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Introduction to a special issue entitled *Perspectives on Implementing Benefit-Cost Analysis in Climate Assessment*

Abstract: Over the past half-century or more, economists have developed a robust literature on the theory and practice of benefit-cost analysis (BCA) as applied to diverse projects and policies. Recent years have seen a growing demand for practical applications of BCA to climate change policy questions. As economists seek to meet this demand, they face challenges that arise from the nature of climate change impacts, such as the long time frame and the potential for non-marginal changes, the importance of intangible effects, and the need to grapple with Knightian uncertainty. As a result of these and other characteristics of climate change, many of the fundamental tenets of BCA are coming under scrutiny and the limits of BCA's methodological and practical boundaries are being tested. This special issue assembles a set of papers that review the growing body of literature on the economics of climate change. The papers describe the state of the literature valuing climate change impacts, both globally and at more disaggregated levels. The papers also discuss the challenges economists face in applying BCA to support climate change decision making and adaptation planning. This introduction provides background and context on the current use of BCA in climate change analysis, and sets each paper firmly in that context, identifying also areas for future research. While the challenges in conducting BCA and interpreting its results are significant, across the papers it becomes clear that economic analysis in general, and the tools and methods of BCA in particular, have a central role to play in supporting decision-making about how to respond to climate change.

Keywords: benefit-cost analysis; climate change; decision-making; uncertainty; valuation.

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1 Introduction

This special issue, *Perspectives on Implementing Benefit-Cost Analysis in Climate Assessment,* assembles a set of articles that review and assess a portion of the growing body of literature on the economics of climate change. The articles focus on the frontiers of ongoing research applying the framework of benefit-cost analysis (BCA) to the environmental problem of climate change, and the challenges that economists face in adapting BCA techniques to respond to growing demand for economic assessment.

The use of economic analysis to explore the issues surrounding climate change – and the challenges in doing so – is not new. The IPCC's *Climate Change 1995* (referred to as the Second Assessment Report, or SAR), contained a report from Working Group III entitled "Economic and Social Dimensions of Climate Change." This landmark volume contained some of the earliest estimates of the global costs and damages of climate change to appear in a highly visible and public forum. The SAR also contained chapters authored by Nobel-prize winner Kenneth Arrow, Mohan Munasinghe, and other eminent climate researchers and economists, entitled, "Decision-Making Frameworks for Addressing Climate Change," and "Applicability of Techniques of Cost-Benefit Analysis to Climate Change," which contained thoughtful discussions of the challenges of using BCA to analyze climate change (IPCC, 1995).

In the years leading up to and those following the IPCC report, some topics in the economics of climate change have been well studied while others have received far less attention. For example, the cost and effectiveness of technologies to reduce emissions of greenhouse gases, and the ramifications of long-term control costs on national and global economies, have received considerable attention in subsequent IPCC reports and academic forums, such as the Energy Modeling Forum at Stanford University.[1] However, much less has been accomplished in valuing the economic effects of climate change on human health and welfare and the environment, and in estimating the cost and effectiveness of measures to adapt to climate change.

In the US, national control costs have been estimated in great detail and for a wide range of emission sources and greenhouse gases. However, the prominent National Climate Assessment Reports – the most recent of which was released in 2014 (U.S. Global Change Research Program, 2014) – contain almost no economic data on projected impacts and adaptation costs, despite significant advances over the past two decades in understanding impacts at the sectoral level and nationally, and in estimating the costs of adaptation. In contrast, climate impacts and the

1 See https://emf.stanford.edu/.

economics of adaptation are increasingly becoming important in both public discussions and in national, state, and local decision making. In the US, for example, President Obama's national Climate Action Plan (The White House, 2013) includes not only policies and measures to reduce greenhouse gas emissions but also those that enhance climate resilience – the ability of infrastructure, resources, and development patterns to withstand projected climate change – a topic that has only in the past few years begun to gain traction at all levels of government.

