How Costly is Climate Change Mitigation? A Methodological Critique of the CRAI Modeling Approach

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Introduction

Now that the scientific evidence concerning global climate change is becoming irrefutable, opponents of climate change mitigation legislation are increasingly moving to economic arguments, claiming that such policy would be "bad for the economy." The American Council for Capital Formation (ACCF), the U.S. Chamber of Commerce, and related industry groups have begun a campaign to convince the public that even modest climate change mitigation legislation will impose unbearably high costs on U.S. society (ACCF, 2008; U.S. Chamber of Commerce et al, 2008). For this purpose, they are presenting national and state-level results from an extensive and complex model called MRN-NEEM. This "computable general equilibrium" (CGE) model has been developed by CRA International (CRAI), a large consulting firm funded in part by contracts with the Electrical Power Research Institute, Duke Energy, the Petroleum Institute, and other groups with interests in carbon-intensive energy production.

The MRN-NEEM model used by CRAI is flawed on a number of fronts, and even other leaders in the energy industry are now criticizing its overly high estimates of the costs of the Lieberman/Warner Climate Security Act (Dorschner, 2008). Environmental Defense has pointed out how exaggerated its estimates are compared to other studies, its

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lack of transparency, its lack of consideration of the costs of *in*action on climate change, and its failures to incorporate reasonable assumptions about specific factors such as emissions credits and the banking of allowances (Environmental Defense, 2008).

This document examines the economic modeling methodology behind MRN-NEEM at a more general level, explaining how it relies on highly questionable assumptions and contains profound internal inconsistencies. As economic analysis becomes increasingly important in climate change policy debates, it is important that the public become better informed about what goes into such economic models, rather than being daunted by their apparent sophistication.

The Role of Economics

Policymakers look to economists to advise them about the economic impacts of proposed legislation. Economists, it is assumed, have a real-world knowledge of how prices, markets, taxes, employment levels, production technologies and consumer preferences knit together to create economic outcomes. Many economists create mathematical economic models, of varying levels of complexity, to analyze aspects of economic phenomena.

The MRN-NEEM model used by CRAI to generate its estimates is a Computable General Equilibrium (CGE) model supplemented by additional modeling of energy sector technologies. Many economists use CGE models to derive their economic forecasts. Building these models, however, requires economists to make many working assumptions which empirical research—or even everyday honest observation—show to be very questionable. And while the incredible level of complexity, detail, and mathematical sophistication that goes into the full specification of a CGE model such as MRN-NEEM may make it appear "scientific," such complexity may in fact serve to bury the most crucial assumptions from public scrutiny. This is especially the case with the CRAI MRN-NEEM model, since its proprietary nature shields it from peer review. The mathematical complexity of this model, we will show, serves as a smoke-screen for deliberate and apparently politically-motivated logical inconsistencies, rather than as a guard against them.

Many economists, the authors of this paper among them, find general equilibrium modeling—while useful for some purposes—plagued by internal inconsistencies (Ackerman and Nadal 2004; DeCanio 2003) and often misleading as a general guideline for policy. In particular, we argue that CGE models like MRN-NEEM are particularly poor models for understanding and forecasting the economic impacts of climate change policy. CRAI claims that its model "is based on the theoretical concept of an Arrow-Debreu equilibrium in which macro-level outcomes are driven by the decisions of self-interested consumers and producers as they are in the real economy" (Smith 2007a, Appendix 1, p. 7). While it is true that the model is based on assumptions of Arrow-Debreu equilibrium and self-interest, we strongly contest the idea that this model reflects "the real economy." The general equilibrium model was not built up by economists from careful observation of real world producers, consumers, and markets, but rather from a priori assumptions about individual and market behavior chosen so as to create seemingly elegant and mathematically tractable representations of a fictional, idealized world. In this case, the desire of many economists to emulate the methodologies of geometry and theoretical physics seems to have gotten in the way of a more suitable goal of analyzing economic behavior as it really exists within actual societies (Nelson 2006).

In this next section of the paper, we describe the type of economics which forms the core of the CRAI analysis. We then critique the CRAI analysis for a lack of coherence between its fundamental theoretical approach and the issues presented by climate change, and for its internal inconsistencies.

The General Equilibrium Approach

The general equilibrium economic approach that forms the base for the CRAI analysis prescribes a particular way of viewing the world and formulating a policy problem. These are summarized in the following assumptions:

1. The goal of an economy is the achievement of the optimal (highest) level of consumer utility (well-being).
2. Consumers are self-interested, and each maximizes his or her own utility level. That is, each one's goal is their own highest satisfaction from their own consumption, and they are able to achieve this because they are each fully rational and fully informed.

