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A retrospective on The Allocation of Energy Resource by William D. Nordhaus

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A retrospective on *The Allocation of Energy Resource* by William D. Nordhaus

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Nordhaus (1973) does have important implications in energy policy. Nordhaus develops a general equilibrium model to determine the path of prices of energy resources and efficiently allocate four main energy resources (petroleum, coal, natural gas, and uranium-235) over time, space and different energy demand categories. Additionally, he explores whether the resulting optimal price paths are close to market-determined ones. His formulation of the model follows a standard dynamic optimization problem; and thus the price paths associated with his optimal solution (shadow prices for resources over time) are interpreted as rents that a competitive market would impute to scarce resources (Hotelling's Rule). The main empirical conclusion of the paper is that the calculated prices are not very far from the actual market ones, with the exception of petroleum products and coal.

According to natural resources economic theory, in an efficient allocation, resources are extracted such that the stream of discounted profits (from selling a unit of the resource at each time period) is maximized. The time horizon, nevertheless, Nordhaus considers, is a very long one (200 years). Furthermore, in discounting future values, Nordhaus applies a constant interest rate.[1] The following paragraphs discuss how both these aspects in natural resources modeling have been questioned by economists.

Economists have argued extensively, in the context of Net Present Value criterion (in Cost Benefit Analysis, CBA), over the choice of the appropriate discount rate. The conclusion of the debate is that the choice of the discount rate depends on the extent to which a project is funded by consumption or private investment. For example, if the project is entirely funded by consumption, then it has been argued that it should be discounted by the Social Rate of Time Preference; while if it is funded by displaced investment, then it should be discounted by the Private Return to investment (other economists have argued we may want to use a mix of these two). In any case, the standard practice has been to use the same value for discount rate across all time periods, the latter thus leading to exponential discounting.

Nevertheless, the classic constant discount rates have been proven to perform well in short–medium time horizons. However, over the recent years, economists have shown that discounting at a constant positive rate is problematic, particularly in long-run environmental problems (such as climate change, nuclear waste, or biodiversity loss). The reason is that a constant discount rate over time discounts so heavily the welfare (costs or benefits) of future generations, such that it appears small (in present value terms). The

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proposed solution in the literature has been the use of a declining discount rate (DDR) over time: a DDR increases the weight attached to welfare of future generations; and thus corrects the insufficient representation of future generations.

In a series of papers, Gollier, Koundouri, and Pantelidis (2008), Pearce, Groom, Hepburn, and Koundouri (2003), Hepburn, Koundouri, Panopoulou, and Pantelidis (2009), and Groom, Hepburn, Koundouri, and Pearce (2005) show that a declining pattern of discount rates is justified both theoretically and empirically (i.e., from historical data). All papers suggest that standard discounting is more suitable for formulating policies in the short or medium term, but DDRs should be used in CBA with long time horizons.

Regarding the theoretical justifications for using a DDR, Groom et al. (2005, 2007) explain how DDRs can emerge in a deterministic world, but focus mainly on the case of uncertainty, and show how the case for DDRs is then even more compelling. In short, in an uncertain economic environment, the persistence of shocks on the growth rate of consumption (consumption-based approach), and the persistence on short-term rates of return to capital (production-based approach), both imply a declining pattern in discount rates. The results are intuitive: when there is uncertainty about how consumption will grow in the future, we want to apply a smaller discount rate, that is, sacrifice a larger amount of our current consumption in favor of future generations (formally, the Ramsey rule is extended by the 'precautionary saving motive'). In the production-based approach, the authors show how uncertainty in the equilibrium interest rate in the economy, together with persistence of interest rates (persistence meaning that high discount rates tend to clump together over time; they are 'sticky') can lead to DDRs.