2 The challenges in conducting BCA of climate change and state of the literature

The aggregate economic cost of climate change includes three components: the cost of taking action to reduce emissions and slow climate change (mitigation), the cost of adapting to climate changes, and the economic value of residual damages and lost services that persist, even after adaptive action is taken. These costs and benefits are often estimated in isolation. For example, estimates of aggregate adaptation costs can be used to inform long-term funding needs for infrastructure. Estimates of costs and benefits can be combined using BCA to address policy-relevant questions. For example, at a national or local level, BCA can be used to analyze and compare alternative mitigation and adaptation options or investment paths. At a global level, studies have estimated the optimal trajectory of mitigating greenhouse gases, i.e., the path along which marginal benefits equal marginal costs of mitigation.

Many economists, philosophers, policy analysts, and others debate the appropriateness of using the framework of BCA to analyze a problem as far-reaching as climate change. Together, the papers in this issue focus on the state of key bodies of literature and on the unique challenges each type of analysis faces, in the context of the BCA framework. In addition, papers explore how economic analysis itself contributes to broader analytical and decision-making frameworks, and discuss its role in alternative approaches that may be more robust and multi-dimensional than conventional BCA methods.

2.1 Climate change, BCA, and welfare economics

Sussman, Weaver and Grambsch (2014) sets the stage for this *Special Issue* by systematically exploring the complications that arise in analyzing climate change trajectories using the framework and techniques of BCA. The types of conceptual, methodological, and practical challenges that arise will be familiar to practitioners of BCA, who deal routinely with a range of public (and in some cases private) sector projects and policies of varying magnitude and impact.

The focus in this paper is primarily on questions surrounding economic impacts, i.e., economists' ability to quantify, value, and in some cases aggregate, effects on natural and human systems that result from climate change. Climate change has characteristics that make it difficult to value: effects extend over multiple generations, and are ubiquitous and yet unevenly distributed across regions, sectors, and natural and human systems. Further, effects in many cases may be non-marginal and/or hard to value using market information, as well as profoundly uncertain over long timescales. The paper identifies four categories of challenges that economists face in conducting BCA, and maps the characteristics of the climate change problem to these challenges.

The first set of challenges stems from the premises on which BCA rests. One premise is the distinction between efficiency and equity. This distinction is difficult to maintain in the face of disproportionate, and in some cases, dramatic effects on health and welfare across and within countries. The foundations of BCA also include the value judgments underlying the interpretation of BCA as an efficiency improvement. The importance of non-economic or difficult-to-quantify effects, such as instability of political and economic systems or the loss or degradation of natural ecosystems, raises questions about the appropriateness of some assumptions, such as the reliance on individualistic welfare and values.

The paper also examines the methodological challenges that economists face in conducting a BCA – challenges that are exacerbated by climate change. For example, the tasks of estimating values for less tangible, non-economic effects, or choosing discount rates, are more difficult for a problem spanning decades if not centuries. Further, practitioners must incorporate not only stochastic information, but "deep" uncertainty of the type identified by Knight (1921), where probabilities are unknown, and perhaps unknowable, at least within the time frame relevant to decision making. Last, practical challenges result from the breadth and depth of climate impacts; these challenges result not only from the geographic spread and diversity in human and natural systems that are affected, but also the time frame over which effects occur, and the complex interactions between physical and social systems.

Despite the challenges, it is a mistake to let the controversy lead the debate; economists have produced high-quality studies of benefits and costs for many aspects of climate change. In reality, the challenges for some types of analyses may be fairly modest. For example, conventional methodologies can be readily applied to estimate short-term cost-effectiveness of adaptive actions, suggesting that considerable progress may be possible in expanding our knowledge base for the economics of adaptation. In some cases, methodological improvements may be possible that heighten our ability to value some of the less intangible climate impacts, such as ecosystem services or health effects.

Some aspects of climate change, however, have proven to be much more difficult to accommodate in a welfare economics context, necessitating new approaches that appropriately recognize deep uncertainty, the value of low-probability but extremely high-impact events, difficulties in aggregating, and the controversy about discount rates over the long term. Moreover, alternative systems of value – those that do not focus on individual welfare – might yield very different results from an economic approach. As discussed in the papers by Toman and by Lempert (2014), some analysts have argued that BCA should be replaced by (or used as part of) alternative decision rules and approaches.

2.2 Application of BCA in climate-related decision-making: State of the literature

The challenges in conducting BCA are explored more specifically in the papers by Weyant (2014) and Neumann and Strzepek (2014). These two papers focus on the research and insights that are emerging in two very different bodies of literature: the analyses conducted using global integrated assessment models and the estimates of economic impacts of climate in the US at the sectoral level.