3. Utility (or consumer well-being) arises from the consumption of goods and services that are bought and sold in markets. (No *non*-marketed contributors to well-being are recognized.)
4. Firms maximize profits. That is, their goal is the largest excess of revenues over costs, and they are able to achieve this because they are able to act as a fully rational and fully informed agent with this single goal.
5. Markets are perfectly competitive and arrive quickly at equilibrium, defined as a situation where the quantity supplied of any good or service is exactly equal to the quantity demanded.
6. The market system is perfectly competitive and perfectly functioning, so that consumer well-being and producer efficiency are maximized given the existing distribution of resources.

These assumptions are often supplemented by three more, concerning economies in the aggregate and how they evolve over time:

7. At an aggregate level, the total market value of goods and services in an economy is given by Gross Domestic Product (GDP). Therefore, higher GDP means higher well-being.
8. In a dynamic economy, consumers choose consumption levels in different periods to maximize the discounted sum of their current and future utility levels.
9. In a dynamic economy, price signals motivate firms to innovate in creating new products desired by consumers, and to design and adopt cost-saving technologies.

Such assumptions form the base of the type of economic theory that is at the heart of the MRN-NEEM analysis.[1] While CGE models are often used by economists for evaluating policy, they make a particularly inappropriate base for evaluating climate change issues because of first, the assumptions made about market failures, and second, the way in which the policy problem is formulated.

The Existence of "Market Failures" is Generally Dismissed

The general equilibrium assumption that markets are perfectly competitive and fully functional is critical to the analysis contained in the MRN-NEEM model. As CRAI itself has stressed, the crucial difference between its findings and those of other analysts who have recommended more strenuous government actions is that "MRN-NEEM assumed perfectly functioning markets" (Bernstein et al. 2007).

This is an ideologically driven assumption that is at odds with the realities of climate change. When markets do not function perfectly, a "market failure" is said to occur. Economists have noted that market failures can be caused by a lack of full

information (about prices, costs, or the characteristics of a good or service), by a price or wage that does not move quickly to equilibrium, and—most importantly—by externalities, which occur when benefits or costs associated with an economic activity are not reflected in any marketized exchange. Global climate change is a classic and oft-cited example of a massive externality, and of the distortions created when a crucial price signal in the economy—the price of fossil fuels—is wrong. Policies such as the Lieberman/Warner Climate Security Act are needed precisely *because* the market does not lead to an efficient, welfare-maximizing outcome in the face of market failures!

CRAI argues that "there is a large body of economic literature that supports the …view that market failures, though present, are relatively small" (Bernstein et al. 2007). Denying the existence of market failures in the case of climate change is akin to denying that the climate change problem even exists. By starting out in a "best of all possible worlds" in which all markets are functioning perfectly, the CRAI analysis, by design, *is guaranteed* to show that the only direction in which government policy can affect the economy is for the worse. By emphasizing market perfection and deciding to exclude any *benefits* from climate change policy, CRAI reveals its inherent bias against acknowledging that there is now a scientific consensus concerning the human causes of climate change and its potential damaging impacts.

Climate Change Policy is Framed as a Marginal Price Change

The problem of climate change mitigation is, in simple terms, framed along the following lines in a general equilibrium framework. Attempts to limit carbon (and other greenhouse gas) emissions through a cap-and-trade program (or a carbon tax) are seen as raising the price of certain types of energy. This will raise the costs of production, and therefore the costs of both energy and produced goods to consumers. To the extent the price increase also lowers profits, it reduces household incomes derived from capital. Consumers will thus pay more for the emissions-intensive goods they consume, and perhaps have lower incomes, leading to welfare loss. Consumers will to some extent substitute away from the goods and services that have now become more expensive, but this rearrangement of their consumption pattern also involves a welfare loss.[2] This sort of

analysis was designed for the evaluation of small (or "marginal") price changes that take place within markets that can be assumed to be otherwise unchanged.

Cost-benefit analysis in an equilibrium framework directly estimates these welfare changes in terms of changes in utility, using sophisticated extensions of what economists label the "welfare triangles" of consumer and producer "surplus" in intermediate economics courses.[3] To make these very technical results more accessible to a lay audience, these utility changes are often rephrased in terms of equivalent losses in consumer income or consumption, or in terms of an aggregate loss in GDP.

Of course, in the MRN-NEEM analysis, only half of a traditional cost-benefit analysis is attempted: The net costs of climate change mitigation policy are estimated, but (having assumed a starting point of "perfect markets") the welfare benefits from the mitigation are not. Meanwhile, the framing of climate change as involving only marginal price changes within an otherwise unchanged economy ignores the depth of the problem. Climate change is a global, serious, and potentially catastrophic problem. Its solution will require deep analysis, flexibility, innovation in institutions, the generation of new goods and new markets, and attention to equity issues, economy- and society-wide, if severe damage to human well-being is to be avoided. Analysis of the subtle well-being effects of marginal price changes within an otherwise unchanged economy, as done in general equilibrium cost-benefit analysis, is simply a tool of a very wrong dimension for dealing with this magnitude of crisis.

