The Florida Economy and a Federal Carbon Cap

A QUANTITATIVE ANALYSIS

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Contents

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Executive summary

Since 2007, Florida Governor Charlie Crist has pursued a series of bold statewide initiatives to bring down Florida's greenhouse gas emissions. In late 2008, the Governor's Action Team on Energy and Climate Change unanimously recommended that Florida "advocate for" a "strong national cap-and-trade program" as the best way to take effective action against climate change.

This paper uses state-of-the-art economic modeling techniques to assess the impact of a national cap-and-trade program—the policy recommended by Governor Crist's Action Team—on the Florida economy over the coming decades. The model looks at the entire Florida economy on an interactive basis over time, and takes into account complex interactions between different sectors of the economy.

Under a cap-and-trade program, utilities and other large emitters would need to acquire "allowances" for their emissions of carbon dioxide and other greenhouse gases. The U.S. Environmental Protection Agency has developed expert estimates of the likely future prices of these allowances, based on the bill approved by the House Energy & Commerce Committee in May 2009. The analysis discussed here incorporates those consensus price estimates and evaluates their impact on the Florida economy.

The analysis done here is conservative: among other things, it pessimistically assumes that putting a cap on carbon will not prompt any extra technological (or business) innovations in how we produce and use energy. The history of regulating air pollution since 1970 tells us the opposite: that as the old proverb about necessity and invention tells us, legal limits on pollution are a huge spur to technological creativity.

But even with that conservative assumption, the analysis shows that Florida's economy can readily adapt to a cap on carbon: Florida's economy grows from $809 billion in 2008 to nearly $1.5 trillion in 2025 in both the Baseline and the Cap-and-Trade scenarios. The difference in Florida's Gross State Product in 2025—that is, the difference between $1.472 trillion (Baseline) and $1.466 trillion (Cap-and-Trade)—is less than the Baseline state growth over two consecutive months. In other words, with a strong federal cap-and-trade regime, Florida's economy would hit $1.472 billion in February 2025, or only eight weeks later than under the Baseline scenario.

The analysis is conservative in a second way as well: it does not take into account the costs of *inaction*—that is, the additional costs (for example, for reconstruction after hurricanes) that Florida will incur in coming decades if the United States fails to take action to fight climate change. We do, however, provide some useful data about those costs from other researchers.

In short, this new study shows that Florida's economy can thrive under the national cap-and-trade policy recommended by Governor Crist's Action Team.

Introduction

Florida Governor Charlie Crist has, in cooperation with the Florida legislature, businesses, and environmentalists, launched a bold climate action initiative. In 2007, Governor Crist issued three Executive orders aimed at reducing the state's carbon footprint,[1] with the overall objective of returning the state to 1990 greenhouse gas ("GHG") emission levels by 2025. One of those Orders created the Governor's Action Team on Energy and Climate Change, which was charged with developing a statewide plan to address those issues. The Action Team's final report, released in October 2008, contains dozens of recommendations for ways of addressing climate change. A central theme of the final report, however, is this:

> *First and foremost,* a strong national cap-and-trade program is the preferred method for achieving substantial reductions in GHGs*, and Florida should advocate for a national program.*[2]

Since the Governor's Action Team has identified a national cap-and-trade program as the best way to reduce greenhouse gases, this report analyzes the likely impact of such a program on the Florida economy. We go on to discuss certain important factors—including entrepreneurship and innovation—that are difficult to capture in economic modeling, but that are important drivers of economic growth. Finally, we compare the likely economic effects of a national cap-and-trade policy to the economic impact on Florida of *inaction*, such as the costs of recovering from stronger and more frequent hurricanes and losses of tourism from excessive heat.

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Florida Governor Charlie Crist with Colorado Governor Bill Ritter at 2009 Governors' conference on energy.

Background

Cap-and-trade programs

Traditionally, governments have limited emissions of pollutants through "command and control" regulation—national or state limits on the amounts of pollutants that particular companies may emit. Implementing long-standing recommendations by economists, the United States began, almost two decades ago, to experiment with an alternative approach: imposing a cap on emissions by entire industries, requiring firms to obtain permits (or "allowances") to make a certain amount of emissions, and then allowing firms to buy and sell permits from one another. Economic theory predicts that trading will reduce compliance costs, because firms whose options for reducing emissions are costly can buy permits from firms that can reduce emissions more cheaply. Over time, the government reduces the total volume of permits that are available each year, thereby reducing overall emissions levels.

This new approach—called cap-and-trade—was implemented in the 1990 Clean Air Act Amendments Act, which was designed to attack the pollutants (such as sulfur dioxide) that create acid rain. As it turned out, cap-and-trade was highly successful in reducing acid raid pollution, and at a lower cost than predicted when the program was designed.