2.2.1 Global assessment

Weyant (2014) examines how integrated models are being applied at the national and global scales to assess the costs and benefits of alternative emissions paths and to calculate optimal emission trajectories. The paper also describes how the results of some of these models are being used to provide input into the development of the social cost of carbon (SCC). The SCC represents the value of the damages attributable to an incremental metric ton of carbon dioxide emitted in a given year, and is being incorporated by the U.S. federal government into regulatory BCA in cases where the regulations are expected to affect greenhouse gas emissions.

Integrated assessment models (IAMs) combine climate, physical, and economic models to represent a complex set of systems and interrelationships, which together estimate greenhouse gas emissions and control costs, a trajectory of climatic changes, and associated dollar impacts on human and natural systems. Versions of IAMs have been in existence for more than two decades, and have contributed prominently to climate policy analysis by providing insights into the costs of alternative mitigation strategies, or the development of emissions trajectories that balance marginal damages and marginal costs of control. IAMs also play an important role in the widely cited Stern Review (Stern, 2007), a large-scale BCA of global climate change using an integrated modeling approach, which has raised awareness of the potential costs of climate change and engendered much debate about the framework, assumptions, and results of the analysis. IAMs continue to evolve, adding components to capture complex interactions between natural and human systems (e.g., between energy, water, and land resources) at finer scales to address questions about the magnitude of economic impacts and the respective roles of adaptation and emissions mitigation in reducing net those impacts.

Using IAMs to conduct BCA in support of policy has generated considerable controversy and discussion, sometimes acrimonious, in both the academic and the policy literatures, not to mention the "blogosphere." The debate has been motivated in large part by concerns about the ethical implications of the model results, and whether moving in the directions suggested by the results – in terms of the magnitude of emissions reductions warranted and subsequent climate change – would lead in the long term to outcomes that are economically feasible, fair in their distributional consequences, and provide a sustainable future for natural and human systems. Of particular concern have been questions of how to treat, in a BCA framework, the more intractable aspects of climate change mentioned above. Other concerns focus on choices made for the analysis – including the choice of emissions baseline, nature of the damage functions, magnitude of the discount rate, method of aggregation across countries – and the extent to which these choices dominate the results.

Weyant identifies five categories of critiques of global benefit-cost analyses: (1) the omission of the potential for abrupt, irreversible, or catastrophic impacts, (2) the treatment of geographic equity, (3) treatment of intertemporal discounting and intergenerational equity, (4) the large uncertainty range in mitigation cost projections, and (5) the appropriate means of analyzing decision making under uncertainty. Many of these critiques stem from challenges similar to those discussed in other papers in this issue. The consequences of ignoring the critiques may not be purely academic: Weyant points out, for example, that SCC estimates can vary substantially – by roughly an order of magnitude – across the models used to estimate SCC, and that plausible ranges of inputs also produce order of magnitude differences. He concludes that the challenges in producing BCA and SCC estimates and the underlying uncertainties suggest the numbers produced by IAMs represent good rough guides to policy development, but will require much refinement over time.

2.2.2 Sectoral impacts in the United States

Neumann and Strzepek (2014) explores a very different – although related – body of literature from that in Weyant's paper. Neumann and Strzepek examine the state of knowledge about economic impacts in the US. Conceptually, economic impacts encompass both the cost of measures to adapt to climate change and the value of residual damages and impacts, after measures to adapt are undertaken. This literature has become increasingly important in recent years because of growing concern about the aggregate impacts of climate change on the U.S. economy and the cost that may fall to federal, state, and local governments to strengthen the ability of sectors (such as infrastructure) to withstand future climatic changes, or to rebuild or restore damaged human and natural systems and lost services. Estimates of economic impacts (reflecting both effectiveness in reducing damages and adaptation costs) can contribute useful information and support the development of adaptation strategies.