Inconsistencies in the CRAI Analysis

Although the general equilibrium approach is a flawed tool for analysis of climate change, at least if the MRN-NEEM model stayed strictly within the traditional CGE framework it would be no more internally inconsistent than other such models. But, in fact, CRAI cherry-picks among possible assumptions, choosing at each point in the analysis those that will show climate mitigation policy in the worst possible light. The result is a model that is fundamentally inconsistent in its approach to market failures, particularly in the areas of employment and technological innovation.

Employment is Treated Inconsistently

This faith in perfectly functioning markets that CRAI has expressed makes its conclusions regarding employment levels quite surprising. In a model that consistently stays within a general equilibrium welfare economics framework, unemployment is *impossible*. CGE models cannot forecast hardship from job losses—the issue most policy makers want clarity on—because supply equals demand in every market, *including the labor market*, by design. In equilibrium, the models assumes, all the people who want to work at the wages being offered will find jobs.

Exactly how CRAI projections of substantial job losses are generated is not well-documented in publicly available descriptions of MRN-NEEM, and a request to Dr. Anne Smith of CRAI for more documentation has gone unanswered. In the 113-page document supplied by CRAI to Senator Lieberman in reference to Smith's testimony before a Senate committee discussing the Lieberman/Warner act, the words "job" and "employment" are each used only once, and no detail is given about how the employment forecasts are made (Smith 2007a). Another document on MRN-NEEM notes that the model can be made to include an "unemployment sticky wage" labor market (a variety of "market failure"), but that "for most of the scenario runs" this is not used (CRA International 2006, 49). The model apparently includes some sector-by-sector calculations of job losses and gains, but this is also not the main driver.[4]

One is left to infer the method used from the CRAI statement that "Naturally, *with reductions in GDP come* reductions in real wages and *job losses*…There is a substantial increase in jobs associated with 'green' businesses (e.g. to produce renewable generation technologies), but even accounting for these there is a projected net loss in jobs *due to the generalized macroeconomic impacts of the bill*" (Smith 2007c, 6, emphasis added). That is, what apparently happens is that:

1. In a first stage of analysis, microeconomic consumer welfare losses are derived from general equilibrium analysis, which assumes full employment of all capital and labor resources.
2. This welfare loss is then converted into the macroeconomic metric of projected reductions in GDP.
3. These macroeconomic projected reductions in GDP (relative to a baseline case) are then converted to reduced employment levels (relative to a baseline case).

The last step is most likely accomplished using some conversion factor derived from historical patterns. Historically speaking, faster GDP growth during booms has been generally associated with faster employment growth, while employment grows more slowly or even falls when GDP grows more slowly or declines, as during recessions. From this pattern a conversion factor from GDP growth to employment growth could be estimated.

Meanwhile, however, the labor force is assumed in the MRN-NEEM model to be growing, presumably at the same rate in both the baseline and policy cases.[5] How are we to reconcile the arrival of same number of new workers in the economy with the claim that the national economy will, in 2020 in the policy case, be offering "3.7 million" fewer jobs (ACCF, 2008)? To envision the economy as being in a recession, with many workers *unemployed*, would violate the (stage one) general equilibrium assumptions of the model. Yet to envision the new workers being *employed* violates the (stage three) macroeconomic prediction that fewer jobs will be available!

CRAI's reasoning is, in fact, incoherent. At a theoretical level, the cause of this incoherence goes back to a root divide within economics, between an ideological loyalty to the general equilibrium model of perfectly functioning markets, and real world observation of—and concern about—economic malfunctions including unemployment. At a practical level, cherry-picking full employment assumptions when they are convenient, but jumping to unemployment assumptions in order to create spurious estimates of job losses, serves the interests of the sponsors of CRAI's study in presenting the highest-cost scenario possible.[6]

One can also note that in the first (CGE) stage of modeling, employment generated by climate mitigation efforts is regarded primarily as a *cost* to the economy: "all 'green' activities …*draw resources from one limited pool* of labor and capital resources available in the economy" (Smith 2007a, 12, emphasis added). That is, since putting people to work retrofitting houses and building wind farms would mean that fewer workers would be available to make autos and serve restaurant meals, consumers are predicted to suffer from a reduction in the production of conventional goods and services. At the third stage, however, employment generation is interpreted as a *benefit*, rather than a cost, relative to the problem of possible unemployment—which, in a twist,

also implies, because of supposed overall employment losses, that climate change mitigation is costly. This classic "heads I win, tails you lose" structure is designed to make climate change policy appear as costly as possible at every turn.

