



HAL
open science

How the "Ramsey formula" came to define time discounting in economics (1950-2000)

Beatrice Cherrier, Béatrice Cherrier, Pedro Garcia Duarte

► To cite this version:

Beatrice Cherrier, Béatrice Cherrier, Pedro Garcia Duarte. How the "Ramsey formula" came to define time discounting in economics (1950-2000). 2024. hal-04719083

HAL Id: hal-04719083

<https://hal.science/hal-04719083v1>

Preprint submitted on 2 Oct 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0 International License

How the “Ramsey formula” came to define time discounting in economics (1950-2000)

Beatrice Cherrier & Pedro Garcia Duarte
CNRS, CREST INSPER

September 2024

“Identifying the proper discount rate is probably the single most important analytical step in economic analysis of global warming. It is also the most profound ethical question, since it inherently confronts present pain of abatement cost against damages suffered by future generations if no action is taken” (IPCC discount chapter, draft Sept 1994, page 1)

1. Introduction

In November 2023, the US Office of Management Budget (OMB) released Circular A-4, which contained new guidelines for the cost benefit evaluation of federal public policies, investments and regulations. For months already, several of these guidelines had stirred controversies among economists. One bone of contention was the proposal that the discount rate, aka the tool used to make future costs and benefits commensurable with present ones, should be in the range of 1.1-2%, which some economists took to be too low (implying that future costs and benefits weight more in present-day decisions). Several environmental economists signed a letter contending that the OMB did not properly adjust the discount rate for risks. Beyond discussing numbers, the economists debating the OMB guidelines also reflected on the dominant framework to think about discounting. The A-4 draft circulated during the Spring of 2023 extensively discussed an equation often known as the “Ramsey formula”:¹

$$r_t = \rho + \eta \cdot g_t,$$

where r is the discount rate, ρ is the pure rate of time preference, η is the elasticity of the marginal utility of consumption and g is the growth rate of per-capita consumption.²

But many commenters challenged the use of the formula. As one reviewer noted, “[a]lthough the Ramsey formula has been in the economics literature since 1928, no consensus

¹ It’s also called the “Ramsey rule” or “Ramsey equation,” sometimes interchangeably and sometimes to designate slightly different “discount rates,” as will be explained later. We use the “formula” terminology because there is another “Ramsey rule” in the economic literature dealing with growth and another “Ramsey equation” on taxation.
²The emphasis was in line with the guidelines circulated a few months before by the US Environmental Protection Agency for computing the social cost of carbon. Altogether focused on the Ramsey formula, the EPA authors argued that “the use of the Ramsey formula provides internal consistency within the modeling between the socio-economic scenarios and the discount rates when accounting for the effect of correlations between climate change damages and economic growth” (EPA 2022, 56). They added that the formula “remains widely used in the peer review literature and is consistent with the National Academies’ (2017) recommendations.””

appears to have been reached concerning parameter values, with a wide range of possible parameter values” (OMB 2023, 88-89). Another explained that one implication of using the formula was that “the discount rate is inherently linked to the growth rate of the economy.” Several commenters concluded that the Ramsey formula is “a better guide to prescriptive discounting rather than descriptive discounting.” In the final draft, therefore, the OMB “decided to reduce ... discussion of the Ramsey approach at this time” (p.89). The current debate is not the first involving the Ramsey formula. The famed controversy between British economist Nicholas Stern and William Nordhaus from Yale on discounting, which took place twenty years ago, centered on how to parametrize the above equation, but both economists agreed that it was the right framework for such discussions.³

Despite its prominence, the formula’s exact origins and path to widespread adoption in economics remain unclear. It is absent from the historical work that have tracked the rise of discounting among late 16th century clergymen, 17th century merchants, 19th century foresters, to become ubiquitous in 20th century business (Doganova 2024; Deringer 2024). The formula is also peripheral in histories of cost-benefit analysis, with which discounting became intertwined after World War II (Berman 2023, Banzhaf 2009). This comes from the framing choices of these works: with the exception of Banzhaf, they do not cover academic economics, where the formula originates, and they stop with the large-scale dissemination of Discounted Cash Flow and cost-benefit methods in the 1960s and the 1970s, when the Ramsey formula had not yet stabilized.

In fact, despite the widespread misperception that such formula originates in an 1928 influential article by the British mathematician Frank Ramsey, it is not to be found there. The ambiguities found in Ramsey’s article nonetheless perfectly encapsulate how economists had since struggled with discounting. To understand how much a nation should save over time, he wrote down a model of a stationary economy (without population growth or technical change), with an objective function that was an intertemporal sum of utilities over the indefinite future – a setting widely reused in the postwar period. As his oft-quoted statement that discounting “is ethically indefensible and arises merely from the weakness of imagination” shows, Ramsey (1928, 543) avoided discounting future utilities for most of the paper. He reckoned that *individuals* may be myopic or impatient, but he thought that it would be unfair for *societies* to discount the future when allocating resources across generations. As a mathematician, he however recognized that this would have a cost: without discounting, the objective function, an infinite sum, might not converge. He addressed this tractability issue by assuming a maximum obtainable utility, which he called “bliss,” and rather sought to minimize the distance between bliss and current utility over the indefinite future. Later in the paper, he turned to considering a single individual, and reintroduced discounting (Duarte 2016). Thus, while Ramsey provided the model from which the discounting formula could be derived, he did not formulate it himself.

In this paper, we document the interplay of these various motives in the works of economists between the 1950s and 2000, and address the following questions: if not in the 1928 Ramsey article, then how and when did this “formula” emerge in economics? When did it stabilize and become dominant? To answer them, we garnered evidence from seven archival sources and from exchanges with key protagonists. Our narrative emphasizes the importance of contexts in shaping discounting debates: reflecting on water resources, public investment, the energy crisis, development or global warming led economists to focus on different

³ The “Ramsey equation [is] embraced by the [Stern] *Review* as the organizing concept for thinking about intertemporal choices for policies for global warming,” Stern and Nicholas Taylor (2007, 203) clarified in *Science*.

discounting-related issues: time-horizon, fairness, risk, etc.⁴ We also highlight the role of a few pivotal individual who framed discounting through the Ramsey formula and circulated it across various academic and policy settings, in particular Kenneth Arrow. Finally, we discuss the diverse combinations of theoretical leanings, ethical preferences, and tractability concerns in the history of discounting, testified by the fact that economists consider Ramsey’s contribution to have both initiated intergenerational welfare economics (Dasgupta 2019), placed an ethical curse on discounting future generations, and provided a tractable formula for discounting.⁵

Our analysis is chronological, starting with how discounting attracted academic economists’ attention in the 1950s and 1960s in the context of public investment debates. Defining the discount rate in cost-benefit calculations for water resource management in the US raised issues about the consistency between individual, collective and government time preferences. This gave rise to the notion of a “social discount rate.” We show that at this time growth theorists too were struggling with discounting. Its ethical unawareness was offset by its theoretical consistency and its mathematical tractability. It was Arrow, with Mordecai Kurz, who insisted that public investment decisions should be grounded on optimal growth models, allowing them to derive an equation for the discount rate “implicit in Ramsey.”

We then unpack how discounting became a more crucial issue in the 1970s and 1980s when economists started analyzing governments’ choices on the energy mix, nuclear investment or how to consume exhaustible resources. In doing so, they had to model the “distant future,” one that extended beyond the usual thirty- to fifty-year time horizon. These were perplexing decades that witnessed a growing reliance on the optimal growth framework but also hands-on practical choices of discounting parameters, as well as deep reinvestigation of the welfare foundations of discounting in response to challenges put forth by philosophers such as John Rawls and Derek Parfit. By the early 1980s, it seemed that an academic consensus had been reached, one eschewing the Ramsey framework, considered “non operational.”

This relative consensus was upset again as the energy crisis was replaced with a growing concern with global warming. Economists’ development of climate models to study greenhouse gas emission abatement policies led to the stabilization of the Ramsey formula as a framework to understand the discount rate. This further increased the ambiguity around the formula. Already used as a welfare calculation and an optimal growth condition, it became a *definition* of the discount rate and a guide for empirical work. Debates thus shifted from how to conceptualize the discount rate to how to feed the formula with proper parameters, with two competing approaches: a “descriptive” and a “prescriptive” one (Portney and Weyant 1999). Largely responsible for the stabilization of the Ramsey formula, as well as the characterization of disagreement on how to parametrize it, was the IPCC chapter on discounting, published in 1995. We unpack how this chapter was written in the context of worldwide debates on how to develop and operate climate models. We conclude by asking how documenting the context-dependency and ambiguities surrounding the rise of the Ramsey formula can help framing contemporary debates on discounting.

⁴ It is thus consistent with Doganova’s framing of discounting as a “situated practice,” even though she explicitly excluded academic economists’ works from the scope of her book. Our analysis implies that some discounting practice embedded in the Ramsey formula carry a *diversity* of theories of values and theories of action at the same time (see Doganova 2024, introduction)

⁵ On the importance of tractability, a.k.a seemingly technical and secondary modeling choices meant to help manipulating and solving models in shaping the development of economics throughout the last century, see Cherrier (2023).

2. From discounting in water resource projects to optimal public investment (1952-1970)

2.1 Beyond the number game: economists debating cost-benefit analysis

Before World War II, academic debates on discounting were limited. Harold Hotelling's work, one that did not refer to Ramsey's stance, was in line with early 20th century theoretical work on exhaustible resources.⁶ In the US, economists such as Griffith Evans and Charles Roos developed dynamic models with and without discounting (Duarte 2016). It was the rise of cost-benefit analysis, first in US water resource management in the 1930s, then in public management at large, that fueled discounting debates. Beyond the agreed upon notion of quantifying and comparing the future costs and benefits accruing to a project, there was diversity on how to quantify and weight them, and crucially, how to commensurate *present* costs and benefits with *future* ones: "Interest rates are a measure of the value attached to time differences and, hence, provide a means for converting estimates to a common time point," the US Federal Inter-Agency River Basin Committee wrote in its 1950 guidelines, known as the "Green Book" (Subcommittee on Benefits and Costs 1950, 22). Many public agencies, first in the US, then worldwide, started producing, curating and revising indicative or compulsory numbers for discounting.

Those government guidelines initially offered little guidance on the rationale underlying rate selection. What mattered mostly for practitioners and politicians was the *number* plugged into the cost benefit analysis. In a review of the early debates economist Warren Gramm (1963, 706) indeed joked that the "discount debate of the 1950s" could be summarized as "Pick a Number from One to Ten." It was well understood that these had direct political implications: the higher the discount rate, the less important future benefits compared with present costs, and fewer investment projects passed the bar. Wisconsin Senator William Proxmire, which the *New York Times* later described as "the longtime gadfly of the United States Senate who thrived on exposing frivolous federal spending," organized a series of congressional hearing on discounting in 1967. Gradually, however, the choice of the discount rate became a policy and academic issue of its own, making the economists' longstanding disagreements on numbers and rationales more salient (Banzhaf 2009).