Despite interest in the magnitude of projected economic impacts of climate change, no comprehensive estimates are available for the US. Rather, our knowledge of economic impacts concentrates on a few sectors, including agriculture, coastal areas and sea level rise, water resources, some types of infrastructure, energy consumption and production, and (to a lesser extent) crime and health. These sectors tend to have a number of characteristics in common: (1) resources in these sectors are expected to be vulnerable to climate change, (2) the sectors and climate pathways are relatively better understood and can be projected into the future, (3) goods and services in these sectors are largely market-based or market-based proxies for value exist, and (4) impacts in these sectors may involve long-term investment decisions or irreversibilities in outcomes. Consequently, some impact categories, such as ecological services (other than recreation) and effects on cultural icons, have received much less attention. Moreover, even within sectors that are relatively well studied, there may be gaps in the coverage of impacts, inconsistencies in the assumptions about the extent to which adaptation occurs, and significant differences in the climate scenarios that are analyzed.

Neumann and Strzepek focus on the contributions made to the literature by two recent initiatives: the group of studies being produced by the CIRA program (Waldhoff et al., 2014) and the Risky Business report (Gordon, 2014). These studies use internally consistent analytical frameworks to evaluate climate impacts at the sectoral level, but the frameworks are very different. CIRA uses a multi-model framework to systematically assess the risks, impacts, and economic damages from climate change in the US, placing a greater emphasis on detailed simulation models. In contrast, Risky Business assesses climate risks from the perspective of business and the US economy, relying primarily on reduced-form damage functions developed from the results of existing analyses. Together, these studies have expanded our understanding of impacts and adaptation in key sectors, including agriculture, water resources, road infrastructure, and coastal resources.

Neumann and Strzepek identify a number of gaps and challenges going forward that relate to our ability to project climate change impacts, at least some of which are not surprising, given the challenges discussed in Sussman et al., (2014). Collectively, the existence of heterogeneity in impacts, the non-economic nature of some impacts, and the number of sectors and impact categories involved, challenge the estimation of valuation and cost information at a very practical level. Cataloging and aggregating impacts may, for some sectors, involve controversial tradeoffs, such as those between physical effects (e.g., those on infrastructure) and effects on individuals (e.g., health). High-impact events – those for which adaptive measures are particularly needed – are likely the result of projected climate effects about which we know least, such as extreme events, and may be impossible to analyze stochastically.

2.3 Applications of BCA to support adaptation decision-making

National and sectoral climate change adaptation strategies have begun to emerge in the US and other countries in recent years. Li, Mullan, and Helgeson (2014) examines available economic tools to support the development of these strategies and associated, more detailed project-level planning and on-the-ground assessments. The paper also describes some recent developments in BCA of climate adaptation and related applications at the national, sectoral, and local levels in the US and in selected countries of the Organisation for Economic Co-operation and Development (OECD).

Government agencies in both the US and OECD countries have long used BCA to evaluate policies and projects that address concerns similar to those of climate change, particularly hazards and extreme events such as hurricanes and flooding. To date, BCA is used mostly in regulatory analysis and project-level appraisal where BCA is required for policy adoption or public funding. Climate adaptation BCAs are emerging in a variety of contexts, providing support for decisions regarding infrastructure investments, disaster management and natural resource management.

Many of the challenges faced by economists seeking to analyze the costs and benefits of adaptation are similar to those that surface when economists conduct BCA in other contexts. Economists have a long history of identifying and employing best practices for BCA. Such practices are intended not only to improve the quality of the analysis itself, but also to expand its usefulness to decision makers by promoting transparency in methods and output, and recognizing that BCA may be viewed by decision makers as part of a suite of analytical methods. However, the review in Li et al. suggests that the best practices of economic analysis are not fully reflected in the BCA supporting decisions relevant to climate adaptation.

Key challenges to the economic analysis of adaptation measures include our limited understanding of the pathways by which impacts are generated and the effectiveness of adaptation measures. These challenges are exacerbated by uncertainty, which may be particularly great at the regional and local levels where many adaptation actions take place. Both Li et al. (2014) and Neumann and Strzepek (2014) observe that gaps exist in economic analyses of intersectoral effects of adaptation efforts (such as energy and water), as well as feedback effects between these sectors and the broader economy, an area particularly important for national and sectoral adaptation planning. In addition, Li et al. discusses the balance between the depth and complexity of economic analysis and the need to provide economic information to decision makers in different decision contexts, particularly at the local levels and in developing countries where data, capacity, and resource are constrained.