But, whether this persistence in the shocks exists or not, is clearly an empirical question. Therefore, Gollier et al. (2008) estimate country-specific trajectories for the social discount rates (based on the production-based approach) from historic data: a series of discount factors and DDRs is estimated (from data on risk-free market interest rates) for France, India, Japan, and South Africa based on the simulation procedure of Newell and Pizer (2003); the simulation for Australia, Canada, Germany, and the UK, was based on the model of Hepburn et al. (2009); while for the US, it was based on Pearce et al. (2003). In short, the empirical estimation is described by a univariate time series model, in which future interest rates are determined by past values, that is, past behavior reveals useful information about the future dynamics of the series. In the univariate time series model, uncertainty about the future path of interest rates is captured by the uncertainty of the estimated parameters of a two-regime switching model. All papers conclude that the decision to replace constant discount rates with DDRs has significant policy implications (for instance, in estimating the social cost of carbon in climate change policies). Furthermore, there is significant country heterogeneity in terms of the empirically estimated discount rates; therefore, transferring a discount rate scheduled from one area to another would be unwise (Hepburn et al., 2009). The aforesaid statement could imply that (1) the discount rate that Nordhaus uses in the description of the problem should not be constant over time, and (2) adding to the previous proposition, a subscript denoting the country where the resources of the model are located, should be added to the variable that describes the discount rate informing that each one of the countries is assigned a different rate of discounting.

In the light of the above theoretical justifications and empirical findings towards the use of declining rather than constant discount rates (particularly in the context of long-term horizon problems), it seems that Nordhaus' optimal price paths for energy resources, over a 200-year horizon, will follow different trajectories from the ones simulated.

Apart from the issue of choosing the appropriate pattern of discount rates in an optimization problem, another issue that has been questioned by the literature is the monotonic quadratic trend of natural resource prices over time. A strand of the literature has considered stochastic trends in the evolution of prices; however, there is not strong evidence to support such specifications. Antypas, Koundouri, and Kourogenis (2013) have also challenged the standard theoretical finding for prices of natural resources. The authors provide evidence that oscillatory behavior in real natural resource prices is more common than the existence of a long-run quadratic trend. More specifically, the authors estimate four specifications for the trends of prices for 11 major natural resources (their specifications allow for a more general than the standard quadratic trend model; that is, they nest both oscillatory and quadratic trends). The competing specifications are then evaluated, for each natural resource, based on three information criteria (where the criteria disagreed, they performed a simulation study to decide on the best specification). Overall, the results showed that in nine out of the 11 examined natural resources, a trigonometric trend function captured better the dynamics of prices than a quadratic function alone (the latter was selected only for aluminum and perhaps for nickel). The reason behind the failure of simple quadratic functions to empirically capture the long-term evolution of prices of natural resources is that quadratic functions are explosive. These empirical findings allow authors to restate Hotelling's rule as follows: the price of an exhaustible resource which corresponds to a competitive (or efficient) utilization path will oscillate around the interest rate. This provides evidence that projects with high extraction costs should consider upper bounds of the prices of the real prices.

The motivation for Nordhaus´s work was the 'insatiable appetite for energy' that caused anxiety given the limited amount of energy resources. He notes that apart from hydrogen, other renewable resources were not of much use in the 1970s. Therefore, the wide spectrum of renewable resources was not taken into account in the analysis. However, from that time there has been a significant increase in the production of energy with the use of renewable resources. This trend has been facilitated by technological developments. Additionally, due to the increase in the price of conventional sources of energy, their low limited quantity and the environmental effects their use yields, renewable sources of energy have been considered the most appropriate solution to the energy problem, simultaneously satisfying the environmental constraints related to production of emissions and exacerbation of greenhouse gas emissions and their impacts on ecosystems.

The consideration of renewable resources in the problem would have definitely had an impact in the solution of the problem, that is, the allocation of energy over time, space. This is due to the fact that the resources are not – at least a part of them – exhaustible; therefore, the increasing production of energy through renewable resources could lead to depleting scarcity cost of resources. Intuitively, this will be observed at times when the decreasing rate of stock natural energy resources is lower than the increasing rate of growth of quantity of renewable energy resources. Undoubtedly, such an occurrence has an effect on the long-run price path of energy. More specifically, since some of the resources will be replenished in the end of each extraction period, Hotelling´s rule should be transformed to one that takes into account the growth rate of the renewable resources. This might lead to further restate Hotelling´s rule as: the price of an exhaustible resource, which corresponds to a competitive (or efficient) utilization path will oscillate around the interest rate minus the growth rate. Overall, the price of energy over time might be lower due to the inclusion of the growth rate. This, however, needs to be empirically justified.

Note

1. Nordhaus considers a 10% interest rate in the baseline scenario and several alternate values (but still constant over time) in the sensitivity analysis.

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