Although cap-and-trade is not a good choice for pollutants that may create local "hot spots," such as mercury, it is a good fit for greenhouse gas pollutants such as carbon dioxide, which do global, not local, harm. For that reason, many have advocated adoption of a cap-and-trade system for greenhouse gases at the national level, or, failing that, at a state or regional level. Indeed, Florida's Energy, Climate Change, and Economic Security Act, signed by Governor Crist in June 2008, calls for development of a plan for Florida to join a regional GHG cap-and-trade system. And several states have already joined regional GHG alliances, such as the Regional Greenhouse Gas Initiative ("RGGI") and the Western Climate Alliance ("WCI").

As the recommendation from Governor Crist's Action Team makes clear, however, a patchwork of regional GHG cap-and-trade systems is much more cumbersome—and less likely to be effective—than a uniform, national system. For that reason, the Action Team urges that "there should be a strong federal cap-and-trade program and . . . Florida should be an advocate for national action."[3] In addition, as the trading pool (i.e., the number of sectors and companies under a cap-and-trade system) becomes larger, the gains from trade in the system grow as well.

In most proposals for a national cap-and-trade system for GHGs, the federal government would limit emissions by the largest sources of GHGs, such as electric (and natural gas) utilities, manufacturers, and fuel producers. These sectors collectively produce the vast majority (roughly 80 to 85%) of GHG emissions nationally. Other sectors, such as agriculture, would not be subject to the cap, but could sell "offsets" to covered businesses if they show they have eliminated emissions they would otherwise have made. For example, a coal-fired power plant might purchase offsets from an agricultural facility that has begun capturing methane—a highly potent greenhouse gas—from animal wastes. Because agriculture is not covered by the cap-and-trade program, the result, if the offset meets relevant quality criteria, is that total GHG emissions are reduced. Both the European Union Emissions Trading

Scheme (EU ETS) and the Regional Greenhouse Gas Initiative (RGGI) allow offsets to be used to some extent.

Because cap-and-trade policies are market-oriented, they enable flexible, price-directed allocation of pollution rights and decentralization of innovation decisions. Both these characteristics of cap-and-trade contribute to more efficient structural transition and adaptation of the economy to the need to sharply reduce CO_2 emissions.

To reduce GHG emissions, a cap-and-trade mechanism like the one modeled here relies on private actors to make the relevant choices: the newly created carbon market offers firms the choice between reducing emissions, for example, through investing to increase efficiency, or purchasing increasingly expensive pollution rights to cover their emissions. Economists believe that a cap-and-trade system will be more efficient than command and control systems, which have high monitoring costs and can lead to mandatory investments in less-than-optimal solutions.

The task: predicting how a national GHG cap-and-trade program would affect the Florida economy

A variety of studies have used economic models to project the likely impact of a GHG cap-and-trade system on the *national* economy. Although the models vary in their detailed predictions, the consensus is that even a strong cap-and-trade program would have only a very small impact—about ½ of 1%—on household consumption nationally.[4]

Economists working for Governor Crist's Climate Action Team have developed their own set of projections, looking at the effects of a variety of measures *other* than a carbon cap, such as tougher fuel efficiency standards, renewable portfolio standards for utilities, and incentives for utilities to help their customers reduce energy use. The Action Team found that some of these measures would actually result in net savings to Floridians, while others would result in (typically a modest) net cost.[5]

The purpose of the present study is different: to evaluate the impact on Florida's economy of a national cap-and-trade program.

Research economists are developing assessment tools to support more effective design and evaluation of policy proposals, such as cap-and-trade. Some tools focus on particular industries, or take a "bottom-up" look at economic activity. Here, we use a different approach, relying on a detailed and dynamic economic simulation model that traces the complex linkage effects across the Florida economy of policy choices and external conditions. This type of model is called a calibrated general equilibrium, or "CGE," model. By contrast, a partial equilibrium model analyzes a specific sector of the economy without attempting to examine its linkages to the rest of the economy—essentially, holding the remainder of the economy constant.

The specific CGE model used here is the Berkeley Energy and Resource ("BEAR") model. BEAR has already been used to produce estimates for the California Environmental Protection Agency, as well as the California Air Resources Board, the implementing agency for California's Global Warming Solutions Initiative. Because of the high level of institutional detail captured by the BEAR model and its database, it can be applied to a broad spectrum of policy scenarios. And because it determines prices and emission levels dynamically and endogenously, BEAR also captures policy interactions that would be lost in partial equilibrium, static, or sector-specific analyses. ("Endogenous" means that a price is determined by the operation of the model, as opposed to an "exogenous" price that is externally determined.) Indeed, the model was designed to examine the detailed market and incentive properties of a new generation of climate action policies.