2.4 The role of BCA in decision-making frameworks

Despite the possibility of methodological advances, some aspects of climate change may well remain intractable within the BCA paradigm, or at least controversial, for some time. The most difficult challenges include the presence of deep uncertainty, the debate about how to discount the far distant future, or the treatment of diverse impacts across countries with very different incomes and capacity to deal with climate impacts. In all cases, the question will be how to apply the tools and techniques of economic analysis in ways that recognize the context of the decision or policy, address the needs of decision makers for analytical decision support, and reflect the multifaceted and interdisciplinary aspects of decision making with respect to climate change. These issues are addressed in Toman (2014) and Lempert (2014), both of which reassesses the challenges in applying convention BCA to climate change.

2.4.1 The need for multiple types of information

Toman (2014) explores the issue of aggregation of disparate information. Toman argues that conventional BCA is unable to adequately assess the systemic effects of climate change on ecosystems. The impacts of climate change will be long term, potentially quite large scale and irreversible (evoking loss aversion and concerns about fairness), and inherently "messy" (in the sense of not fitting comfortably into a single system of values). In this situation, standard economic analysis is incapable of capturing all the factors that truly drive choice and preferences. Moreover, the nature of impacts is subject to Knightian uncertainty, further confounding the question of whether economic analysis provides information in a form that reflects how individuals perceive and evaluate climate risks, and thus provides information that can be used in decision making.

The appropriate response to these challenges, Toman argues, is to adopt a multi-criteria approach that recognizes differences in perceptions, values, and how climate change policies and actions are evaluated. These differences in the criteria driving decisions cannot be summarized with a small number of economic statistics, even in cases where the statistics are transparently calculated and presented according to best practice. Shifting from economic to physical indicators is not a complete solution, since it can be as difficult to link physical metrics to potential future human well-being as to use economic values. Rather, he argues that improved information is needed about key aspects of climate change that drive decisions, including the scale and irreversibility of climate change impacts and the speed of change, and a better understanding of how the public perceives climate change risks in comparison with other policy-relevant risks. In addition, non-economic information, such as measures of the change in ecosystem characteristics (as well as measures of economic values of services flows), should complement the application of cost-benefit analysis to climate change.

2.4.2 Leveraging BCA in decision support

Lempert (2014) examines the role of BCA under conditions of deep uncertainty, and explores ways in which BCA can contribute to alternative decision making frameworks. The paper recognizes the importance of BCA results as a critical source of insights for decision makers; at the same time, the author emphasizes the need to incorporate these insights into alternative decision-making frameworks that recognize two key challenges: (1) disparities in worldviews and ethical frames for decision making that are often difficult to capture by aggregating diverse values and costs into a single metric, and (2) the poor choices that can result when uncertainty is viewed as probabilistic, when in fact it is "deep."

The paper argues that a viable approach to these challenges is to reorganize how different components of BCA methodologies are used to inform decision processes. Analytic approaches are emerging that aim to help decision makers manage the challenges by facilitating participatory processes and interactions among analysts and decision makers. Rather than adopting the “agree on assumptions” approach typically used in BCA and a number of other risk management frameworks, these emerging “agree on decisions” approaches defer the agreement on assumptions until decision options have been analyzed under many alternative sets of expectations and values.

One example of such a “reverse process” approach is Robust Decision Making (RDM). This approach stress-tests different policies or plans against scenarios and futures most relevant to the success of the plan or policy. Using simulation models and Monte Carlo analysis, RDM seeks to identify and seek consensus on actions that are robust over a wide range of ethical and epistemological viewpoints. Lempert draws on sectoral case studies to illustrate how it can be possible to apply economic analysis using available science and judgment within alternative processes. The paper finds that, despite the unique challenges of the climate change problem for economic analysis, the core concepts of BCA can effectively be used within alternative analytic frameworks to provide critically important support for a broad spectrum of climate-related decision making.

3 Future directions and research needs

Looking across the papers in this special issue, several common themes become apparent. First is the observation that economic analysis has the potential to play a central role in climate change policy analysis and formulation. A considerable – and varied – body of literature exists on the benefits and costs of climate change globally, nationally, and to some extent at state and local levels. BCA already plays a role in some forms of climate policy making. For example, the tools of BCA have been deployed in estimating the SCC, which is being integrated into U.S. regulations that have climate change implications. BCA and related metrics, such as cost-effectiveness, are being employed in sectoral planning and strategy development (see, e.g., World Bank, 2010). Economic analyses can provide key insights into the extent to which climate change could affect important economic sectors such as agriculture, water resources, infrastructure, and energy, as well as the quality of life. BCA can be a powerful tool to support climate change decision making by informing policy formulation, guiding implementation of adaptation measures and planning, and justifying response actions (i.e., “making the case”).

