounted (in contrast to future well-beings, which are discounted at the rate δ).

There is an attractive class of functional forms of H(C) for which equation (6) simplifies enormously. Consider the form

$$H(C) = B - C^{-(\alpha-1)}, \qquad \text{where } B > 0 \text{ and } \alpha > 1.^{20} \qquad (7)$$

If H(C) satisfies formula (7), the elasticity of $H'(C)$, which is $\alpha(C)$, is independent of C. In the economics literature, formula (7) is ubiquitous. As we see below, it offers a most instructive laboratory for conducting thought experiments.

On using expression (7) in equation (6) and re-arranging terms, we obtain,

$$g(C_t) = (\mu - \delta)/\alpha. \qquad (8)$$

For vividness, imagine that δ is chosen to be less than μ. Equation (8) tells us that, since the right hand side is a positive constant, justice demands that consumption should increase at the exponential rate $(\mu - \delta)/\alpha$. Notice though that, as δ and α are two free ethical parameters in Koopmans' theory, that same growth rate would be implied by an infinite family of (δ, α) pairs. Presumably, a concern for equity in consumption among the generations would lead us to insist that $g(C_t)$ should not be too large. Otherwise, earlier generations would enjoy far lower consumption levels than later generations. Lowering the right hand side of equation (8) would flatten the optimum consumption stream somewhat. But just as $g(C_t)$ would have a low value if, other things being equal, δ were chosen to be nearly μ, the same low value would be realized if, other things being equal, α were chosen to be large. This is the sense in which δ and α are ethically dual to each other.

9 Population Growth

As Earth is finite, changes in the size of population, when averaged over time, must be zero over the very long run. The base case we have been considering so far, that population size remains constant, is thus valid when the reckoning is the very long run. But for the not-so-very long run, population can be expected to change. What is the right concept of intergenerational well-being when population size is expected to change over time?

Two alternatives have been much discussed in the literature. Both reduce to expression (4) if population is constant. After presenting them I introduce a third conception, which has been shown to be the natural one to adopt when we try to formulate the concept of sustainable development (Dasgupta, 2001). It too reduces to expression (4) if population is constant.

One alternative is to regard the well-being of a generation to be the per capita well-being of that generation (with no allowance for the numbers involved) and sum the per capita well-beings of all generations, possibly using a discount rate. To formalize, imagine for simplicity that members of the same generation are awarded the same consumption level. Let U_τ be the well-being of the representative person in generation τ. We then have (Cass, 1965; Koopmans, 1965),

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[20] The constant B plays no role, in view of what was mentioned in footnote 16. I have introduced it, nonetheless, in case the reader feels that H(C) ought to be negative for very low values of C, but positive for sufficiently large values of C.

$$V_t = \sum_{t}^{\infty} G(U_\tau)\beta^{(\tau-t)}, \text{ for } t \geq 0, \text{ where } \beta \equiv 1/(1+\delta), \text{ and } \delta > 0. \quad (9)$$

The other view is to regard intergenerational well-being to be the sum of the discounted flow of each generation's well-being. Specifically, if N_τ is the size of generation τ, then (Meade, 1955; Mirrlees, 1967; Arrow and Kurz, 1970),

$$V_t = \sum_{t}^{\infty} N_\tau G(U_\tau)\beta^{(\tau-t)}, \text{ for } t \geq 0, \text{ where } \beta \equiv 1/(1+\delta), \text{ and } \delta > 0. \quad (10)$$

Expression (9) regards generations, not people, to be the claimants. In contrast, expression (10) regards people, not generations, to be the claimants. Koopmans' ethical axioms, when applied to the case where generations are regarded as the claimants, yields expression (9); they yield expression (10) if people are regarded as the claimants.

Which is right? To answer, it pays to study the ways in which their recommendations differ. Imagine an economy consisting of two islands, with populations N_1 and N_2, respectively. People are assumed to be identical. A person's well-being is denoted by U, which increases with consumption, but at a diminishing rate. There is a fixed amount of consumption services, C, that the government is to distribute.[21] Let C_1 and C_2 be the amounts distributed to the two islands. We take it that, no matter how much were awarded to each island, the distribution of consumption *within* each would be equal. The economy is timeless.

If numbers count, then analogous to expression (10), social well-being would be $[N_1U(C_1/N_1) + N_2U(C_2/N_2)]$ and the government would distribute C in such a way that consumption is equalized among all citizens.[22] This is obviously the right allocation, because geographical differences are an artifact for the problem in hand. On the other hand, if numbers don't count, so that social well-being is taken to be $[U(C_1/N_1) + U(C_2/N_2)]$, the government should distribute less to each person in the more populous island[23], which is to say that the use of expression (9) discriminates against more numerous generations. This simply cannot be right. Extending this example to the case of a sequence of generations, we conclude that, of expressions (9) and (10), it is the latter that reflects the notion of intergenerational well-being.