The underlying bone of contention was *whose* discounting rate should be used? That of investors trading on financial markets, RAND economists James DeHaven, Jack Hirschleifer (PHD Harvard) and Jerome Milliman argued. They complained about the national "overinvestment" in water infrastructures, one they attributed to a "history of over optimism in estimates of projects benefits." They advocated for the use of a 10% discounting rate which reflected a "fundamental postulate of neutrality...between publicly and privately owned enterprises" (DeHaven 1963). They emphasized the opportunity cost of private investments, as reflected in capital market rates.

In the late 1950s, however, MIT economist Francis Bator coined the term "market failures" to encapsulate a growing body of work in taxation, spending public finance,

⁶ See Franco, Gaspard and Mueller (2019) on the history of discounting in exhaustible resource research, including Hotelling's struggles with discounting future utilities in natural resource consumption models.

externalities and public goods (Medema and Marciano 2015, Desmarais-Tremblais, Johnson and Sturm 2023). An increasing number of scholars, including Harvard PhDs Otto Eckstein and John Krutilla working for the Harvard Water Project and Resources for the Future indeed emphasized that market imperfections prevented an efficient assessment of risks by lenders. They added that since public investment was funded by taxes -which further deviated from the marginal rate of return in the private sector- the relevant question was “how much consumption is divested by the public investment” (Eckstein 1958, 97-99). The discount rate should be that of consumers, not investors, they argued. The emphasis on consumers sparked another debate: should economists model the discount rate as a consumer’s time preference, or should it represent a collection of consumers? The government, a planner, or even society at large? In a book on cost-benefit analysis Krutilla and Eckstein (1958, 78) advocated for the latter: “whenever the ballot box and the political process replace market choice, investment decisions will not be made by comparing the rate of return of investments with the market rate of interest”, and would include “ethical judgments,” they warned.

This series of questions led to growing use of the term “*social discount rate*,” which compelled scholars to consider what “society” represents and to what extent a collective body should be modeled differently from an individual. The question divided welfare economists. William Baumol (1968) acknowledged the social nature of the discount rate but argued it should primarily be interpreted as the social opportunity cost of capital paid by the government. Conversely, Amartya Sen (1961, 495) emphasized that market and collective decisions were fundamentally different “in nature,” advocating for a wider gap between market and social discount rates: “it is, for example, perfectly possible that in a society where no one saves anything, everyone might nevertheless be ready to vote for a political proposal requiring each member of the society to save, say, 20% of his income for the sake of future generations,” he wrote. Stephen Marglin (1963), who had worked on the Harvard Water program before contributing to the OMB’s cost-benefit guidelines revision, agreed that the social discount rate should reflect ethical preferences and the government’s stewardship of present and future generations. This perspective pointed toward a lower discount rate (2-3%). The ethical aspect of discounting were largely acknowledged in these debates, as well as its political one – the lower the rate, the more public projects were funded.

By the late 1960s, the existence of several “schools of thought” about discounting for public investment had stabilized (OMB 1968 cited in Lind 1982; see also Prest and Turvey 1965, Shishko 1976). Martin Feldstein (1964, 361) summarized the state of the debate by opposing “two types of discount rates...social time preference (S.T.P.) and social opportunity cost (S.O.C.). A social time...is a normative function reflecting society’s evaluation of the relative desirability of consumption at different points in time... The social opportunity cost (S.O.C.) is a measure of the value to society of the next best alternative use to which funds employed in the public project might otherwise have been put.”⁷ Economists had thus moved beyond the institutional “number game” in an attempt to instill more economic rationale. However, rifts quickly appeared between those who viewed the discount rate as a market rate, those who aligned it with individual behavior theory, and those who saw it as reflecting some sort of social valuation. Nor did economists agree on whether those rates should reflect the effect of public investment on private investment or consumption, or how to account for risk. A 1971 article on the social discount rate characteristically opened with the remark that “the search for a single discount rate in the evaluation of government projects has failed” (Somers 1971, 565). In the same decades, similar disagreements were seen in a distinct, then blossoming

⁷ Feldstein rejected the social opportunity cost approach and argued in favor of social discount rates lower than market rates.

literature (Boianovsky and Hoover 2014) that was brought to bear on the issue of rational public investment: optimal growth.

2.2 The optimal growth roots of discounting

When economists began systematically modeling mathematically optimal savings and growth paths beginning in the 1950s, they were initially unsettled on whether or not to discount.⁸ Going back to Ramsey's 1928 article, growth theorists did not just borrow the mathematics of intertemporal maximization of the utility of consumption over the indefinite future, which they reframed with optimal control tools. They also imported Ramsey's own struggles with writing down models that would be theoretically and ethically consistent, as well as tractable, all at once.

A good example is provided by a leading theorist of public policy, Dutch economist Jan Tinbergen.⁹ In a 1956 contribution on the problem of optimal savings in developing countries, he considered Ramsey's bliss approach. He then reflected that "there need not be, in principle, any difference between the choice an individual makes and the choices to be made for the nation as a whole" and endorsed a discounted intertemporal utility function (Tinbergen 1956, p. 603). But a 1960 publication for the United Nations Commission for Asia and the Far East saw him using the undiscounted sum of utilities over the indefinite future. Tinbergen (1960, 488-489) explained that discounting was "avoided on purpose, since, in the opinion of many economists, such a time discount should not govern a nation's decisions." He doubled down on this stance two years later: "for a country's planning, future generations should count as much as present generations. According to this philosophy, a discount may be realistic for the individual's plans but not necessarily for a nation's... Instead of a discount, a finite horizon T may be introduced" (Bos and Tinbergen, 1962, 25-26).

Finite horizons and bliss were two alternatives to discounting that former Tinbergen student turned Cowles director Tjalling Koopmans and Stanford graduate student David Cass also considered when developing their own model in the early 1960s. Another was simultaneously proposed by Hiroshi Atsumi (1965) and Carl Christian von Weitzsäcker (1965). The idea was to identify a specific date after which a consumption path would systematically provide greater utility than another, which turned the unbounded mathematical problem into a bounded one. Koopmans (1960) demonstrated that this criterion fails to order all possible consumption paths, but he later acknowledged that it was useful "if one wishes to consider the no-discounting case, for ethical or other reasons" (Koopmans 1972, 92).

Koopmans (1960) approached discounting in the context of the axiomatization of time preferences. He showed that reasonable postulates about the utility function for consumption programs extending over the indefinite future (some of which unrelated to time preference), imply that agents are impatient. He also demonstrated how a modification of one of those postulates turns the intertemporal utility function into the sum of future utilities over the

⁸ The following account of the status of discounting in the 1960s growth theory draws heavily on Duarte (2016), who discusses extensively the contributions of major protagonists.

⁹ In the 1930s, Tinbergen had already argued for studying policymaking in utilitarian terms, but found it difficult to apply empirically. He finally succeeded in the 1950s and 1960s when he proposed a scientific basis on which developing countries would choose their saving rates (Boumans 1993, Duarte 2016, Dekker 2021).

indefinite future with a constant discount rate.¹⁰ In doing so, he provided a theoretical justification for discounting. While his 1965 seminal article on growth discussed all the modeling strategies above, and in spite of admitting “an ethical preference for neutrality as between the welfare of different generations” (Koopmans 1965, 239), he eventually settled on the utilitarian objective function with discounting. He explained that such function could indifferently endow an individual or a central planner.

Cass’s model also assumed the sum of discounted utilities as the welfare criterion, which he quickly legitimized by pointing that “planning obligation is stronger to present and near future generations than to far removed future generations” (Cass 1965, 234). But in the closing paragraph of his article, he pointed to some alternatives mentioned above and acknowledged that his “(also somewhat artificial) positive effective social discount rate glosses over a difficult problem, the proper weighting of future generations in the concept of social welfare, in particular, when population is growing (p. 240).”

If positive discounting in optimal growth models had stabilized as a dominant modeling strategy by the end of the 1960s, then, it was more as a by-product of efforts to spread infinite time-horizon models with objective functions represented by the intertemporal sum of utilities rather than to be consistent with the behavioral characteristics of individual agents. Under the influence of Edmond Malinvaud, Koopmans and his colleagues were adamant to endorse such function (Duarte and Assaf 2020). The most tractable way to ensure that it converged in an indefinite future setting was positive discounting. The tractability appeal of discounting had not escaped observers. One was Richard Bellman, the Carnegie mathematician who proposed the recursive methods to solve those dynamic models. While discussing cost minimization over the indefinite future in his book *Dynamic Programming* (1957, 156), he explained that:

“If we wish to consider an unbounded period of time over which this [cost minimization] process operates, we must introduce some device to prevent infinite costs from entering. The most natural such device is that of discounting the future costs. This possesses a certain amount of economic justification and a great deal of mathematical virtue.”

But to other participants in the growth modeling soul-searching of the decade, such “economic justification” had been altogether overridden by tractability constraints. While visiting MIT in 1961, Tinbergen’s former student Sukhamoy Chakravarty worked on a review of solutions to the optimal saving problem. He concluded the paper by complaining that while both Ramsey’s bliss and the intertemporal maximization of discounted utilities with infinite time horizon “impose some ordering on the utility space, they do it in completely arbitrary ways... one cannot avoid feeling that such formulations have very little significance apart from ensuring solvability of the mathematical problem of maximizing a functional” (Chakravarty 1962, 187).

2.3 Taking the equation “implicit in Ramsey” to public investment decisions

Growth theorists’ approach to discounting entered policy-oriented debates on the choice of a rate in cost-benefit analysis thanks to the boundary work of Arrow. By the mid-1960s, he had contributed to social choice theory, general equilibrium theory, endogenous growth theory,

¹⁰ Duarte (2016) explains that Koopmans recognized such objective function in the work of Ramsey, but also Samuelson and Solow (who zeroed the discount rate) or Strotz (who used a positive rate). The article details that even in the case of a finite horizon, when discounting is no longer needed for guaranteeing a well-defined objective function, discounting was still a disputed issue.

mathematical programming, as well as health economics, emphasizing market failures and was in high demand from policy-makers. He generally accepted such invitations as opportunities to develop an optimal allocation theory and the determination of optimal policy. In 1965, Kennedy's Council of Economic Advisors asked him to discuss investment in public goods, and Arrow (1965) highlighted the gap between private and social time preferences due to the government's stewardship of unborn generations. For him, this was "a matter of value judgment. Its validity and its importance, if valid, are both subject to considerable dispute" (p.8).

In that same year, the US *Water Resource Planning Act* created a federal system for water resources planning and funding. At the request of the Resourced for the Future (RFF), Arrow reflected on the status of discounting in the theory of optimal public investment. He wrote several drafts, including one for a July 1965 conference on water resource management whose proceedings were published the following year by environmental economists Allan Kneese and Stephen Smith.¹¹ In just three introductory pages, Arrow (1966, 13-14) argued that (1) capital market imperfections alone justify dismissing the use of market rates (though he also invoked Sen and Marglin to highlight a "special collective responsibility for future generations") and (2) since "public investment policy by definition involves commitment over time, as modern economic theory makes clear, [it] must be judged in the context of a growing economy." He thus argued that "optimal policies" should be analyzed in an optimal growth framework and outlined a model with private and public capital, explicitly drawing on Ramsey (1928) (p.16). Without going into technical analysis, he demonstrated the gap that existed between this Ramsey benchmark, in which the saving rate maximizes the sum of discounted utilities of consumption, and the reality created by market imperfections.