Technology and Innovation are Treated Inconsistently

The costs of climate change mitigation policy are also exaggerated by another divergence from the general equilibrium model, in the area of technology and innovation. CRAI again cherry-picks among assumptions.

Many economists argue that one of the important reasons for bringing the market price of carbon more in line with its social cost (that is, cost including the externality of climate change) is to stimulate investment in the development and deployment of carbon-emissions-reducing technology. The idea that agents will respond to higher costs by coming up with new innovations is supposed to be one of the major strong points of a market economic system. Clearly, the stronger the market response is to carbon price changes, the quicker new technologies can be developed, and the less costly will be climate change mitigation.

Yet technological progress is incorporated in MRN-NEEM by way of a single parameter, "autonomous energy efficiency improvement" (AEEI), that is assumed to capture developments over time. Its value is largely set based on extrapolations from the past. This parameter (in being "autonomous") is generally *not* seen as being particularly sensitive to changes in prices—nor to changes in other policies nor to an increasing awareness of climate problems among business leaders. The link between market price signals and innovation that is part of standard economic theory is all but ignored.

"Placing a price on carbon emissions, …would affect the pattern of private sector R&D," CRAI acknowledges. "However," they claim, "this so-called 'induced-innovation effect' *would be small*" (Smith 2007b, 16, emphasis added). How do they justify this claim? In spite of vociferously arguing that market failures are in general negligible (see above), CRAI turns around and argues that markets *do* fail in the case of technology research and development: "Economic analysis shows that market forces produce a less than socially optimal quantity of R&D" (Smith 2007b, 16).

This technological inflexibility built into the MRN-NEEM model causes the costs of mitigation to be overstated. The assumptions built into the model about the development of renewable energy sources, for example, show very little increase in production and no fall-off in cost over time (Johnson, 2008).

The use of an "autonomous" energy efficiency parameter also results in a rather perverse conclusion being drawn, in many studies that take this approach. Emissions reductions should be put off until the future, such studies conclude, because technological progress that is *assumed* to have taken place by then (without any substantial change in carbon prices or apparent government or business effort) will have (magically) made such reductions cheaper to carry out.

A More Appropriate Approach

The previous sections show that the general equilibrium approach to the modeling of climate change has some shortcomings, and that CRAI further introduces serious inconsistencies in its modeling in order to show mitigation policy in the worst possible light. Their model generally assumes full employment and perfect markets —but only up until the point at which it becomes more convenient to flip sides and assume the opposites, unemployment and market failure.

Economists who find shortcomings in general equilibrium analysis still take markets seriously, and some also use models as a tool for understanding. But we need a more perceptive and responsible framing of the problem of climate change, and a better understanding about how people and markets work, than are provided by the general equilibrium approach.

Climate Change Is Not a Marginal Problem

A more appropriate approach than that of general equilibrium is to think of climate change in the class of issues requiring national mobilizations, such as wars or epidemics. During a war, each military expenditure is not required to prove itself in terms of a general equilibrium analysis of consumer and producer surplus. During World War II, people accepted a great deal of change from their customary lifestyles—rationing, victory gardens, bond drives, and the mass sending of sons and brothers overseas. The

Afghanistan and Iraq wars have hardly been micromanaged relative to welfare optimization. A similar response—in size, though not in direction, and arguably with clearer justification—is required for climate change. Because the problem is global, an even better metaphor might be taken from science fiction: Accumulating greenhouse gases can be likened to an alien race threatening to take over and destroy the earth, so that people from different nations must set aside their differences and fight a common enemy.

This is not to say that climate change policies should be economically stupid. But CGE modeling of small changes, and claims that additional research is needed before action can be taken, amount to fiddling while Rome burns, or attacking a problem that needs a bulldozer with a sewing needle. There are some things we know about how economies work, and about how past government programs have worked, that can immediately inform policy. Inasmuch as many of these real-world facts, moreover, directly contradict the general equilibrium approach, avoiding becoming mired in that mindframe is especially crucial.

People Are Interested in More than Consumption

The general equilibrium approach assumes that people are primarily "consumers," interested only in their own consumption of conventional goods and services. If this were truly the case, then, of course—since the worst impacts of climate change will not be felt for some decades and even centuries—there is practically no climate change problem at all.