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[21] The example is taken from Meade (1955: 87-89) and Arrow and Kurz (1970: 13-14).

[22] To prove this, simply maximise $[N_1U(C_1/N_1) + N_2U(C_2/N_2)]$ by suitable choice of C_1 and C_2, subject to the constraint $C_1 + C_2 = C$.

[23] To prove this, simply maximise $[U(C_1/N_1) + U(C_2/N_2)]$ by suitable choice of C_1 and C_2, subject to the constraint $C_1 + C_2 = C$.

Expression (10) measures *total* (discounted) well-being. But there is another formulation of the concept of intergenerational well-being which is equally compelling. It is the *average* well-being of all who are to appear on the scene:

$$V_t = \left(\sum_t^{\infty} N_\tau G(U_\tau)\beta^{(\tau-t)}\right)/\left(\sum_t^{\infty} N_\tau\beta^{(\tau-t)}\right), \text{ for } t \geq 0, \text{ where } \beta \equiv 1/(1+\delta), \text{ and } \delta > 0. \qquad (11)$$

Notice that, since $\sum_t^{\infty} N_\tau\beta^{(\tau-t)}$ is a positive constant, expressions (10) and (11) are numerical representations of the same underlying ordering of infinite streams of well-being. Koopmans' axioms, when applied to the ethical sensibility that regards people to be the claimants, simultaneously yield expressions (10) and (11). This implies that, as conceptions of justice among the generations, there is nothing to choose between total well-being (expression (10)) and average well-being (expression (11)). A policy deemed to be just if expression (10) were used as the criterion of choice would also be judged to be just if instead expression (11) were used as the criterion of choice. In this sense, the two expressions would amount to the same.

However, Arrow, Dasgupta, and Mäler (2003a,b) have shown that the two expressions would have different implications if they were used to decide whether a policy leads to an outcome where intergenerational well-being is *sustained*. In particular, it can be shown that expression (11) is the more natural formula to use in discussions of *sustainable development* (Dasgupta and Mäler, 2000; Dasgupta, 2001). Justice and sustainability are different concepts, serving different purposes. In the following section, I use expected utility theory as the basis of choice behind Rawls' veil of ignorance to provide an alternative interpretation of expression (11).

10 Uncertainty

How should uncertainty be accommodated? The theory of choice under uncertainty, in its normative guise, is called the *expected-utility* theory. There is a large and still-growing experimental literature attesting to the fact that in laboratory conditions people don't choose in accordance with the theory.[24] But here we are concerned with normative questions. That the choices we make in the laboratory don't conform to expected utility theory does not mean that the theory is not the correct ethical basis for evaluating the policy alternatives Government House faces.

When applied to the valuation of uncertain well-being streams, probabilities are imputed to future events. The probabilities are taken to be subjective, such as those involving long-range climate, although

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[24] See, for example, Bell, Raiffa, and Tversky (1988).

there can be objective components, such as those involving the weather. Let E_t denote generation t's expectation. Imagine once again that population remains constant. Intergenerational well-being can then be expressed as,

$$V_t = E_t\left(\sum_{t}^{\infty} G(U)\beta^{(\tau-t)}\right), \text{ for } t \geq 0, \text{ where } \beta \equiv 1/(1+\delta), \text{ with } \delta > 0. \qquad (12)$$

The function G(U) in expression (12) reflects the attitude to risk in Government House.

The discount rate δ in expression (12) can be given an additional interpretation. The time horizon has so far been taken to be infinity. But we know that Earth will become uninhabitable some time in the future, even though we don't know when that will be. Consider those causes of extinction that are beyond our control. The simplest (though not the most plausible) way to formulate this uncertainty is to suppose that the date of extinction is subject to a *Poisson process*, which is to say that the probability of extinction facing any generation, given that extinction hasn't occured until its arrival, is constant. That constant is called the Poisson "hazard" rate. It can be shown (Yaari, 1965) that choice under uncertainty governed by a Poisson process is equivalent to choice in a world where there *is* no chance of extinction, but where future well-beings are discounted at the Poisson hazard rate. For example, suppose that for each generation t, conditional on Earth surviving until t, the probability of extinction is 0.001 percent. Then, in evaluating well-being streams, one may pretend that extinction won't occur, but add a premium of 0.001 per generation to the rate of discount on future well-beings. In expression (12), uncertainty in the date of extinction is included in δ. Extinction at some unpredictable date offers an additional reason why the future should be discounted.