After RFF gave him a grant to pursue this work, in 1967 Arrow asked his fellow Stanford theorist Mordecai Kurz to collaborate with him on a series of papers, culminating in their 1970 book *Public Investment, the Rate of Return, and Political Fiscal Policy*. A student of Arthur Okun and Ed Phelps at Yale, Kurz (1965) was one of the earliest adopters of Pontryagin's maximum principle. He was not specifically interested in discounting, but as he joined Stanford full time around 1966, he was deeply involved in defining optimal investment rules for public goods.¹² Their 1970 book was primarily written for academic specialists, but through an opening informal summary and introduction to optimal control theory, the authors also hoped to draw the attention of cost-benefit practitioners.

They framed the book as a theory of economic policy in the tradition of Tinbergen, but one set in a dynamic context and centering on market imperfections (credit rationing, the lack of forward markets etc). Their justification for discounting reflected the usual blend of theoretical, ethical and tractability concerns. They first clarified that any choice of objective function to be maximized was open to criticism and explained that they chose the intertemporal maximization of discounted utility over the indefinite future because it was "analytically manageable," "reasonable" and reflected "value judgments about intertemporal distribution" (Arrow and Kurz, 1970, 11). Citing Pigou's earlier idea that "our telescopic faculty is defective"

¹¹ Arrow apparently presented two papers at a RFF seminar on the discount rate for public on March 24, 1965. The papers, titled "The Imperfections of the Private Capital Markets" and "Optimal Public Investment Policy", appear in the annotated bibliography of Wood and Campbell (1970, pp. 59-60) with their abstracts, and are very much aligned with the other works we discuss here. Unfortunately we could not locate copies of those papers, including in Arrow's archives at Duke University.

¹² Arrow was one of Kurz's professors when he went to Stanford for a Master's in statistics in 1959 (Kurz interview).

and Koopmans's axiomatization, they defended discounting as consistent with individual choice theory. They countered Ramsey's 1928 famous quote against discounting ethics with an earlier pro-discounting statement that the British mathematician had offered in an Apostles talk (the Cambridge male-only secretive debating society): "in time the world will cool and everything will die; but it is a long time off still, and *its present value at compound interest is almost nothing*," Ramsey had said (p12).

Arrow and Kurz then presented a simple Ramsey-inspired growth model. They explicitly derived a relationship between the consumption discount factor, the pure rate of time preference and the marginal utility of consumption *on the optimal growth path*, which they related to Eckstein, Eugene Böhm-Bawerk and explained that it was "implicit in Ramsey (1928)" (p. 60). On the optimal path, the consumption rate of interest equals the marginal productivity of capital. However, Arrow and Kurz subsequently examined how these rates diverge when introducing public goods, risky investments, increasing returns to scale, and various public investment financing schemes. Kurz went on to study other topics, but not before attempting to measure individual discount rates through survey methods, yielding results from 30% to 150% per year (Kurz interview). For Arrow, however, this five-year work establishing a theoretical framework on "the determination of the rate of interest appropriate for making investment decisions" was just the beginning.

At the turn of the 1970s, then, an equation determining the rate of interest on the optimal growth path was thus circulating among economic theorists. Not yet a rule or formula, but Arrow and Kurz's advocacy notwithstanding, it did not reflect how cost-benefit analysis specialists defined discount rates for public investment decisions. While they had moved from picking numbers to discussing underlying rationale, they did not agree on whether to rely on market rates reflecting capital cost of opportunity or consumption rates, whether to ground discounting in individual or social preferences, whether to prioritize consistent choice axiomatics, ethical principles or tractability constraints. The equation "implicit in Ramsey" might have remained obscure to the latter, had the economic, social and intellectual landscape not dramatically shifted in the next decade, with the energy crisis, the publication of the Meadows report and associated debates on the role of exhaustible natural resources in growth.

3. From disagreements to consensus without the "non operational" formula (1970s-1980s)

3.1 Discounting for energy policies

The 1972 publication of the Meadows report, followed by the October 1973 OPEC oil embargo, threw world citizens, governments, and economists into disarray. Based on system dynamic modeling techniques developed by MIT engineer Jay Forrester, the simulations commissioned by the Club of Rome predicted that by 2050, growing population, pollution, and overconsumption of exhaustible resources, would lead to collapse. Combined with books like Paul Ehrlich's *The Population Bomb* (1968), this created a growing sense of uncertainty about the future which was reinforced by the burgeoning energy crisis. The US had experienced oil

shortages and crippling price rises since the late 1960s, but within the four months after the embargo, the price of a gallon quadrupled.¹³

Existing national and international organizations commissioned scenarios on world energy, and economic and social futures: the International Labor Organization, the OECD and the UN produced reports titled *Catastrophe or New Society? A Latin American World Model* (1976) or *The Future of the World Economy* (1977). In 1972, the International Institute for Applied Systems Analysis (IIASA) was established in a castle near Vienna, to foster scientific cooperation between the East and the West. Its large-scale interdisciplinary “Energy Project” involved more than 250 scientists, who produce a set of integrated models and scenarios published in 1981 as *Energy in a Finite World*. While France’s Messmer plan ushered the country into an era of nuclear investment, in 1975 the president of the newly founded US Energy Research and Development Administration asked an ad-hoc committee, the Committee on Nuclear and Alternative Energy Systems (CONAES) to prepare an extensive study on energy mix alternatives for the coming decades.

The Meadows report had set a standard for growth and energy modeling: computational models that aimed to integrate natural and economic dynamics without referencing the economists’ growth models (Vieille Blanchard 2011, Schmelzer 2017). This, combined with the energy crisis, led economists to discuss the role of exhaustible resources in growth models. In seminars, special issues and lectures, many economists highlighted the flaws of what they called “doomsday models.” For instance, Robert Solow (1974a) devoted his December 1973 *AEA Ely Lecture* to a long criticism of the Meadows report’s lack of economic reasoning. In a companion paper (Solow 1974b), he showed that a growth model with the substitutability between aggregate capital and exhaustible resources can generate unbounded resource productivity and thus an indefinite positive level of consumption if the output elasticity of capital is greater than the resource elasticity. Coincidentally, Solow’s former graduate student Joseph Stiglitz (1974) modeled constant consumption by assuming that resource augmenting technical progress is greater than the growth rate of the population. In the UK, Partha Dasgupta and Geoffrey Heal (1974) explored a “cake eating” situation with uncertain prospect of developing new technologies that reflected the state of research on nuclear fusion (Dasgupta 1991, 21). In their model, the optimal consumption path decreased to zero.¹⁴

The (re)introduction of exhaustible natural resources in growth models drew economists’ attention to Hotelling’s earlier result (Erreygers 2009). The idea that the net price of exhaustible resources should rise at the interest rate was christened the “Hotelling rule” by Solow – selling the resource and reinvesting the proceeds at some interest rate should be equivalent to keeping the resource and selling it at a later date (Gaspard and Missemer 2022). This raised the stakes for adequately determining the discount rate as it was now crucial for cost-benefit analysis, growth paths and the depletion rate of exhaustible resources. Yet among the three 1974 articles proposing growth models with exhaustible resources just mentioned, Solow’s model opted for no-discounting (see next section). Dasgupta and Heal (1974) choose a Ramsey model and derived a “familiar Ramsey condition” on the optimal growth path. In a book expanding on the topic, they called the equation linking the social rate of return on

¹³ See Cassen and Cointe 2022, both for the history of the rise of international climate computer models since the 1970s and the many references to the making and reactions to the Meadows report. See in particular Vieille Blanchard 2011 and Schmelzer 2017. See Jacobs 2016 on the history of the long energy crisis in the US.

¹⁴ See Couix 2020 for a detailed account of Solow’s and Stiglitz’s growth models with exhaustible resources; Gaspard and Missemer 2022 surveys the consequences of Solow’s reaction to the Meadows report on MIT students, including Nordhaus. See also Nordhaus and Tobin 1972.

investment with the pure rate of time preference and the growth-times-elasticity parameter the “Ramsey rule.” “Its virtue lies in its simplicity...the condition brings out in the simplest manner possible the various considerations that may appear to being morally relevant in deciding the optimum rate of accumulation,” they explained (Dasgupta & Heal 1979, 297).

But more than these theoretical exercises, it was the race to build empirical energy models for studying the consequences of alternative energy policies that shaped the discounting debates and the circulation of the Ramsey formula. Up to the 1970s, the demand for energy was considered stable and determined by growth, with the primary objective being to minimize the costs of energy supply. The oil shock prompted economists to model the reverse linkage between the energy sector and the rest of the economy and to estimate price elasticities, and elasticities of substitution for various energy sources. But beyond the growing use of simulation and the need to better integrate energy supply - typically modeled by engineers – and demand -economists’ domain-, there were no established rules to build an energy model. These models used discount rates ranging from 0 to 40%, often with minimal justification. The proliferation and diversity of models was such that in 1976, the US Energy Modeling Forum was established to compare them and facilitate closer collaboration between modelers and users.¹⁵

Economists’ reliance on cost-benefit analysis aligned well with governments’ needs to evaluate a range of alternative policy measures, from conservation policies to nuclear technology investments, taxes, quotas, energy efficiency standards or utility regulation. In 1975, the CONAES set up a Modeling Resource Group, chaired by Koopmans, to investigate the cost and benefits of various energy options. The group employed a diverse set of models: supply-side models (DESOM, SRI); demand-side models (DRI), and three integrated equilibrium models: the PIES of William Hogan, David Nissen and James Sweeny, as well two aggregative models that maximized the sum of discounted future utilities through linear programming techniques. ETA (Energy Technology Assessment) was developed by Alan Manne and his student Richard Richels, and the other model was proposed by William Nordhaus.¹⁶ Just like Koopmans, both Manne and Nordhaus had just spent time at IIASA, where they refined their views on discounting.

After being involved in optimal growth debates, Koopmans continued to explore discounting issues. During his time at IIASA, he issued a short paper entitled “Proof for a case where discounting advances the doomsday” which examined an optimal growth model with exhaustible resources. A former RAND alumnus, Manne was associated to the Stanford business school and the Operation Research Department (Cherrier and Saïdi 2019). A specialist of operations research and industrial planning, he had developed a keen interest in the energy sector, computer programming and simulation. Nordhaus (2018) later described him as the “analyst and algorithmist” of the IIASA group. At a time when the American society, the government and the CONAES were permeated by a “polarization of views concerning nuclear energy” (CONAES 1980, first letter), Manne used his IIASA time to focus on the breeder

¹⁵ See Manne et alii (1979) for a survey of selected models of the 1970s, and Weyant and Sweeny (1979) on the early history of the Energy Modeling Forum. Crassous (2008) offers some history and classification of energy and climate models since the 1970s.

