Energy Economics 40 (2013) 61–71

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Benefit–cost analysis of non-marginal climate and energy projects☆

Simon Dietz [a,b,*], Cameron Hepburn [a,c]

[a] Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science, United Kingdom
[b] Department of Geography and Environment, London School of Economics and Political Science, United Kingdom
[c] New College, University of Oxford, United Kingdom

ARTICLE INFO

Article history:
Received 17 August 2012
Received in revised form 23 May 2013
Accepted 28 May 2013
Available online 19 June 2013

JEL classification:
H43
D61
Q54

Keywords:
Benefit–cost analysis
Non-marginal
Project appraisal
Discount rate
Infrastructure investment
Climate change
Energy
Hydropower dam

ABSTRACT

Conventional benefit–cost analysis incorporates the normally reasonable assumption that the policy or project under examination is marginal. Among the assumptions this entails is that the policy or project is small, so the underlying growth rate of the economy does not change. However, this assumption may be inappropriate in some important circumstances, including in climate-change and energy policy. One example is global targets for carbon emissions, while another is a large renewable energy project in a small economy, such as a hydropower dam. This paper develops some theory on the evaluation of non-marginal projects, with empirical applications to climate change and energy. We examine the conditions under which evaluation of a non-marginal project using marginal methods may be wrong, and in our empirical examples we show that both qualitative and large quantitative errors are plausible.

1. Introduction

Benefit–cost analysis (BCA) of major policies, programmes and projects is becoming more widely used to inform and improve decisions (Hahn and Tetlock, 2008). In the United States and the United Kingdom, for instance, there is now a legislative requirement to conduct BCA of significant new policies and policy reforms, while other countries and regional organisations such as the European Commission have made steps in the same direction (Pearce et al., 2006). In addition, there is a long tradition of BCA of major projects by the World Bank and other multilateral financial institutions.

Conventional BCA, which extends the basic practice of discounted cash flow (DCF) analysis to the net social benefits of projects,[1] incorporates the normally reasonable assumption that the project under examination is marginal. A marginal project does not significantly change relative prices, and it is on relative prices that most of the literature has focussed. However, a marginal project must also be small enough that the underlying growth rate of the economy is not significantly changed. This class of project has received much less attention, even though a number of candidates can be identified, including in the realm of climate-change and energy policy.

Most notably, proposals to spend several per cent of global GDP on the deployment of 'low-carbon' technologies, such as renewable energy, smart electricity grids and transport infrastructure, are explicitly intended to shift the global growth path by avoiding climate change (e.g. Stern, 2007). As part of this global infrastructure investment programme, there is likely to be a renewed impetus for large development projects in small economies, for example to generate renewable

☆ We thank David Anthoff, Partha Dasgupta, Francis Dennig, Christian Gollier, Chris Hope, John Quah, Robert Ritz, Sjak Smulders, Nick Stern, seminar participants at EAERE 2009 and at the Toulouse School of Economics, and the editor. Special thanks for detailed comments go to two anonymous referees as well as Antony Millner. We would also like to acknowledge the financial support of the Grantham Foundation for the Protection of the Environment, as well as the Centre for Climate Change Economics and Policy, which is funded by the UK's Economic and Social Research Council and by Munich Re. The usual disclaimer applies.

* Corresponding author at: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science, United Kingdom. Tel.: +44 207 955 7589; fax: +44 207 107 5441.
E-mail address: s.dietz@lse.ac.uk (S. Dietz).

[1] Henceforth we will use the word 'project' to denote any change in 'business as usual', whether arising from a private-sector or government policy, programme or project.

0140-9883/$ – see front matter © 2013 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.eneco.2013.05.023

electricity (e.g. solar power in North Africa for supply to Europe), while adaptation to climate change will require similarly large projects to, for example, store freshwater and protect against coastal flooding. Such projects may also change the growth rate of the small economies in which they are developed.

In the literature on project appraisal, the limitations of marginal analysis in the context of large projects have been recognised for many years.[2] In their classic text, Dasgupta et al. (1972) focus largely on marginal projects. Nevertheless they do note that different considerations may apply to large projects:

> we tacitly assumed that…the proposed project is "small", i.e. the "range" of the net benefits of the project is small compared with the size of aggregate consumption. [Where this assumption is untrue], it might seem plain that the EPV rule will not suffice then. One would like to know what rule should replace it. One would also like to know whether the evaluator would make serious errors if he stuck to the EPV rule in such cases. (p111).

Similar observations were made by Harberger (1971), while Little and Mirrlees (1974) also recognised in the other classic project-appraisal text of the time that "we must know where the economy ought to be going…before we can decide on how it ought to start off" (p304). However, while the potential for "serious errors" has been acknowledged in general terms, surprisingly little is known about the particular circumstances leading to such errors, and that is the primary aim of our paper.