The well-being of future generations is downplayed in the CRAI analysis by the practice of putting less weight on future utility than on present utility. Discounting, when extended to long-term models of climate change, means that the long-range future essentially does not matter (see Ackerman and Finlayson 2006; Nelson 2007; Stern 2006). Though discounting does not play a large role in the numerical MRN-NEEM results discussed here given their short, ten- to fifty-year time horizons, it does underlie CRAI's "go slow" policy prescription: "Given that climate change risks are a long-term, cumulative phenomenon and *not a near-term acute concern*, true policy cost-effectiveness will come from a policy that allows a *more gradual* and steady transition to a low-carbon economy" (Smith 2007c, 12, emphasis added). In other words, discounting

prescribes giving priority to our own current consumption desires, even at the expense of further compromises of the environment, and leaving our grandchildren and their grandchildren fend for themselves.

The well-being of poorer citizens of our nation, and of the earth, are also downplayed in general equilibrium modeling. Evaluation of welfare changes in models such as MRN-NEEM works on the principle of "one dollar, one vote"—that is, well-being changes are measured in a money metric based on people's ability to pay. Those with less ability to pay, count less in the analysis. MRN-NEEM goes a step further in glossing over distributional issues by assuming the fiction of a "representative consumer"—modeling the demand side of the economy as though demand comes from a single household.

Optimal mitigation policy should, under the assumptions that people are most interested in their own personal, current consumption, be *no* mitigation policy. Yet this view of economic agents is quite insulting to people as citizens, as members of communities, as parents and grandparents, and as creatures endowed with the capacity for responsible and ethical actions.

Some Changes are Cost-Free or Cost-Saving

The behavior of individual households and firms is also at issue. Because general equilibrium modeling assumes perfection in the baseline case, the only way a policy can change the economy is for the worse. The idea that all agents are already optimizing is often colloquially expressed by the phrase, "There are no dollar bills on the sidewalk." That is, if there were some opportunity for an agent to save on costs or take some other action so as to reach a higher utility or profit level than they currently reach, the model assumes that—being perfectly informed and perfectly rational—the agent will have already have taken advantage of it (i.e., picked up the dollar bill).

Empirical evidence contradicts this, particularly in the case of energy technologies. Activities by groups such as the American Council for an Energy Efficiency Economy and the audit program of the Department of Energy's Industrial Technology Program give evidence that there *are*, in fact, energy dollar bills on the sidewalk. A recent independent study by the McKinsey company, supported by major

players among both energy companies and environmental groups, suggests "almost 40% of abatement" called for in recently proposed legislation in the United States "could be achieved at 'negative' marginal costs" (Creyts et al. 2007). Some studies argue that environmental regulations can, by stimulating innovation, creating positive spillover effects among various activities, and overcoming organizational inertia, actually serve to maintain or improve overall business productivity and profitability (DeCanio, Dibble and Amir-Atefi 2001; Krause et al. 2002; Porter and van der Linde 1995). Such "no regrets" implementations of technologies and processes could make initial attempts at mitigation—far from being as costly as CRAI suggests—free, or even cost-saving. While the "no regrets" options are unlikely to be sufficient in themselves to get the economy all the way to sustainability, they will be very helpful in pushing it in the right direction.

Some industry groups, however, seem more interested in preserving the status quo than in exploring such possibilities. Historically, industry studies of pollution or health and safety regulations, for example, undertaken in protest of proposed legislation, have often predicted steep increases in production costs and sizeable layoffs of workers. The industry studies have often assumed a great deal of rigidity, such that the only options in the face of legislation would be to shut down the offending production processes or install costly current-generation technologies. Government-sponsored studies sometimes make similar assumptions, based on data provided to them by industry. Analysis of *actual* costs and layoffs *post*-regulation however, have frequently found such estimates of costs and job losses to be far overstated (Ackerman 2006; Goodstein 1999). The possibilities of revamping production processes, substituting among inputs, and innovating in technology have often led to far more flexible and cheaper responses than those forecast.

A Plethora of Policies are Available

General equilibrium models focus our attention on prices and markets, and often assume that these are the sole shapers of household and firm behavior. With preferences being taken as "given," agents already assumed to be performing to perfection, and no institutional frictions, only policies that affect price signals are thought to lead to behavioral changes. While policies that use such price and market mechanisms, such as

carbon taxes and cap-and-trade mechanisms, could indeed play an important role in climate change mitigation, focusing on them to the exclusion of other policies simply reflects the biases of the general equilibrium approach.

Policies such as energy audits, demonstration projects, emission standards, efficiency standards, public education campaigns, and the like have often had dramatic success in changing behavior in the past, in efforts ranging from the "green revolution" to household recycling to pollution control to war bond drives. While people pay attention to prices, they also pay attention to what they observe, what is expected of them, what they feel is right or responsible, and the (perhaps changeable and changing) social norms of their community. Institutional rigidities, such as the problem that homeowners and home renters face different incentives, or that credit may not be easily available for profitable projects, can also get in the way of innovation, and be meliorated by policies such as direct provision of services, tax credits, or loan guarantees. And even within market-based policies, the question of distributional consequences should not be ignored.