¹⁶ The approach and results of the Modeling Resource Group is detailed in a report published in 1978, “Energy Modeling for an Uncertain Future” (National Research Council (1978)), largely authored by Koopmans.

reactor. This was a new type of reactor that produced more fissile material than it consumed, and thus seen as an uncertain but promising solution to the scarcity of uranium.¹⁷

Manne investigated which combination of energy sources should be used while “Waiting for the Breeder” in a paper that employed sequential probabilistic linear programming (decisions trees). His findings revealed that a 10% discount rate made near future decisions insensitive to the long term technological uncertainty, whereas a 3% rate significantly enhanced the appeal of nuclear power over fossil fuel. Manne (1974) detailed potential objections to lowering the discount rate: inefficient allocation of public investment, substantial decrease of present consumption leading to shifts in relative prices. He concluded that a 10% rate remained justifiable “even though it is known that this tends to speed up the exhaustion of some energy resources that would otherwise be available to our yet unborn descendants” (pp. 4-5).

Nordhaus, by this time, had settled on a 10% discount rate. A Solow MIT PhD student, he was well-versed in the Ramsey foundations of optimal growth as taught by Karl Shell in the late 1960s (Shell 1967, v). The Meadows report, which he extensively criticized in print, prompted him to develop models incorporating exhaustible resources (Gaspard and Missemmer 2022). An early 1973 contribution presented at a Brookings Panel saw him grappling with the problem of discounting. While acknowledging that markets “may be unreliable ways to allocate exhaustible resources” due to myopic decisions, imperfections and taxes, his dive into planning intricacies led him to choose a discount rate reflecting “an index of the supply price for capital and of the opportunity cost of capital, not of the social rate of time preferences,” which he set at 10% (Nordhaus 1973, 535; note 14 p. 548).¹⁸ His goal was to minimize the discounted costs of meeting a set of final demands with linear programming techniques. He too discussed the “rapid depletion of petroleum and natural gas” (p. 549) that such a discount rate might entail by pointing that the funds could be used to build gasification plants and breeder reactors. Acknowledging that the chosen rate could be too high for proponents of a social rate and too low for others, he conducted sensitivity tests with a range of rates. He retained a 10% rate for most models that he developed throughout the decade. At IIASA in 1974-1975, Nordhaus (1975) expanded his model to include CO₂ emissions, and he explored the interpretation of the resulting shadow price for carbon.

When the group convened at CONAES in 1976, selecting common discount rates to plug into their respective models proved particularly challenging. They received all sorts of advice from industry and academic energy specialists, ranging from 5% to a mechanical engineer writing that “expected returns of 40% are not unknown” for risky energy diversification projects. The inclusion of nuclear investment among other energy options dramatically extended the time horizon because their benefits might only materialize after 30 to 70 years, while costs related to nuclear waste management and contamination risks could span centuries or more. Moreover, Manne discovered that the simulations were highly sensitive

¹⁷ In the end, the breeder proved more costly than water-cooler reactors and interest waned as new reserves and cheaper uranium enrichment technologies emerged. Halfway through the CONAES’s operations, president Carter dramatically reversed previous nuclear policies out of concerns with the proliferation of nuclear weapons. He announced that nuclear breeder reactor projects would be slowed and the reprocessing of spent nuclear reactor fuel deferred indefinitely (CONAES 1980, introduction).

¹⁸ He explained that 10% was the “average pretax return on reproducible tangible capital, and as such is a reasonable estimate on the social productivity of investment.” Though his statements on market imperfections echoed Arrow and Kurz (1970), Nordhaus did not cite any specific work on discounting.

to discount rates. A pre-tax capital cost of 13% rendered the breeder reactor economically unviable, whereas a 10% rate made it the preferred option.¹⁹

Koopmans, Nordhaus and Robert Litan thus wrote to Arrow inquiring about “the correct discounting procedure” both “in theory” and “in practice.” Arrow came to the Modeling Research Group to lecture on discounting in June 1976. He opened his presentation arguing for the consumer’s utility rate as the theoretical benchmark, over the private market rate. To support this, he solved a Ramsey model, subsequently adding growth and market imperfections, and demonstrated that the riskless rate of return in these models obeyed a Ramsey formula (though it was not mentioned by name in the minutes of the meeting). However, his practical advice did not rely on such theoretical foundation. He proposed a dual discount rate scheme, with a 13% pre-tax rate of return on private investment to calculate the *costs* of new technologies, and a 6% after-tax return on investment to discount the net *benefits* of these R&D project on society. He further recommended adjusting these rates to account for project-specific uncertainties. The week after, the team grappled with whether Arrow’s suggestions could be extended to allocating exhaustible resources, a challenge he had not addressed.²⁰

Arrow thus brought the Ramsey formula from the 1970s discounting discussions, but it was then more a theoretical benchmark to convince audiences that the appropriate rate was the social rate for consumption rather than investment. When it came to empirical work, the Ramsey formula then seemed of no use. A similar gap was evident, a few years earlier, when UK growth theorists familiar with deriving Ramsey formulas from optimal growth models started writing project evaluation guidelines for developing countries, particularly India. Two competing reports came out, one by James Mirlees and Ian Little for OECD, the other by Sen, Dasgupta and Marglin for the UN (Mirlees and Little 1968; Sen, Dasgupta and Marglin, 1972). Significant disagreements arose, in particular regarding the adoption of a social discount rate on consumption vs investment. These disagreements reflected underlying conflicting assumptions about the rationality of governments tasked with implementing development projects (Dasgupta 1972). While Dasgupta (1991)’s recollections testify to UK theorists’ familiarity with Ramsey’s work, the Ramsey formula, whether the name itself or the equations deriving from intertemporal welfare maximization or the optimal growth path, was nowhere to be found in those debates.²¹

3.2 Discounting as a normative endeavor

Though the debates on energy modeling focused on theoretical, even axiomatic consistency and tractability requirements, this did not purge ethical consideration out of the picture. Several of the protagonists above indeed wrote their models of growth with exhaustible resources while arguing with perhaps the most famous political philosopher of the 20th century, John Rawls. These exchanges followed Rawls’s publication of *A Theory of Justice* (1971), a

¹⁹ Brogli (General Atomic Company) to Manne, 11/02/1976; Rose to CONAES? 08/09/1976, “Comments on the Synthesis Panel Report”, Undated memo beginning with “Addition,” Manne to Koopmans, 06/09/1976; *archive source redacted*. Manne to Koopmans, 08/17/1976; Manne to Koopmans, 01/27/1977, *archive source redacted*.

²⁰ Koopmans, Nordhaus and Litan to Arrow, undated; “Minutes of the Modeling Resource Group Meeting, 06/12/1976 (misdated) and Appendix (06/03/1976); “The discounting problem” memo, 08/06/1976; Manne to Arrow, 06/09/1976 “Implementation of your suggestions...,” *archive source redacted*.

²¹ According to Dasgupta (1991), in the 1960s and 1970s, Cambridge economists talked about “doing Ramsey on Mahalanobis” (p7), about “unconstrained Ramsey path,” or the “Ramsey criterion for intergenerational justice,” or “Ramseyesque preferences” (p30). In the same essay, he summarized the disagreement over evaluation: “Little and Mirlees assumed in effect that the project evaluator was part of an optimizing government, whereas we had supposed that the government project evaluator was someone who today would be called a policy reformer” (p.??).

treaty that was partly inspired by, partly written against, and definitely meant for economists.²² Rawls intended to offer an alternative to the utilitarianism that dominated economic theory. He famously proposed that, placed under a veil of ignorance about their circumstances, citizens would choose a system that, first, guarantees basic freedom, and second, ensures fair equality of opportunity and only allows inequalities that benefit the worst off (the difference principle, which economists call the maximin).

Rawls (1971, 291) made it clear that the difference principle should only apply to justice within generations, as “[t]here is no way for later generations to improve the situation of the least fortunate first generation.” But then, how to deal with “the problem of justice between generations”? He devoted chapters 44 and 45 to the issue. His idea was that “each generation must not only preserve the gains of culture and civilization, and maintain intact those just institutions that have been established, but it must also put aside in each period of time a suitable amount of real capital accumulation” (Rawls 1971, 286). Citing Sen, Koopmans, Solow, Ramsey and most extensively Chakravarty, he called his vague substitute for the difference principle the “just saving principle.” He also recognized that economists had long connected savings, growth and intergenerational justice with discounting. His take on it was a bit fuzzy: he reminded readers that there was no moral ground for discounting, but also admitted that the “utilitarian principle may lead to an extremely high rate of saving which imposes excessive hardships on earlier generations.” He concluded that this “can be to some degree corrected by discounting the welfare of those living in the future” (p. 297).

Naturally, Rawls’s stance triggered correspondence and contributions from those economists who were working on the theory of optimal savings (see Erreygers 2009). Solow sent him a draft of his 1974 article on “Intergenerational Equity and Exhaustible Resources,” aiming to apply the maximin principle to intergenerational equity and optimal capital accumulation. Rawls pushed back, reaffirming that his principle was not to be applied between generation, and should be replaced with the just saving principle:

“What determines the rate of capital accumulation is the just savings principle. This principle is unfortunately only specified within broad limits; it is given by the balance between what a typical son feels it reasonable to ask of his father and what this son is prepared to do for his son. This balance varies as these compromised attitudes adjust to different levels of economic advance on the way to the conditions necessary for a just and well-ordered society.”²³

Unfazed, Solow (1974, 30) doubled down, and, in the published paper, declared to be “plus Rawlsien que le Rawls.” Arrow (1973) proposed his own intergenerational difference principle, while Dasgupta (1974) interpreted of the just saving principle as a Nash equilibrium game between generations. Rawls liked the latter interpretation better: “I... imagine... that one tries to ascertain at each stage of accumulation how much one would be willing to save for one’s immediate descendants by balancing that against what one feels entitled to claim of one’s immediate predecessors.... Therefore your Nash equilibrium reading of the savings principle is certainly justified.”²⁴

²² Guizzo and Paré-Ogg (2023) and Igersheim (2022) detail the debates between Rawls and economists that followed the publication of the *Theory of Justice*, as well as Rawls’s growing frustration with it.

²³ Rawls to Solow, 02/15/1973; Rawls to Solow, 03/07/1973, *archive source redacted*.

²⁴ Solow to Rawls, 02/26/1973; Rawls to Dasgupta, 07/17/1973, *archive source redacted*. Solow believed that Dasgupta took Rawl’s ‘father and son’ statement “too literally” and that “his problem is not contractarian at all.”

Discounting surfaced in these exchanges too, with the usual ambiguities. Solow told Rawls that “Ramsey does not believe in a time-discount rate bigger than zero; that makes three of us, including you and me.” For Solow “the choice of a social discount rate (which we prefer to be zero) and a social valuation of consumption at different points of time and of different amounts is what has to be done to formulate a well-posed problem about optimal saving.”²⁵ In his 1974 article on the maximin and exhaustible resources, he therefore chose not to discount. But as he was discussing with Rawls, Solow also attended the Brookings panel where Nordhaus (1973) grappled with discounting. Rather than advocating for a 0 discount rate, he argued that “even with a utility discount rate of zero, the consumption rate of discount would be positive if per capita incomes are expected to be higher in the future, because of the diminishing marginal utility of income. I do not know if 10% is exactly the right rate of discount; but I would not use a very different number” (Solow quoted in Nordhaus 1973, 574).