Rigorous policy research tools like the BEAR model can shed important light on the detailed economic consequences of energy and climate policies. By making it possible to observe—within a simulation—both direct and indirect effects across a broad spectrum of stakeholders, a CGE exercise can help policy makers develop more effective policy responses to climate change. For example, although most direct (adoption and monitoring) costs of a cap-and-trade regime are easy to identify, the economic effects of that regime extend over long supply and expenditure chains, the cumulative impact of which can best be assessed with methods like that used here.

To assess the economic effects on Florida of a federal cap-and-trade policy, we use the BEAR model to forecast the policy's contributions to greenhouse gas reduction by Florida firms and other economic and social indicators. By running the model with different design characteristics, better practices can be identified, as well as special adjustment needs for individual stakeholders. Initial conditions, such as varying allocation/auction rules and cap phase-ins, can be compared across explicit annual time paths. BEAR can also be used to assess the effects of dynamic policy components, such as sequencing, banking, safety valves, and adjustment paths. Equity effects of policies, such as energy price changes, also warrant attention, and the explicit distributional information in BEAR captures this. While the researchers who developed and implement the BEAR model do not advocate particular climate policies, their primary objective is to promote evidence-based dialogue that can make public policies more effective and transparent.

Crucially, an economic model such as BEAR does not predict that the economy will in fact follow a specific path—for example, that the Gross State Product of Florida will grow by a particular amount between now and 2025. Rather, the principal contribution of economic modeling is to enable a *comparison* between the outcomes predicted for varying sets of policies.

How a CGE model works

Somewhat like a highly sophisticated version of The Sims, a CGE model seeks to simulate the functioning of a complex market economy, containing many different buyers and sellers of many different goods and services, over an extended period of time. In technical terms, a CGE model is a system of simultaneous equations that simulate price-directed interactions between firms and households in commodity and factor markets. ("Factor" means capital or labor used to create goods and services.) The roles of government, capital markets, and other trading partners are also specified, with varying degrees of detail, to close the model and account for economy-wide resource allocation, production, and income determination.

The role of markets is to mediate exchange, usually with a flexible system of prices, the most important endogenous variables in a typical CGE model. As in a real market economy, changes in the prices of goods and services lead to changes in the level and composition of supply and demand, production and income, and the other endogenous variables in the system.

The Seminole Theatre in Homestead, Florida, part of the service sector reflected in the BEAR economic model.

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In CGE models, an equation system is solved for prices that correspond to equilibrium in markets and satisfy the accounting identities governing economic behavior—for example, that the price paid by a buyer must be the same as the price accepted by the seller. If such a system is precisely specified, equilibrium always exists, and a consistent model can be calibrated to a base period data set. The resulting calibrated general equilibrium model is then used to simulate the economy-wide (and regional) effects of alternative policies or external events.[6]

What distinguishes a general equilibrium model is that it is a complete economic system, which includes all activities in the economic world under study. By contrast, in a more traditional partial equilibrium analysis, linkages to other domestic markets and agents are deliberately excluded from consideration. One benefit of looking at the entire economy—rather than simply one piece of it—is that it exposes indirect effects (e.g., upstream and downstream production linkages) that may be both substantial and unexpected. Indeed, in a multi-country model like that used here, indirect effects include trade linkages between countries and regions, which themselves can have policy implications.

The model we use for this work has been constructed according to generally accepted specification standards, implemented in the GAMS programming language, and calibrated to the new Florida Social Accounting Matrix ("SAM") estimated for the year 2003. The result is a single economy model calibrated over the 18-year time path from 2008 to 2025.

The two scenarios: baseline vs. cap-and-trade

The heart of this study is a comparison between two scenarios: a baseline scenario in which the United States does *not* adopt a national cap on greenhouse gas pollution and a cap-and-trade scenario in which the nation does adopt that policy.

The baseline scenario: business as usual

The initial scenario we examine is a calibrated Baseline for the BEAR model, taking explicit account of state projections of economic activity and anticipated improvements in state energy efficiency over the period 2008–2025. The Baseline relies on the official Gross State Product (GSP) growth rates published by the U.S. Bureau of Economic Analysis (www.bea.gov).[7] As to energy use, the baseline scenario—unlike some models that ostensibly reflect "business as usual"—does not assume that there will be no further improvements (absent a carbon cap) in Florida's use of energy. Rather, the Baseline makes the more optimistic assumption that Florida will continue—as it has in the past—to achieve annual improvements of 1.4% in the energy efficiency and emission intensity of GSP. This Baseline is then used as the basis for comparison with the alternative model described below, which incorporates a federal cap-and-trade policy.

What type of cap-and-trade policy should be used in the alternative scenario?