The Analysis Has to Move Beyond GDP

The argument that climate change mitigation is "bad for the economy" is usually based on the idea that it "will slow GDP growth." CRAI expresses the costs of policy in terms of losses in Gross Domestic Product, or, at the state level, Gross State Product. While changes in GDP or GSP or their growth rates are common currency for expressing the cost of policies, these measures are infamously poor measures of actual human welfare.[7]

While we economists are partly to blame for the popularity of these measures, thoughtful commentators—economists among them—have for decades pointed out that GDP rises with the production of unhealthy or dangerous products. It also rises with expenditures made to defend against harmful events (such as a rise in medical care expenditures for respiratory illnesses following a rise in air pollution). Meanwhile, it fails to account for unpaid work, for the benefits of leisure, for the quality of work or family life, and many other costs and benefits that arise *outside* of market channels. It fails to account for the distribution of well-being across people and—of course, and very relevant to the present discussion—for degradation of the natural resource base of the economy.

GDP is a crude measure of the level of market activity; its iconic status as a measure of the health of "the economy" is not justifiable.

The project at hand is not one of maintaining the economy as close as possible to a fictional perfect-market outcome and optimal future GDP growth path, as imagined in the general equilibrium modeling used by CRAI, but of converting a currently fossil-fuel dependent, high through-put economy to a more sustainable form. Measures such as GDP growth become nearly meaningless in this context, because they simply do not measure the relevant quantities. The *composition, shape, and quality* of future economic activity will be far more important than a contrived measure of its *level*.

The rebuilding of New Orleans after Hurricane Katrina, for example, is an economic activity that has contributed to GDP by enlivening the construction industry. The building and retrofitting of homes to be more energy-efficient would also contribute to GDP by enlivening the construction industry. So we could envision a future in which a particular level of GDP could be reached either by neglecting to address climate change and inviting more of the former sort of economic activities, or by dealing with climate change and shifting resources to the latter sort of economic activities. The level of GDP would be the same, but the policy choices would have very different consequences for well-being.

Or consider another example, raised recently by thoughtful economists working on climate change (Sterner and Persson 2007). At a global level, agriculture currently represents about 24% of GDP. From this, could we reason that a total loss of global agricultural output would reduce GDP by only 24%? Of course not. But by naively assuming that the environmental capacities on which life relies do not play a unique role—that conventional sorts of investment can be easily substituted for degraded natural resources—many GDP-focused models essentially make this assumption.

Because of GDP's popularity, analyses that express costs in terms of reductions or increases in GDP relative to a baseline case may remain politically important for some time to come.[8] One should not, however, be fooled into thinking that this one metric adequately expresses the real effects on human well-being of the policies proposed.

CRAI linked reductions in GDP to reductions in jobs, but here again a more sophisticated analysis is needed. An examination of how the economy could be converted

to a more sustainable structure requires detailed examination of where labor will be released, where it will be needed, and how policy could facilitate these transitions while assuring that the costs do not fall on too narrow a group. Jobs likely to be lost in, for example, coal mining are indeed a hardship to the people involved. But this loss of particular jobs also represents a release of labor made available to other sectors of the economy. "Green" industries are one sector that could boom under climate change mitigation policies, but so too could health, education, and other low-emission intensity services—particularly in light of the needs of an aging population—with the right policy encouragement. Job losses could also be at least partially addressed by retraining, community development, and income support programs. And since climate change is a long-run issue, a broader concern than job losses or changes for currently-employed workers is the question of what kind of jobs the economy *will be creating* in the future. In looking toward the future, the question is very clearly not one of robbing-Peter-to-pay-Paul (since a job cannot be "lost" that is not yet created), but one of choosing a direction. The future gives a new canvas for a qualitatively different economy. But what that economy will look like will depend on what we choose from the palette of investments—and policies—available now.

The Chamber of Commerce and ACCF Uses of the CRAI Analysis

In its portrayal of climate change policy as excessively costly, the CRAI analysis distorts economic reality and cherry-picks among logically inconsistent economic assumptions. There is, however, a further level of distortion and cherry-picking as one moves from the CRAI analysis to the campaign being waged by the Chamber of Commerce, the ACCF, and other related groups.