Thus while Dasgupta et al. (1972) briefly examine whether errors might occur, they do so with a simple back-of-the-envelope calculation involving a highly specific utility function ($u(c) = -10,000/c$) and a project that results in a once-off benefit. Similarly, Little and Mirrlees (1974) note the relationship between project valuation and the inter-temporal profile of the economy, but do not develop this to consider projects that could themselves shift that profile. Hammond (1990) makes limited reference to non-marginal projects, and only considers the impact of changes to relative prices, rather than the economic growth rate, which is characteristic of the literature as a whole. Perhaps the most extended discussion of large projects is in Starrett (1988), who is thorough in his explanation of why marginal analysis may be inappropriate in the context of projects large enough to change relative prices and overall incomes. Our analysis is complementary, because it attempts to better understand the sign and size of the error.

In the case of global carbon emissions abatement, many analyses have ignored the possibility that investing in abatement could be 'non-marginal', at least in terms of how they conducted BCA. For example, Tol's (2005) review of the empirical literature shows that, of the 103 estimates of the shadow value of emissions abatement he considered, 62 ignored the possibility of a shift in the growth path, because they set the consumption discount rate (which depends on estimated future growth) irrespective of the size of the future net benefits of the project and their effect on the growth rate. That is to say, these 62 cases carried out marginal analysis. Other analyses, such as those of Nordhaus (1994, 2008) and Stern (2007), did use a non-marginal approach, evaluating the project in a general-equilibrium framework in which the consumption discount rate was endogenous. However, little is currently known about whether the move from marginal to non-marginal analysis matters empirically. For instance, does it matter as much as celebrated controversies in the literature, notably over the parameters of the social discount rate? The lack of attention to this issue could explain why marginal analysis of this potentially non-marginal project continues: in its recent exercise to set a shadow price of carbon for Regulatory Impact Analysis in the United States (Interagency Working Group on Social Cost of Carbon, 2010), a federal interagency working group also applied an exogenous consumption discount rate, despite having at its disposal a set of integrated assessment models capable of endogenising it.

Furthermore, we should ask whether the move from marginal to non-marginal analysis matters to project appraisal more widely, for instance as practised by multilateral institutions such as the World Bank. Standard procedure in this area is to apply a marginal analysis with an exogenous discount rate, irrespective of the size of a project's net benefits. Climate change will require an increase in the rate of energy infrastructure investment worldwide (IEA, 2009), as well as increased investment in various forms of climate resilience such as freshwater storage and flood defence (Agrawala and Fankhauser, 2008), including in small economies. We can expect project appraisal to play an important role in the design and implementation of such projects on the ground.

Hence this paper attempts to address the question of whether "serious errors" could be made by evaluating non-marginal projects with conventional BCA, which uses DCF-type analysis to determine net present value (NPV). By the term "non-marginal", we mean sufficiently large for the first-order Taylor approximation of the utility function of aggregate consumption per capita not to hold (see Proposition 1 below). In defining non-marginal projects this way, we are interested not in the effects of projects on relative prices, which have been much more comprehensively explored, but on the effects of projects on aggregate consumption.

The paper proceeds as follows. Section 2 reviews the relevant economic theory and reminds readers of the result that if a project is evaluated to have positive NPV, then it is also welfare-improving, provided that the project is marginal. It follows that if the project is non-marginal, the result may not hold. A Taylor-series expansion provides an expression of the error involved in evaluating non-marginal projects with DCF analysis, and comparative statics, including the impact of growing population, are examined. These provide intuition for the circumstances in which DCF analysis may produce an error, especially errors of large size. Section 3 then applies this theory to two examples: climate-change mitigation and large-scale electric power plant construction. The first employs a well-known integrated assessment model (IAM) of climate change to estimate the value of a project to reduce global carbon emissions. The second uses data from the World Bank to evaluate a large renewable energy project in a small economy, namely the "Nam Theun II" hydroelectric power project in Laos. Armed with these examples, we are able to examine numerically the sign and size of the potential error caused by evaluation of a large project using marginal analysis. We find that it is possible for marginal BCA to provide both qualitatively and quantitatively incorrect guidance, by ignoring the impacts of projects on the underlying economic growth path. Section 4 concludes.

2. Theory

2.1. Marginal BCA of a large project

A basic proposition of BCA is that if DCF analysis shows that a project has positive NPV, then the project is welfare-improving (see Proposition 1). In practice, problems can arise with the use of BCA for a number of reasons (Starrett, 1988, Chapters 14–16). For instance, if there are general equilibrium effects, yet only partial equilibrium approaches are employed to evaluate the project, then it is likely that the real net benefits from the project, Δ_t, will be incorrectly estimated. The omission of general equilibrium effects is a common problem with BCA in practice, but is not the focus here.

Nor is the focus of this paper on the errors arising if it is assumed that other sectors are optimising, when in fact they are not. The

[2] In the wider theory of public economics, there is the more general problem of conducting marginal analysis when the economic problem is non-convex (e.g. Baumol and Oates, 1988).