The exchanges between Rawls and economists on intergenerational justice and discounting was not a one-off episode. Soon after political philosophers, moral philosophers turned their gaze to intergenerational justice and discounting. At the turn of the 1980s, Gregory Kavka, Mary B. Williams and other contributors to a book on obligations towards future generations (Sikora and Barry 1978), John Broome (1985), and Derek Parfit weighed in on discounting. Parfit’s intellectual development since the 1970s combined a long-term interest in identity across time with a concern for future generations with more pressing issues of energy policy. This is the context for his “An Attack on the Social Discount Rate” 1981 article (Parfit 1981; see also Parfit 1983; Parfit and Cowen 1994). Aside from the economic arguments for or against discounting that gradually became embedded in the Ramsey formula, these philosophers proposed new arguments against it. They asked difficult questions: should our attitudes toward future generations reflect our moral obligations to strangers? Do we have more responsibilities towards people in the near future? Should we use the same discount rate for all effects? Does uncertainty over the future mean that moral priority should be given to living individuals?

Over time, a general impression formed that economists were pro-discounting while philosophers were against it. This resulted from the ambiguity in the discount rate debates (the pure rate of time preference or the social discount rate), and in the type of argument that was made: ethical, on tractability, or axiomatic (for instance on properties of the social welfare function)?²⁶ While an understanding of the influence that these philosophers had on economists’ approaches to discounting is beyond the scope of this article, the constant pushback that they provided beginning in the 1970s forced economists to articulate more systematically their ethical argument for or against discounting and selecting such and such parameter for the pure rate of time preference in the Ramsey formula. Their rationale could not just rely on theoretical, axiomatic or tractability arguments. The ethical rationale gradually became the primary focus of Arrow, for instance (see next section).²⁷

²⁵ Solow to Rawls, 03/12/1973, *archive source redacted*. See also Erreygers (2009).

²⁶ There has recently been a convergence between the 2 groups on numbers, though not on underlying rationales (Nesje et alii 2023).

²⁷ A 1997 letter saw him reflecting on “agent-relative morality” and “the opposition between our moral instinct for zero rate...and the Koopmans argument (if you care that much for the future, then you don’t care at all about the present).” Arrow explained that it was Parfit who “delicately informed me that this was a well-known idea” before crediting Samuel Scheffler with it. This testifies to the influence of philosophers’ on economists’ approach to discounting and later, the interpretation of the Ramsey formula.

3.3 *The making of a consensus*

While theorists, energy modelers and philosophers engaged in intense discussion on the theoretical consistency, tractability and ethics of discounting, cost-benefit practitioners also refined their micro approaches, trying to reconcile social cost of capital and social discount rate approaches (see for instance Bradford 1975). Some, like Stanford economist Robert Lind, felt it was high time to nail down a consensus on how to set these rates.²⁸

After attending the CONAES meeting where Arrow presented his framework, Lind was asked by the Electric Power Research Institute and Resources for the Future to host a full conference on “discounting for time and risk in energy policy.” This gathering brought together US and Europe-based heavyweights like Arrow, Martin Feldstein, Stiglitz, Robert Wilson, Dasgupta, Robert Dorfman, Koopmans, Sen, etc. with the goal of providing “recommendations.” If the resulting collective book, published in 1982, gained substantial fame and influence, it was largely due to Lind’s introduction and survey chapters. Here, he laid bare the fault lines preventing economists from achieving a consensus, and proposed a practical procedure for selecting a discount rate. The conference cast a long shadow – the next major conference on discounting wouldn’t happen for another two decades. When it did, organizers Paul Portney and John Weyant (1999, 3) noted in the introduction of the resulting book:

“it is fair to say that Lind’s primer came to assume great importance. This was due in large part to a compromise he proposed...for fifteen years or so after the publication of the book, when the questions ‘what discount rate should be used to calculate the present value of benefits and costs?’ was posed, the standard answer was a brief: ‘See Lind.’”

Lind argued that part of the disagreements over discounting “the distant future” stem from difficulties in disentangling debates on the social rate of time preference, private capital displacement, and risk. He built on ideas from Eckstein, Feldstein and Bradford suggesting to look at how public investments ripple through private investment streams, then convert these to consumption equivalents using a “shadow price of capital” (aka “the present value of the future stream of consumption associated with \$1 of private investment discounted at the social rate of time preference,” p.39). The rationale for not discounting at the return on private capital was that it would unfairly penalize long-term projects like energy investments. Lind also pushed back against the then common practice of adjusting project discount rates for risk, citing recent empirical studies that showed that the risk of energy investments was generally not correlated with the risk of a portfolio representing the whole economy (pp. 69-71). His proposed rates were in the 2-4% range, much lower than those used by US government institutions.

Despite the book’s various mentions of the Ramsey formula, Lind avoided diving into the normative foundations of discounting. Indeed, the chapters by Arrow, Stiglitz, Sen and Dasgupta proposed theoretical frameworks for “infer[ring] the social discount rate from optimal policy” (p.90). Arrow opened the book by deepening the now well-known optimal growth framework he developed with Kurz. Dasgupta likewise extended his analysis of resource depletion to an optimal growth model. He was perhaps the most articulate in distinguishing two equations associated with Ramsey. First, he clarified that the determination of the consumption rate of discount as the pure rate of time preference plus the elasticity of marginal utility times the consumption growth rate sprung from choosing a Ramseyesque social welfare function.

²⁸ Lind had contributed to the discounting debate in the 1960s and has worked with Arrow toward improving the Arrow-Kurz framework for public investment decisions to take into account uncertainty.

Second, he explained that the “Ramsey rule” – which states that this consumption rate of discount should equal the interest rate for private investment – is an optimality condition in the growth model (p. 284). Both Stiglitz’s and Sen’s contributions explored discounting rates in a Ramsey framework with the maximization of a social welfare function in a second-best world -with Sen proposing to move beyond such framework.

Whether rooted in welfare analysis, optimal growth, or both, Lind rejected inferring the discount rate from solving theoretical models for the optimal policy. He lamented that in such analyses, “in order to make the analysis tractable, we have to deal with a highly simplified economy” (p. 38), for instance through assuming that the economy is in steady state. The “Arrow-Kurz framework,” in his view, failed to provide an “operational basis” for choosing the discount rate in public investment policy. For “practical” reasons, he concluded, he had chosen an approach “more in the tradition of partial-equilibrium analysis than of general-equilibrium analysis” (p. 90). The “tentative consensus” reached in the early 1980s thus mirrored the disconnect between growing references to the determination of a discount rate in an optimal growth framework and the practical guidelines for discounting that we have already highlighted in Arrow’s dual discounting scheme and the debate on the evaluation of development policies at the UN and OECD. Lind’s consensus was very much one forged by and for practitioners. Those insisting on working within an optimal growth framework were still the exception.

One such economist was Nordhaus, who was pursuing his quest to endogenize CO₂ abatement pathways. In a 1980 Cowles working paper, he proposed to integrate a carbon cycle into an optimal growth model so as to map out “the shape of the optimal carbon control strategy over time.” His goal was to integrate the economic consequences of various CO₂ control strategies to the intertemporal choice between consumption paths. This required making “value judgments” over how CO₂ emission would be spread across time and generations, leading him into a deep dive on discounting. Without fully solving his model, he found himself providing an exegesis of a kind of Ramsey formula. “In an optimal growth framework with no population growth and in steady state,” the “goods discount rate” was the sum of a “time discount” variable (how we weight different generations) and a “growth discount” factor (the elasticity of marginal utility of income, which he called a “redistributive parameter” and the growth rate of real income, their product reflecting future generations’ increased wealth). He explained that the goods discount rate “can be observed as a real...market interest rate,” around 7% at the time. “It is hard to defend a social rate of time preference above zero,” he continued, so that the value of the goods discount rate was mostly driven by the “high aversion to inequality” built into growth discounting. He used his definition of the discount rate to explore various theoretical and empirical scenarios and concluded that the discount rate was key in determining the ultimate level of CO₂ control and the control strategy over time (along with carbon cycle parameters, the damage function and growth rate) Though an outlier at the time, Nordhaus’s work foreshadowed the rise and stabilization of the Ramsey formula a decade later. It was one due to the irresistible rise of climate modeling in the 1990s.

4. “Two approaches to discounting” but one equation (the 1990s)

4.1 Discounting debates in the context of climate change

The “Lind consensus” turned out to be short-lived. Built around energy debates, it fell apart in less than a decade as economists’ focus shifted from exhaustible resources to global warming. Evidence of CO₂ emissions raising global temperatures had been piling up since the 1960s. In response, the United Nations set up the Intergovernmental Panel on Climate Change (hereafter IPCC) in 1988. Tasked with summing up what scientists knew about climate change, it produced a first report in 1992. It covered research on emissions and temperature effects (Working Group I), ecosystem impacts (Working Group II) and future emission scenarios (Working Group III). In a second assessment IPCC leaders sensed the growing importance of economics in climate research and reoriented the third working group for the “technical assessments of the socioeconomics of impacts, adaptation, and mitigation of climate change over both the short and long term and at the regional and global levels” (Bolin 2010).

While today’s discussions often point to a lack of mainstream economists’ involvement in IPCC reports, the early rounds heavily relied on them. The team determining the scope of the second assessment included Joseph Stiglitz, who gathered a large cast of economists from developed and developing countries: among our protagonists, Arrow, Weyant, Richels, and William Cline were joined by Jean-Charles Hourcade, John Robinson and Dale Jorgenson, among many others. The energy modelers involved in the writing of the second IPCC report formed an Energy and Industry subgroup, and organized three IIASA meetings in Laxenburg where energy models and integrated assessments for carbon mitigation were debated.²⁹ At the first workshop in October 1992, disagreements over discounting loomed large enough so that a “new session by popular demand” on discounting was added late in the program, without prepared papers (Kaya et alii 1993, 588). Chaired by Thomas Schelling, it gathered Cline, Manne and Nordhaus.

Nordhaus’s participation was unsurprising. Since 1980, he had completed his full model of optimal growth with an integrated a carbon cycle, as well as damage and abatement functions. The 1980 model only had constant physical flows, but it allowed him to study alternative CO₂ emission abatement paths and calculate the associated social cost of carbon. The Dynamic Integrated Climate-Economy (DICE) model was published in 1992 with a summary appearing in *Science* (Nordhaus 1992a, b). It confirmed Nordhaus’s earlier idea that in the steady state of such model, the discount rate was defined by the Ramsey “equilibrium” formula, aka the time+growth discounting. The model also reinforced the critical importance of the choices for the discount parameter choices to the efficient abatement path. He equated the discount rate with the real rate of return, which he calibrated to be 6-7% in developed countries. Based on this, he concluded that a moderate abatement policy was warranted.

The importance of the discount rate in determining optimal CO₂ abatement was further highlighted by the work of another participant in the impromptu workshop. Earlier that year, Cline (1992) had published a book on the economics of climate change. A development economist with a career in macro and agricultural development and trade at the US Treasury,

²⁹ On the history of the economists’ role in the development of Integrated Assessment Models, see Cointe et alii (2019), Van Beek et alii (2020), Crassous (2008), Pottier (2014),

Brookings, and the Peterson Institute, he had recently undertaken a study of the economic consequences of greenhouse gas emissions at the request of the *Institute for International Economics* (nowadays the Peterson Institute). He viewed this as the most significant long-term development question facing the world (*interview*). “Long term” was key in his analysis. Drawing on early IPCC publications and the work of scientists like Eric Sundquist, Cline concluded that the relevant time horizon was approximately 300 years, considerably longer than previously envisioned (*interview*). This extended timeframe led him to develop a cost-benefit analysis that recommended much higher emission control rates than earlier climate economic analyses.