For example, the Chamber of Commerce sponsors a website with the following message:

> Wake up to Climate Change Legislation!
> November 2007
>
> …On December 5, the Senate will try to move the Lieberman-Warner climate bill through committee and to the Senate floor…

> If this bill becomes law, 3.4 million Americans will lose their jobs. American GDP will decline by $1 trillion. And American consumers will be forced to pay as much as $6 trillion to cope with carbon constraints.*
>
> …Call your Senator …and tell them to vote NO…
>
> **Testimony of Anne E. Smith, Ph.D, before the Committee on Environment and Public Works, United States Senate, November 8, 2007.*
>
> (Chamber of Commerce 2007, emphasis in original)

However, the Chamber of Commerce is clearly more interested in rallying its members to oppose a position it disfavors, than in quoting accurately, as can be seen by comparing its claims with the actual testimony it cites (Smith 2007c, 6):

- *Employment:* The CRAI analysis presented by Smith states that "net job losses" could be *between* 1.5 and 3.4 million jobs by the year 2015. What this actually means is that the model projects that the overall number of jobs will grow, but *grow more slowly*, from 2010 to 2015 if the legislation is adopted, than if it is not.[9] The Chamber of Commerce chose to report only high number as if it were a certainty, and flagrantly misinterprets the study as implying that millions of currently employed "Americans will lose their jobs."
- *GDP loss:* In the CRAI analysis, the projected GDP loss in 2015, the year for which most projections are made, is estimated at $160 to $250 billion. The loss of $1 trillion of GDP cited by the Chamber of Commerce is said in the CRAI analysis to be possible "eventually" (with no date given).
- *Costs to consumers:* While the Chamber's first two statements are at least nominally related to the testimony it cites, there is nothing in the testimony that states or implies that costs to consumers will reach $6 trillion. Much less is it implied that any such costs would come *in addition to* ("and," on the Chamber's web page) the estimated GDP losses, since the testimony presents household spending changes and GDP changes as alternative metrics for representing the same welfare loss.

The Chamber's first two claims are misleading, and the last claim seems to be made up out of whole cloth.

National and state "studies" based on the same CRAI-designed MRN-NEEM model are now being distributed by ACCF. They seem to follow a similar pattern of distortion. Now adjusted to a slightly different range of dates, the ACCF national "study" reports that the "United States would lose 3.7 million jobs in 2020" and production would fall "to 2.6% below the baseline forecast in 2020." Presumably (but again, one cannot check because of the model's proprietary nature) these again cite only the single the extreme ends of the (flawed) model's *ranges* of projections.

Conclusion

How costly is climate change mitigation? It is true that meaningful abatement of carbon emissions and other climate change policies will eventually impose costs, in the sense of requiring people to do less of some activities that we are currently in the habit of enjoying, and removing the need for labor in some sectors that currently generate employment. Even the most optimistic projections about low-carbon technology adoption and innovation do not see these as being enough to substantially meliorate climate problems on their own (Stern 2006). Looking at global equity issues reinforces the argument that, if the costs of climate change are going to be fairly borne by those who primarily created the problem and who have the most ability to pay for the solution, the bulk of mitigation costs should be borne by the residents of industrialized countries (Baer, Athanasiou and Kartha 2007). We actually do not know, however—nor can we know, since the science of climate change forecasting is itself far from exact—exactly what these costs will be. Detailed climate change modeling may, unfortunately, serve in some cases more to give a false sense of precision—and, when politically motivated, as in the case of the CRAI analysis, a falsely overestimated sense of damage to "the economy." Further distortions by groups such as the Chamber of Commerce and ACCF add to this problem.

The question of costs, however, cannot be analyzed in isolation from the question of benefits. The benefit to serious climate change mitigation efforts is, simply, a viable future (Ackerman 2008; Solomon et al. 2007). To *not* take action on climate means to destroy the global (relative) stability of weather patterns—along with many species and low-lying countries—simply to preserve and expand the level of conventional

consumption by the present generation. It is relative to these possibly catastrophic consequences of *in*action, that the costs of action should be evaluated. As one group of economists (including Nobel laureates) has put it, "The most expensive thing we can do is nothing" (Fisher et al. 2006).

We do know that the costs of *in*action are high. We do know that the sooner action is taken, and the more substantial the mitigation achieved, the somewhat more likely it is that the most catastrophic possibilities might be avoided. We do know, from actual studies of industry, consumer behavior, and the effects of past government policies, that a variety of both market-based and regulatory policies could be effective. Economic analysis that is not wedded to the narrow and inappropriate modeling framework adopted by CRAI, and that, unlike the CRAI analysis, is open to public scrutiny, can be helpful in refining the design of policies that redirect the economy along sustainable paths. Desire for such studies, however, should not be taken as an excuse for delaying action--and shifting more of the costs to our grandchildren.