That the possible exogenous causes of Earth's extinction are subject to a Poisson process really does stretch the imagination.[25] It is much more plausible that the probability of extinction for generation t, conditional on Earth surviving until t, will be zero for many centuries, rising thereafter in the very long run. The discount rate that would correspond to such a stochastic process would be a function of time, not a constant.

As an application of the use of expression (12), I now show that the maximization of average intergenerational well-being (expression (11)) can be derived as the criterion for intergenerational justice if we were to appeal to expected utility theory behind Rawls' veil of ignorance. The idea is to regard an economy at t to be a different economy from that same economy at t+1. Now suppose you were asked which of the two economies you would choose to inhabit if you did not know which person's shoes you would occupy in either, but attributed "equi-probability" to each position (Harsanyi, 1955). I have qualified

[25] The Poisson process is often invoked by economists because of its simplicity - a large astroid hitting Earth is a possible interpretation; but there is little else to commend it.

equi-probability, because it makes no sense when the future has no termination date. To give it sense we must suppose that the probability of extinction over the indefinite future is unity. We may then talk of equi-probability of the conditionals.

Suppose for simplicity that the possibility of extinction is governed by a Poisson process, which is to say that the probability rate of extinction at t, conditional on Earth having survived until then is a constant, δ (> 0). Imagine next that in this thought experiment your choice is based on your expected well-being in the two economies. Expected well-being in the economy commencing at t would then be given by expression (11).

It will be observed that V_{t+1} would be of the same form as ${}_tV$, with τ commencing at t+1 in expression (11). You would choose between the two economies on the basis of V_t and V_{t+1}.

Uncertainties regarding events in the very distant future are sometimes called *deep* uncertainties, the qualifier is taken to mean that it may not be possible to assign subjective probabilities to those events. This is another way of saying that when there are deep uncertainties, it is difficult to know what one should choose, or how one should organise one's thoughts regarding what to choose. Examples frequently mentioned involve environmental risks. People observe that it may not be possible today to estimate the risks of environmental catastrophies in the distant future, let alone to enumerate what they may consist of. Bewley (1989) has developed an account of uncertainty that offers a reason why we ought to be reluctant to undertake activities involving inestimable risks. He offers a reason why the *status-quo* should assume a favoured status, which is the hallmark of what many refer to as the *precautionary principle* (e.g., Appell, 2001). Bewley's theory would appeal to someone who feels that it is easier to prevent environmental damage than to repair it subsequently. The theory gives expression to the demand that, in evaluating radically new technology (e.g., biotechnology), the burden of proof ought to shift away from those who advocate protection from environmental damage, to those supporting the new technology.

But these are early days for such theories as Bewley's. The problem is that they can be supremely conservative. Admittedly, even the expected utility theory can be made ultra-conservative if we adopt an infinite aversion to risk - which is to say that the elasticity of $G'(U)$ in expression (12) is infinity - and imagine that the worst that can happen under any change in policy is worse than the worst that can happen under the *status-quo*. But it is difficult to justify such an attitude: we wouldn't adopt it even in our personal lives. At the moment we don't have a theory, normative or otherwise, that covers long-term environmental uncertainties in a satisfactory way.

These are some reasons why the expected-utility theory remains a popular framework for evaluating policy options. In practical decision-making, though, short-cuts have to be made. Simple rules-of-thumb are often followed in the choice of public policy, for example, setting interest rates so as to keep the rate of inflation from exceeding, say, m percent per year. But the expected-utility theory remains the anchor for reasoning about economic policies. If the probability of disasters under radically new processes and products are non-negligible, the expected-utility theory recommends caution. The theory stresses trade-offs, it asks us to articulate our attitude to risk, and it forces us to deliberate on the likelihood of various outcomes. For the moment, it is the only plausible game in town.[26]

11 Conclusions

In this article I have argued that the formal apparatus Frank Ramsey introduced to give shape to the question "How Much of its Income Should a Nation Save?" can be given a far wider interpretation than the one he gave to it. Ramsey's ethics was overtly Utilitarian. Nearly five decades of work by economists working on the ethics of the long run has shown that that ethics will not do. It has also shown that, agreeably, there is a compelling ethical theory that has the same mathematical structure as the one invented by Ramsey. So, although Ramsey's ethics cannot be accepted, the techniques he devised for evaluating the just rate of saving can be adapted for use in worlds that are ethically far richer than the one he considered.

[26] Alternatives to the expected-utility theory were much explored during the 1950s. See Luce and Raiffa (1957: ch.3) for an axiomatic classification of such theories.

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