Nordhaus (1994) joined the conversation and suggested that the difference between his analysis and Cline’s was the choice of a discount rate. Cline, influenced by discussions with EPA colleagues and Bradford’s (1975) work, had revisited Ramsey’s 1928 article and the Lind book (*interview*). After Reagan took office, many US institutions had adopted a 10% discount rate on public investment, but there were dissenting voices. Cline derived the discount rate from utility theory adding up pure time preference (which he set to zero) and expected declining marginal utility (without using a fully microfounded general-equilibrium growth model; Cline 1992, 249; chapter 6). This led to a low discount rate of 1-2%. Nordhaus (1994, 11, fn. 1) disagreed, arguing that “while [Cline’s] approach is philosophically satisfying, it is inconsistent with actual societal decisions on saving and investment.” He insisted that the discount rate should be derived from a general-equilibrium optimal growth model and concluded that “it is essential that the discount be based on actual behavior and returns on assets rather than on a hypothetical view of how societies should behave or an idealized philosophy about treatment of future generations” (Nordhaus 1994, 125).

Manne and Richels too had refined their 1970s energy model to include greenhouse gases emissions. With Robert Mendelsohn, they were developing MERGE, another integrated general equilibrium model (Manne et alii 1995). They too published a book on the economic costs of carbon dioxide, heavily relying on ETA-Macro simulations. They emphasized the importance of considering technological development and scientific uncertainty (Manne and Richels 1992). Using discount rates of 5-6%, they reached conclusions similar to Nordhaus’s. But despite grappling with the sensitivity of discount rate choices for two decades, Manne had not yet specifically written on discounting. Nor had Tom Schelling, who chaired the 1992 IIASA session. While primarily known for his application of game theory to conflict, cooperation, and nuclear deterrence Schelling had been involved in climate policy since 1980. At President Carter’s request, he had attended a summit on the carbon dioxide problem and subsequently joined a US National Academy of Science committee to examine “the policy and welfare implications of climate change” (Schelling 2005). By the early 1990s, Schelling had developed a sustained interest in climate modeling.

The 1992 IIASA session prompted both Manne and Schelling to articulate their views on discounting. A month later, Schelling penned a long letter to the session’s participants that stressed that wasn’t clear whether the time preferences were those of an individual agent or of a social planner. Even in the case of a “genuine ‘single agent,’... there is no theoretical or empirical reason in psychology or physiology for expecting...a uniform discount rate.” Schelling also highlighted the difference between time preferences and “preference over succeeding generations of human beings,” suggesting that people don’t really distinguish between what happens in 150 years versus 250 years. Referring to Art Okun’s work, he proposed to compare people’s willingness to sacrifice distant generations with their willingness to give international aid. “The readers of the Washington Post are presumed more interested in

infant mortality in the hospitals of Washington, DC, than in those of Boston, and more interested in those around the nation than in hospitals in China, India, or Nigeria,” he concluded to back up his skepticism that discount rates should be as low as Cline wanted them.³⁰

At the next IIASA workshop, in October 1993, another session on “intergenerational assessment” was organized. Schelling now had a full paper, as did Manne (along with Lind and Ferenc Toth, one of the workshop organizers).³¹ The contribution showed that Manne also took issue with Cline’s low discount rates, though for different reasons. As a computation-oriented researcher, he emphasized that very low discount rates implied unrealistic sacrifices from the present generation, therefore, unrealistic saving rates and investment take-up. In a letter to the session’s participants on the eve of 1994, Manne grappled with the issue: “to avoid several mathematical paradoxes and ‘horizon effects,’ it may be useful to assign a continually declining discount factor to the utility of future consumption. On logical grounds, this seems preferable to assigning a positive weight to the welfare of one or two cohorts in the future, but zero thereafter.” A month after, Manne told Schelling they were converging on a common position, and explained that he and Cline had altogether different responses to what wasn’t just an ethical and theoretical question, but, as always, also a matter of tractability:

“With this functional form, an infinite planning horizon and no discounting, the optimal solution is unbounded – even if consumption were to remain constant over time. There are two popular escape routes from this logical trap: I’ve taken one route – assuming a positive rate at which future utilities are discounted. Bill Cline has taken another – assuming that the elasticity of marginal utility is greater than unity in absolute values. Either way, one is faced with the fact that today’s marginal productivity of capital is a good deal higher than 1% in real terms. In order to implement Bill’s view of the world (a long-term decline towards 0% or 1%), there will have to be a rapid step-up in the near-term rates of savings and investment.”³²

4.2 One equation but two approaches: the IPCC 1995 chapter and the stabilization of the Ramsey formula

These IIASA discussions formed the cradle for the development of several IPCC chapters, written for the second assessment of 1995. A few months after his 1994 letter to Schelling, Manne received a request to review a full chapter on “Intertemporal Equity, Discounting and Economic Efficiency.” Just as the 1992 IIASA session on the topic, it was a late addition thanks to Arrow, who joined the writing team for another chapter mid-1993 and wrote to the coordinator:

“your outline is very complete, with one exception. There needs to be discussion of discount rates. To a considerable extent, suggested policies require present costs (reduced carbon consumption) to prevent future disutilities and costs.

³⁰Schelling to Manne (cc Nordhaus and Cline), 11/30/1992, *archive source redacted*.

³¹ See Nakicenovic et alii (1994) for a copy of the papers presented at the session. These were then published in 1995 as a special issue of *Energy Policy*. The Rapporteur was John Weyant, and contributors also included Indian economist Jyoti Parikh who was working with Arrow on an IPCC chapter on decision making processes for climate science.

³²Manne to Schelling (cc Cline, Edmonds, Fankhauseur, Nakicenovic, Nordhaus, Richels, Weyant), 02/08/1994, *archive source redacted*.

Clearly, the tradeoff between present and future is very important, controversial though it be."³³

The disagreements around the choice of a discount rate were intense enough so that even the head of the IPCC, Swedish meteorologist Bert Bolin took note: "Heated debates arose in considering the issue of equity...between generations" (Bolin 2007, 117-118). He explained that discounting was the "principal analytical tool" economists use to deal with intergenerational equity and quoted the 1996 report's conclusion that "how best to choose a discount rate is, and will likely remain, an unresolved question in economics." In response to these disagreements, a writing team was assembled with contributors who had previously been recruited for other chapters. Led by Arrow, it included Stiglitz, Cline, as well as Karl-Göran Mäler, a Swedish environmental economist who had just founded the Beijer Institute for Ecological Economics with Dasgupta; Sri-Lankan economist Moran Munasinghe from the World Bank; and US Treasury staff member Ray Squitieri.

The published chapter was influential for three reasons: first, it marked the end of the Lind consensus by highlighting disagreements in discounting approaches. Second, it proposed a widely adopted dichotomy to characterize these disagreements: the "prescriptive" approach, which "begins with ethical considerations" was "usually associated with a relatively low discount rate." The descriptive approach "focuses on the (risk-adjusted) opportunity cost of capital" and "begins with evidence from decisions that people and governments actually make." Third, it established the Ramsey formula as the agreed "general framework" in which "the discount rate can be expressed...It provides a way to think about discounting that subsumes many related subtopics, including treatment of risk, valuing of nonmarket goods, and treatment of intergenerational equity" (p.130). It wasn't called the Ramsey formula in the main text, but it was used throughout the chapter to explain the prescriptive approach (in which the equation defines the social rate of time preference), while implying that, in the descriptive approach, it would equal the cost of capital. It was in the long appendix, that built on Arrow-Kurz and Koopmans to derive the discount rate for the time path of consumption from a social welfare function, that a "Ramsey rule" was introduced. It then extensively covered debates on consumption vs investment discounting, Rawlsian criteria, risk, declining discount rates ("empathetic distance"), and the relationships between notions of intergenerational equity and "sustainable development."

Yet, the first draft that Arrow and his coauthors sent around in the Fall of 1994 differed markedly from the published version. Most of the material that ended up in the appendix was featured in the main text, which was entirely built around the notion that economists were moving "toward an emerging consensus" (p. 3-2). The authors floated a "widespread (but not universal) agreement" that "differences in overall standards of living should be reflected in the discount rate," and on "the inadequacy of simply adopting market rates." They quickly set aside the cost of opportunity approach and presented a Ramsey formula unambiguously defining the *Social Rate of Time Preference* (p 3-6). The authors engaged in long discussions of intergenerational equity, comparing utilitarian and Rawlsian approaches (pp. 3-4 and 3-5). They clarified that arguments for or against zero pure time preference weren't just ethical or theoretical, but also reflected tractability constraints.³⁴ The divides were between alternative

³³ Arrow to Parikh, 09/21/1993, *archive source redacted*

³⁴ Draft of "Chapter 3: Intertemporal Equity and Discounting" sent 09/30/1994, *archive source redacted*. On page 3-8, they explained that "a basic problem with this genre of concern about zero pure time preference has to do with the mathematics of maximization over an infinite (sic) time horizon. If the utility function has no upper limit, any

philosophical approaches (the “utilitarian” and the “Rawlsian”), not economic ones. The terms “prescriptive” and “descriptive” were nowhere to be seen.

The referee reports on the draft chapter testify to the transformation of the consensus around discounting and the Ramsey formula which resulted from these few years of debating climate models. One referee, an ecological economist from a US environmental studies department, rejected the whole discounting approach, along with utilitarianism and cost-benefit analysis.³⁵ But Manne fully endorsed the utilitarian framework, including the Ramsey formula. What he strongly disagreed with was the authors’ interpretation and parametrization of the equation. He explained that “the paper is based on a *prescriptive* rather than *descriptive* view of political economy. It virtually ignores the observable fact that the marginal productivity of capital...is in the range of 4-6% per year on the OECD countries” (italics in the original). In the concluding paragraph, he reiterated that the chapter “places a high weight on the claims of the future. It remains to be seen whether the public can be persuaded to allocate significant amounts of contemporary resources in that direction.”³⁶ He had already begun to use the dichotomy the previous years. Among other instances, one of the papers he presented during the IIASA 1993 workshop opened with a section titled “Time preference: prescription vs description” (Manne in Nakiecnovic et alii 1994, 467; see also p. 168).

The signed reports were transmitted to Arrow, and the chapter was revised in a way that included Manne’s language and his underlying picture of the discounting debate: a growing consensus on the use of the Ramsey formula as a framework, and growing disagreement on how to *use* such equation in empirical work, in particular climate simulations. Accordingly, when the disagreement between Stern and Nordhaus broke onto the public scene a decade later, it was discussed within the boundaries of the Ramsey formula. The paradox, as stated in the IPCC chapter, was striking enough for Portney (the newly minted RFF president) and Weyant (then Energy Modeling Forum director and IPCC lead writer) to organize another conference on discounting in 1996. They circulated the IPCC chapter to potential attendees, noting that “in the mid-1990s, Lind’s apparent compromise seemed to unravel.” Their questions problematized the handling of projects with centuries-long impacts and whether discounting and cost-benefit analysis were really the right framework to tackle climate change or nuclear investments.³⁷

The conference was a mix of familiar faces and newcomers to the topic. Veterans included Schelling, Cline, Manne (using again the prescriptive vs descriptive distinction to present discounting choices in terms of efficiency and equity), Nordhaus, Dasgupta, Goran-Måler, and Arrow. As usual, Arrow (1999) wrote the opening chapter. By this point, he had delved deeper into ethics and contributed a piece on “morality” and discounting. The contributions from newcomers highlighted how quickly the debate was shifting with the rise of

savings-investment optimization problem is not well defined.” On the next page, the authors add that “...the mathematical...complications...might be seen as providing a set of arguments that the rate is greater than zero.”