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[1] For example, assumptions about consumer behavior are spelled out as "Consumers are represented as a single representative household that maximizes lifetime utility subject to its lifetime budget constraint. Utility in a given time period is measured by the consumption of goods"(Smith 2007a, appendix 1, p. 9). About firms, they write, "Firms in the model maximize profit subject to technology constraints to determine the level of optimal production" (Smith 2007a, appendix 1, p. 7). Concerning dynamics, the model assumes that "Consumer decisions maximize utility inter-temporally, which implies that an optimal financial trade-off is made between consumption today and consumption in the future" (Smith 2007a, appendix 1, p. 4). The other assumptions can be inferred by CRAI's claim to be building on "based on rigorous microeconomic theoretical foundations" (Smith 2007a, appendix 1, p. 1).

[2] See Smith 2007a, appendix 1, p. 15.

[3] Non-economists are often puzzled by why this somewhat arcane analysis is necessary. "Isn't the cost to consumers of higher gasoline prices, for example, just equal to the amount extra that they will end up paying?" one might ask. The more elaborate analysis is thought to be necessary because it is likely that the price change will change consumer behavior—the amount of gasoline bought by consumers will go down when the price of gasoline rises. Estimating the cost to consumers by assuming that consumers will pay the new (higher) price for the quantity of gasoline they *used to* buy would tend to overstate the cost, since consumers will find ways to use cheaper substitute goods (e.g. different fuels or public transportation) to cover some of their needs. On the other hand, assuming the cost is just the extra amount consumers are paying for gasoline, once they have *reduced* their gasoline purchases, will tend to understate the cost, since it ignores the fact that consumers somewhat preferred purchasing gasoline to their other options. Welfare economics provides sophisticated methods for splitting this difference. (In its simplest form, each market is considered separately in a "partial equilibrium" framework, and the solution involves cutting an additional-expenditures-rectangle in a demand curve graph in half diagonally, creating a "welfare triangle" that is half the rectangle's size. In more advanced analyses, concepts of "compensating variation" or "equivalent variation" are used to convert welfare changes into monetary terms within a framework of "general equilibrium.") Unfortunately, in focusing on trying to clearly characterize such subtleties of consumer (and producer) responses to price changes, this style of analysis may contribute to larger issues of much greater concern to citizens being neglected.

[4] Presumably, for example, because of the high carbon emissions of coal-fired electricity generation, coal mining will be one the industries hardest hit by carbon mitigation efforts in the coming few decades. While hardship caused to workers in the industry should certainly be of concern to policymakers, there are presently only 78,600 coal miners in the United States (U.S. Bureau of Labor Statistics 2008). This is a far cry from the millions of jobs estimated to be lost, on net at a national level, in MRN-NEEM.

[5] See "labor, which grows exogenously" (Smith 2007a, appendix 1, p. 9). The only way in which projections of both *full* employment and *reduced* employment can be made logically consistent is if the labor force is projected to shrink. This is sometimes incorporated in economic modeling by forecasting a falling wage, and assuming that if the wage goes below some level some people will decide it is not worth it to work and will exit the labor force—or "choose leisure" in economists' lingo. This does not seem to have been used to generate the MRN-NEEM results. If it had been, then the results should have been presented as a forecasted reduction in *workers*, rather than in *jobs*. It is also unclear what the policy implications of such a scenario would be: People would be voluntarily leaving the workforce in order to take vacations or spend more time with their families. This quite different from the unemployment problem that concerns policymakers, which is about people wanting to work but being unable to because of a dearth of employment opportunities.

[6] It is rather disingenuous, then, for CRAI to, in a discussion of models, claim that a particular suggestion "would…creat[e] an internal inconsistency within our analysis—which is exactly what using models is supposed to help analysts avoid" (Bernstein et al. 2007).

[7] The use of GDP per person may be justifiable as a very rough indicator of well-being for low to lower-middle-income countries, where increases in GDP per person are often associated with higher performance on indicators such as life expectancy and infant mortality. Above a subsistence level, however, evidence for interpreting differences in GDP as indicative of differences in well-being is lacking.

[8] The British Stern Review on the Economics of Climate Change (Stern 2006) which recommends immediate and substantial action, for example, uses a GDP metric to come up with a punchy executive summary.

[9] The CRAI high estimate of job loss as given in the Smith testimony (Smith, 2007c) is 3.4 million jobs lost in 2020, relative to a baseline case. Their starting period is 2010, meaning they analyze a 10-year period. They do not report their estimated employment growth is for their baseline case. While not for quite the same time period, the United States Bureau of Labor Statistics projects that employment will grow from 144.4 million to 155.9 million in the ten years from 2006 to 2016, or an increase of 8.5 million jobs (Franklin 2007). If the baseline case growth of employment in the CRAI model can be assumed to be roughly similar, then CRAI would predict that jobs would *grow by only* 5.1 million, rather than by 8.5 million, in the worst case.