A second theme across the papers is that certain characteristics of climate change challenge BCA in profound ways. While analysts are familiar with many of these challenges, the extent and sheer number of challenges tend to make economic analysis of climate change somewhat unique. Indeed, there is an active debate on the use of economic analysis for climate change, with one camp arguing that we should try to improve and fix climate BCA and the other holding that climate BCA is hopeless and may even be unethical. It is easy to get caught up in these debates, losing sight of BCA's virtues: its rigor, consistency, and potential for transparency, all of which force a careful weighing of the positive and negative consequences of the policy, program, or project under consideration. Despite the challenges, the papers in this issue make the case that this ability of economic analysis to evaluate alternatives and tradeoffs is vital to climate change decision making. Moreover, while it is important to recognize BCA's limitations in some applications, it is equally important to recognize that the limitations should be viewed relative to the application: one size does not, indeed, fit all.

The third theme is that we need to seriously upgrade our tools and techniques if economic analysis, including BCA, is going to achieve the goal of providing useful information to climate policy and decision-making processes. Climate change throws into stark relief a number of thorny economic issues (e.g., intergenerational discounting, distributional effects, non-marginal valuation) that require fundamental research in order to achieve better treatment in analyses. Moreover, empirical analysis of behavioral and market responses to climate stimuli is an area of active and growing research. Insights obtained from this literature need to be better integrated into climate modeling and assessments in order to enhance our ability to predict climate change impacts and adaptive capacity of socioeconomic systems. Further, economics has a long history of program evaluation, using rigorous empirical methods such as quasi-experiment and randomized control trials. We need to explore the potential of such techniques and empirical evidence to provide important insights into the effectiveness, costs, and benefits of adaptation measures. In addition, the implications of broader market failures, such as water price distortions, perverse land use incentives, and common resource management problems on climate change impacts and adaptive responses are not well understood. More research is needed in this area to help shed light on the interconnections between climate change and other market failures to design policy responses that enhance efficient outcomes.

A fourth theme found in several of the papers is that improving the underlying methods, practices, and components of BCA is not enough. Because of deep uncertainty (i.e., we cannot put probabilities on future outcomes) and conflicting world views, we also need to expand our thinking about BCA itself and explore decision criteria beyond the usual expected benefits and costs. Approaches that have been noted include decision analysis (e.g., RDM) and multicriteria analysis, where physical measures and indicators are used to measure benefits and/or costs. Clearly multidisciplinary teams – economists working with climate scientists and physical scientists to develop impact assessments – will be needed in order to make progress. However, other disciplines, such as sociology, psychology, risk management, and decision science, also need to be part of these teams if they are to be successful in interpreting the data and supporting decision-making processes and institutions. Opening the analytical process to stimulate dialog with stakeholders can present additional opportunities for BCA to play a key role in informing climate change decision making.

It is important to note that application of BCA to climate change is still a relatively new field. More practical experience will allow best practices to emerge as we explore new and creative ways to use economic tools. Drawing on experiences with BCA in other areas and engaging a wider range of economists in climate change analyses can also accelerate the development of the field. To date, economic analyses of climate change have tended to be “one-offs,” where transparency and accessibility have not been a priority. Coordinated efforts, such as the CIRA and Risky Business studies, are critical to advancing our analytic capabilities and knowledge about the impacts of climate change.

The topics covered in this *Special Issue* are of current relevance and will continue to be important for a number of years. As climate impact assessment moves forward, economic analysis in all its forms, including BCA, is likely to play a growing role in decision making, particularly at the level of adaptation plans and strategies. This collection of papers highlights significant challenges in producing analytically sound, helpful economic information on climate change. Nonetheless, opportunities exist for economists, working in new ways (e.g., in multidisciplinary teams, applying new frameworks, engaging stakeholders), to make substantial contributions to understanding and decision making.

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