³⁵ X to MacCracken, 02/24/1995, *archive source redacted*. As IPCC issued its first assessment reports, ecological economists had completed their intellectual and institutional integration, with the creation of a society and a journal, *Ecological Economics*, in 1989 (see Ropke (2005) and Spash (1999) for a history). Among their disagreements with mainstream environmental economists was their opposition to the utilitarian foundations of the field, hence the use of social discount rates in climate evaluation. See Spash (1994) for a discussion based on rejecting the compensation principle underlying discounting.

³⁶ Manne to Haïtes, 11/09/1994, *archive source redacted*.

³⁷ Portney and Weyant (1999, 3) opened the resulting published book by explaining that “in the mid-1990s ... the authors [of the IPCC chapter] made no pretense that a general agreement had been reached on discounting. Indeed, in the discussion of discounting in benefit-cost analysis, they chose to organize their work by recognizing two opposing schools of thought on the selection of a discount rate, and they made no effort to reconcile the two.” As this paper shows, it wasn’t the authors’ choice.

climate modeling. Every parameter of the formula, which was much discussed at the conference, as well as the framework from which it emerged, became subject to renewed scrutiny. For instance, Maureen Cropper and David Laibson (1991) addressed the growing research on hyperbolic discounting that had gained momentum since Richard Thaler's work (Thaler 1981). The concept of declining discount rates for decisions extending far into the future had been previously considered in Schelling-Manne-Nordhaus-Cline exchanges. However, the advancement of behavioral economics and laboratory reexaminations of individual time preferences provided a more structured approach to this line of inquiry.

At the same time, new axiomatic foundations for models involving indefinite futures or extinction were being developed (Chichilnisky 1996). Lind's proposition that the discount rate was not the appropriate mechanism to account for risk faced challenges. Martin Weitzman presented preliminary thoughts during the conference, anticipating later collective work on gamma discounting and risk-adjusted discounting. The paper by Portney and Kopp (1999) aligned with Schelling's skepticism regarding the adequacy of utilitarian discounting as a framework for addressing intergenerational justice. Adapting or challenging the utilitarian foundations on which discounting rests then developed into a flourishing area of research.

5. Conclusion

The various lines of research that developed since the stabilization of the Ramsey formula form the present of discounting, as covered in many recent surveys (Groom et alii 2022; Fleurbaey et alii 2019, Drupp et alii 2018, Polaski and Dhampa 2021). This article is an invitation to backtrack and understand the contexts in which the Ramsey formula rose and stabilized. We showed that it emerged from a concern with modeling optimal public investment with the new mathematical tools of growth theory. From the 1970s, discounting debates laid bare the challenges that the far distant future bring, in particular in energy policies. During the 1990s debates on climate modeling the formula was adopted as a framework to debate discounting and even to define the discount rate. While economists' approach to the Ramsey formula gradually coalesced around "prescriptivists" and "descriptivists", neither of these groups was a united one. For instance, Nordhaus, Manne, and Schelling each advocated differently for setting discount rates based on observed behavior – be it market data, macro time series, or behavioral surveys.

This long journey of the Ramsey formula was consistently shaped by one main protagonist: Kenneth Arrow. Since the 1960s, he was pivotal in circulating the formula as an equation that embodied the proper way to see discounting: the growth framework, the importance of ethical and tractability concerns, a realistic take on individual behavior, an awareness to market failures. However, this traveling was also pervaded with ambiguities. The term "Ramsey formula" (as well as "Ramsey rule") refers in fact to two equations stemming from two frameworks that were intertwined in Ramsey's work and later theoretical work, particularly Arrow's. The right-hand side of the equation contains the pure rate of time preference, the elasticity of the marginal utility of consumption and the growth rate of per capital consumption, and these variables were used through time without much dissent — though the elasticity of marginal utility was sometimes interpreted as a risk aversion parameter, an inequality aversion parameter, or both. But the left-hand side has been shrouded with ambiguity: when the equation is derived from the intertemporal utilitarian foundations that Ramsey endorsed, it determines the social consumption rate or the social rate of time preference. But when it comes from the post-World War II optimal growth model, it was an

optimality condition determining the rate of return on investment in the steady state. While philosophers such as Paul Kelleher (2025) clearly distinguish between these two frameworks and resulting equations, the distinction has been largely blurred in economists' writings between the 1960s and 1990s.

These ambiguities surfaced in theoretical work, but amplified heavily by the constant back and forth between theoretical and applied economics, in particular cost-benefit analysis. The IPCC chapter, aiming at applications to climate modeling, is a prime example. Here, the Ramsey formula ultimately determines “the discount rate,” whatever it is. The focus has shifted from precise model-based derivations to parameterization. For some economists, it was an ethical decision about social time preference. For others, it was a consumption rate derived from agents' behavior. Still others saw it as a calculated rate of return on investment, or simply a market rate. Finally, we document how the ambiguities on the status and uses of the formula relate to the intertwined motives economists exhibited for discounting or refusing to do so: economists constantly juggled between theoretical and axiomatic consistency, ethical foundations, and tractability constraints. While one of these aspects take center stage when one author either considered a new mathematical technique, or reflected on a new social issue, or engaged with other disciplines, the others are never far from sight. All these motives have been shaping in significant ways the economists' practices to think about and model the distant future. This in turn raises questions for future research: whether the ambiguities surrounding the Ramsey formula made it a successful “trading zone” (Galison 1996) or “boundary object” (Leigh Star 2010), that is, fueled exchanges, joint work or practice transfers across different communities of scientists.

References

- Arrow, KJ, 1966. "Discounting and Public Investment Criteria," in Kneese and Smiths (eds), *Water Research*. Baltimore: John Hopkins Press for Res Future, 13-32
- Arrow, KJ, 1973. "Rawls's Principle of Just Saving." *The Swedish Journal of Economics* 75(4), 323-335.
- Arrow KJ, Kurz M (1970) *Public investment, the rate of return and optimal fiscal policy*. Johns Hopkins University Press, Baltimore
- Arrow KJ, Cline WR, Mäler K-G, Munasinghe M, Squitieri R, Stiglitz JE. (1996). "Intertemporal equity, discounting, and economic efficiency." In *Climate Change 1995: Economic and Social Dimensions of Climate Change. Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change*, ed. JP Bruce, H Lee, EF Haites, pp. 125–44. Cambridge, UK: Cambridge Univ. Press
- Atsumi, H. 1965. "Neoclassical Growth and the Efficient Program of Capital Accumulation." *Review of Economic Studies* 32 (2): 127–36.
- Banzhaf, H. Spencer. 2009. "Objective or Multiobjective? Two Historically Competing Visions for Benefit Cost Analysis." *Land Economics* 85:1–23.
- Baumol WJ. 1968. "On the social rate of discount." *Am. Econ. Rev.* 58:788–802
- Bellman, R. 1953. *An Introduction to the Theory of Dynamic Programming*. Santa Monica: RAND Corporation.
- Berman, EP, 2023. *Thinking Like an Economist*. Princeton: Princeton University Press
- Boianovsky, M. Hoover, K. 2014. "In the Kingdom of Solovia: The Rise of Growth Economics at MIT, 1956–70." *History of Political Economy* 46 (supp): 198–228.
- Bolin, B. 2010. *A History of the Science and Politics of Climate Change*. Cambridge Cambridge University Press.
- Boumans, M. 1993. "Paul Ehrenfest and Jan Tinbergen: A Case of Limited Physics Transfer." In *Non-natural Social Science: Reflecting on the Enterprise of "More Heat Than Light"*, edited by N. de Marchi. *History of Political Economy* 25 (supp), 131-156
- Bradford D.F. 1975. "Constraints on government investment opportunities and the choice of discount rate." *Am. Econ. Rev.* 65:887–99
- Broome, J. (1985). "The Economic value of Life," *Economica* 52 (207), 281-294.
- Cass, D. 1965. "Optimum Growth in an Aggregative Model of Capital Accumulation." *Review of Economic Studies* 32 (3): 233–40.
- Chakravarty, S. 1962. "The Existence of an Optimum Savings Program." *Econometrica*

30 (1): 178–87.

Cherrier, B. (2023). “The Price of Virtue: Some Hypotheses on How Tractability Has Shaped Economic Models,” *Oeconomia* 13-1, 23-48.

Chichilnisky G (1996) “An axiomatic approach to sustainable development.” *Soc ChoiceWelf* 13(2):231–257

Cointe B., Cassen C. & A. Nadai (2019), “Organising policy-relevant knowledge for climate action: Integrated Assessment Modelling, the IPCC, and the emergence of a collective expertise on socioeconomic emission scenarios,” *Science and Technology Studies* 32 (4), 36-57.

CONAES, 1980. *Energy in Transition, 1985-2010: Final Report of the Committee on Nuclear and Alternative Energy Systems*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/11771>.

Cowen, T., Parfit, D. 1992. ‘Against the social discount rate’. In Laslet and Fishkin (eds) *Justice between age groups and generations*. Yale University Press. pp. 144-161.

Crassous R. 2008. *Modéliser le long terme dans un monde de second rang : application au changement climatique*. Thèse de doctorat en sciences économiques, CIRED, AgroParisTech.

Dasgupta 1972 on UNIDO vs OECD

Dasgupta, P. 1974. “On some problems arising from professor Rawl’s conception of distribution justice.” *Theory and Decision* 4, 325-344

Dasgupta, P. 1991. “Population, Resources, Knowledge and Destitution: the making of an economist,” November, ARCHIVE SOURCE REDACTED

Dasgupta, P. 2019. “Notes to Ramsey and Intergenerational Welfare Economics.” *Stanford Encyclopedia of Philosophy Archive*, <https://plato.stanford.edu/archives/win2019/entries/ramsey-economics/notes.html>

Dasgupta, Heal, 1974. “The Optimal Depletion of Exhaustible Resources.” *The Review of Economic Studies* 41: 3–28

Dasgupta, Heal (1979). *Economic Theory and Exhaustible Resources*. Cambridge: Cambridge University Press

DeHaven (1963). “Water Supply, Economics, technology and Policy,” *RAND* working paper, P-2694, January

Dekker, E. 2021. *Jan Tinbergen (1903-1994) and the Rise of Economic Expertise*, Cambridge: Cambridge University Press, 2021

Desmarais-Tremblais, Johnson and Sturm. 2023. “From public finance to public economics.” *The European Journal of the History of Economic Thought*, 30(5), 934–964

Deringer, W. 2024. "Mr. Aecroid's Tables: Economic Calculations and Social Customs in the Early Modern Countryside," *The Journal of Modern History* 96 (1), 1-46

Doganova, L. 2024. *Discounting the Future: The Ascendancy of a Political Technology Zone* Books: Princeton University Press.

Drupp MA, Freeman MC, Groom B, Nesje F. 2018. "Discounting disentangled." *Am. Econ. J. Econ. Policy* 10:109–34

Duarte, Pedro G. 2016. "A Path through the Wilderness: Time Discounting in Growth Models." *History of Political Economy* 48(2), 265-306.

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

EPA .2022. "Supplementary Material for the Regulatory Impact Analysis for the Supplemental Proposed Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review," Docket ID No. EPA-HQ-OAR-2021-0317, September

Erreygers, G. 2009. "Hotelling, Rawls, Solow: How Exhaustible Resources Came to Be Integrated into the Neoclassical Growth Model." *History of Political Economy* 41(ann. suppl.): 263-281.

Feldstein, M.F. 1965. "The Social Time Preference Discount Rate in Cost Benefit Analysis," *Econ Journal*, 74(294), 360-379.

Fleurbay, Marc; Ferranna Maddalena, Budolfson Mark, Denning Francis, Mintz-Woo Kian, Socolow Robert, Spears Dean, Zuber Stéphane (2019). "The Social Cost of Carbon: Valuing Inequality, Risk, and Population for Climate Policy," *The Monist* 102(1), 84-109

Franco, Gaspard and Mueller. 2019. "Time discounting in Harold Hotelling's approach to natural resource economics: The unsolved ethical question." *Ecological Economics* 163©, 52-60.

Galison, P. 1996. "Computer Simulations and the trading Zone" in Galison, Stump (eds). *The Disunity of science: boundaries, contexts, and power*. Stanford: California University Press, 118-157.

Gaspard, M., Missemer, A. 2022. "L'intégration des ressources naturelles dans la modélisation macroéconomique : l'empreinte de Robert M. Solow," *Revue Française d'Economie* 37, 147-184.

Guizzo, Paré-Ogg. 2023. "Economics with(out) ethics? An interdisciplinary encounter between public economists and John Rawls in the 1970s." *The European Journal of the History of Economic Thought* 30(5), 906-933

Groom Ben, Drupp Moritz, Freeman Mark, Nesje Frikk. 2022. "The Future Now: A review of social discounting." *Annual Review of resource Economics*, 467-491.

Igersheim, H. 2022. “Rawls and the Economists: The (Im)possible Dialogue.” *Revue économique* 73, 1013-1037

Jacobs, M. 2016. *Panic at the Pump: the Energy Crisis and the Transformation of American Politics in the 1970s*. New York: Hill and Wang.

Kaya Yoichi ,Nakiecnovic, Nebosja, Nordhaus William, Toth Ferenc (1993). *Costs, Impacts, and Benefits of CO2 Mitigation*. Proceedings of a Workshop Held on 28–30 Sept. 1992 at IIASA.

Koopmans, T. 1960. “Stationary Ordinal Utility and Impatience.” *Econometrica* 28 (2):287–309.

Koopmans, T. 1965. “On the Concept of Optimal Economic Growth.” In pt. 1 of *The Econometric Approach to Development Planning*, 225–87. Vatican City: Pontificia Academia Scientiarvm.

Koopmans, T. 1972. 1972. “Representation of Preference Orderings over Time.” In *Decision and Organization: A Volume in Honor of Jacob Marschak*, edited by C. B. McGuire & R. Radner. Amsterdam: North-Holland

Krutilla, J.V. Eckstein, O. 1958. *Multiple-Purpose River Development: Studies in Applied Economic Analysis*. Baltimore: Johns Hopkins University Press.

Leigh Star, S. 2010. “This is not a boundary object: reflections on the origins of a concept.” *Science, Technology and Human Values* 35(5).

Lind RC, ed 1982. *Discounting for Time and Risk in Energy Policy*. Baltimore: Resource for the Future

Manne, A. 1974. “Waiting for the Breeder,” March, Research Report 75-5, IIASA.

Manne, Richard. Richels, Richard. 1992. *Buying Greenhouse Insurance: the Economics Costs of CO2 Emission Limits*. Boston: MIT Press

Manne, Richels, Weyant. 1979. “Energy Policy Modeling: A Survey.” *Operation Research* 27(1), 1-36.

Manne, A. Mendelsohn, Robert, Richels, Richards (1995). “MERGE: A model for evaluating regional and global effects of GHG reduction policies.” *Energy Policy* 23(1), 17-34

Marglin, S. 1963 “The Social Rate of Discount and the Optimal Rate of Investment,” *Quarterly Journal of Economics* 77 (1), 95-111.

Medema, S.Marciano, A. (eds) 2015. *Market Failure in Context* . Special issue of *History of Political Economy* 47(supp), Duke University Press

Nakiecnovic, Nebosja, Nordhaus William, Richels Richard, Toth Ferenc (1994). *Integrative Assessment of Mitigation, Impacts, and Adaptation to Climate Change*, Proceedings of a Workshop Held on 13–15 Oct. 1993.

Nakiecnovic, Nebosja, Nordhaus William, Richels Richard, Toth Ferenc (1997). *Climate Change: Integrating Science, Economics and Policy*, Proceedings of a Workshop Held on 19–20 Mar. 1996 at IIASA (Laxenburg: IIASA, 1996)

National Research Council. 1978. “Energy Modeling for an Uncertain Future: Supporting Paper 2.” Washington, DC: The National Academies Press. DC: <https://doi.org/10.17226/19960>.

Nesje, F. Drupp, M.A.; Freeman, M.C. Groom, B. 2023. “Philosophers and economists agree on climate policy paths but for different reasons,” *Nature Climate Change* 13, 515–522

Nordhaus, W. 1973. “The Allocation of Energy Resources.” *Brookings Papers on Economic Activity* 1973 (3). 529- 576

Nordhaus, W. 1975. “Can we control carbon dioxide,” June, WP-75-63, IIASA.

Nordhaus, W. 1980. “Thinking about Carbon Dioxide: Theoretical and Empirical Aspects of Optimal Control Strategies,” *Cowles Foundation Discussion Papers* 10-1-1980

Nordhaus, W. 1992a. “The ‘Dice’ Model: Background and Structure of a Dynamic Integrated Climate-Economy Model of the Economics of Global Warming.” *Cowles Foundation Discussion Papers*, 1252.

Nordhaus, W. 1992b. “An Optimal Transition Path for Controlling Greenhouse Gases.” *Science* (258), 20 November.

Nordhaus, W. 2018. “Biographical,” *Nobel Prize Website* <https://www.nobelprize.org/prizes/economic-sciences/2018/nordhaus/biographical/>

OMB 2023. “OMB Circular No. A-4: Explanation and Response to Public Input,” November 9, 2023, <https://www.whitehouse.gov/wp-content/uploads/2023/11/CircularA-4Explanation.pdf>

Parfit 1981. “An Attack on the Social Discount Rate.” *Philosophy & Public Policy Quarterly* 1(8)

Parfit 1983. “Energy policy and the further future : the identity problem.” In Mc Lean, Brown (eds), *Energy and the Future*. Totowa: Rowan and Littlefield, 166-179.

Polaski, Stephen. Dampha, NfamaraK. (2021). “Discounting and Global Environmental Change.” *Annu. Rev. Environ. Resour.* 46:691–717

Portney and Weyant. 1999. *Discounting and Intergenerational Equity*. New York: Resour. Future

Pottier, A. 2014.. *L'économie dans l'impasse climatique*. PhD diss., EHESS, Paris.

Prest, AR, Turvey R. 1965. "Cost-Benefit Analysis: A survey." *Econ journal*, 75(300), 683-735

Ramsey, F. P. 1928. "A Mathematical Theory of Saving." *Economic Journal* 38 (152): 543–59.

Rawls, J., 1971 [2005]. *A Theory of Justice*. Cambridge: Harvard University Press

Røpke, I. 2005. "Trends in the development of ecological economics from the late 1980s to the early 2000s" *Ecological Economics*. 55 (2), 262–290.

Schelling, T. 2005. "Biographical." *Nobel Prize Website*
<https://www.nobelprize.org/prizes/economic-sciences/2005/schelling/biographical/>

Schmelzer, M. 2017. "Born in the Corridors of the OECD": The Forgotten Origins of the Club of Rome, Transnational Networks, and the 1970s in Global History', *Journal of Global History* 12 (1)

Sen, A.K. 1961. "On Optimising the Rate of Saving." *Economic Journal* 71 (283): 479–96.

Shell, 1967.

Shishko, R.1976. "Choosing the Discount Rate for Defense Decisionmaking," *RAND*, ADA028341

Sikora, R.I. Barry B. (eds.) 1978. *Obligations to future generations*. Cambridge, UK: White Horse Press. pp. 169--185

Solow, R. 1974a. "The Economics of Resources or the Resources of Economics." *The American Economic Review*, May, P&P, 64(2), 1-14.

Solow, R. 1974b. "Intergenerational Equity and Exhaustible Resources." *The Review of Economic Studies* 41: 29–45

Somers, H.M. 1971. "On the Demise of the Social Discount Rate," *The Journal of Finance* 26(2), 565-578.

Spash, C. 1994. "Double Co2 and beyond: benefits, costs and compensation." *Ecological Economics* 10, 27-36

Spash, C. L. 1999. "The development of environmental thinking in economics," *Environmental Values* 8 (4): 413–435

Stiglitz, Joseph E. 1974. "Growth with Exhaustible Natural Resources: Efficient and Optimal Growth Paths." *The Review of Economic Studies* 41: 123–137

Stern, N. Taylor, C. 2007. "Economics. Climate change: risk, ethics, and the Stern Review," *Science* 317(5835):203-4

Subcommittee on Benefits and Costs, Federal Inter-Agency River Basin Committee, 1950. "Proposed Practices for Economic Analysis of River Basin Projects; Report to the Federal Inter-Agency River Basin Committee," USDA Miscellaneous 329104, USDA

Sweeney, James, L. Weyant, John, P. "The Energy Modeling Forum, Past, Present and Future." *EMF PP6.1, Fall*.

Thaler, R. 1981. "Some empirical evidence on dynamic inconsistency." *Economics Letters* 8(3), 201-207.

Tinbergen, J. 1956. "The Optimum Rate of Saving." *Economic Journal* 66 (264): 603–9.

Tinbergen, J. 1960. "Optimum Savings and Utility Maximization over Time." *Econometrica* 28 (2): 481–89.

Tinbergen, J. Bos, H. C. 1962. *Mathematical Models of Economic Growth*. New York: McGraw-Hill.

Van Beek, Lisette; Hajer, Maarten; Pelzer, Peter; Van Vuuren Detlef; Cassen, Christophe (2020). "Anticipating Futures through Models: The Rise of Integrated Assessment Modelling in the Climate Science-Policy Interface since 1970," *Global Environmental Change*, 65 102-191.

Vieille Blanchard, E. 2011. *Les limites à la croissance dans un monde global: modélisations, perspectives, réfutations*, PhD thesis, EHESS.

von Weizsäcker, C. C. 1965. "Existence of Optimal Programs of Accumulation for an Infinite Time Horizon." *Review of Economic Studies* 32 (2): 85–104.