There are a number of policy options in designing a cap-and-trade program. The most important choice is one discussed above: we assume a national, rather than a Florida-only or regional, cap-and-trade system. In a Florida-only model, the price of carbon would be determined by the forces of supply and demand within the model. In a national cap-and-trade system, however, the price of carbon is determined in a national marketplace and as a result, here, the price of carbon is an exogenous (externally determined) input to the model.

In the Cap-and-Trade scenarios, the model assumes prices of approximately $7, $9, and $12 per metric ton of CO_2 equivalent in 2012, gradually rising in future years.[8] This set of low, mid-range, and high price estimates is based on economic analyses by the Environmental Protection Agency of the American Clean Energy & Security Act ("ACES"), approved by the House Energy & Commerce Committee in May 2009.[9] The bill provides for a reduction in GHG emissions by about 83% from 2005 levels by 2050. To achieve that result, ACES calls for a gradually tightening cap on carbon starting in 2012; a gradually increasing percentage of allowances that are auctioned (rather than given away); unlimited banking; borrowing of future compliance obligations (at 8% interest) for periods no more than five years in the future; and domestic and international offsets usable to cover up to two billion tons annually.

Table 1 shows the low, medium, and high prices derived from the EPA report. These provide our reference permit prices for Florida's participation in a national trading system.

TABLE 1

Consensus permit prices for a U.S. national cap-and-trade program (current USD per MMTCO$_2$e, based on 2009 American Clean Energy and Security Act)

Year	ADAGE[a]	Average[b]	IGEM[c]
2008	$ 0.00	$ 0.00	$ 0.00
2009	$ 0.00	$ 0.00	$ 0.00
2010	$ 0.00	$ 0.00	$ 0.00
2011	$ 0.00	$ 0.00	$ 0.00
2012	$ 6.90	$ 9.28	$11.66
2013	$10.35	$11.30	$12.25
2014	$13.80	$13.33	$12.86
2015	$17.25	$15.38	$13.50
2016	$18.25	$16.21	$14.18
2017	$19.24	$17.07	$14.89
2018	$20.24	$17.94	$15.63
2019	$21.24	$18.83	$16.41
2020	$22.24	$19.74	$17.23
2021	$23.45	$20.77	$18.10
2022	$24.67	$21.83	$19.00
2023	$25.88	$22.91	$19.95
2024	$27.09	$24.02	$20.95
2025	$28.31	$25.15	$22.00

[a] Prices from EPA ADAGE model.
[b] Average of prices from ADAGE and IGEM models.
[c] Prices from EPA IGEM model.

What's not in the scenarios

Although the BEAR model allows us to take a highly detailed, interactive look at the impact of a carbon cap on the Florida economy, it errs on the side of conservatism in at least two ways: it does not reflect the net additional impacts of climate change in the Baseline model, and it does not include any factor for innovation stimulated by putting a price on carbon.

The model does not take into account the costs of climate change in the baseline model

Like most climate policy assessments to date, the Baseline scenario does not include the cost of damage associated with either inevitable or avoidable climate change over the period in question (through 2025). In reality, climate change is likely to result in a wide variety of costs to the Florida economy, including, most dramatically, the costs of reconstruction after stronger and more frequent hurricanes. The economic impact of climate change is, however, the subject of a separate study by other researchers, who estimate some of the net economic costs that Florida will incur if the United States proceeds with business as usual on greenhouse gas emissions. We summarize these findings below, but the present analysis is focused only on economic impacts of mitigation strategies.

The cap-and-trade scenario does not assume any increase in innovation triggered by putting a price on carbon

As earlier noted, both the Baseline and the Cap-and-Trade scenarios assume that Florida will achieve annual improvements of 1.4% in the efficiency with which it uses energy. To be conservative, however, we do *not* assume that putting a price on carbon will prompt higher levels of efficiency improvements. As discussed in more detail below, the assumption that there would be no "induced innovation" is unrealistic, particularly in the context of unprecedented new policies to achieve GHG mitigation. Given the evidence on innovation-growth linkages, particularly in the context of energy efficiency, this means that the comparison between the Baseline and Cap-and-Trade scenarios probably understate the economic growth potential of climate action.[10]

Results

For the scenarios considered, two salient findings emerge from this analysis:

1. Aggregate real effects of national participation on the Florida economy are negligible

A comparison of the Baseline and the Cap-and-Trade scenarios shows that, even ignoring the costs of inaction and induced innovation, the growth cost of a federal cap-and-trade program is very modest.[11] Specifically, even assuming technological neutrality and no complementary policies, the growth cost of a federal cap-and-trade program would be very small—less than 1/2 of 1%—of baseline real output by 2025.

As Table 2 reveals, personal income and employment decline by between .2% and .4% (depending on the assumed national price of carbon allowances),[12] and Florida's real Gross State Product ("GSP") declines only .3% or .4% by the terminal year (2025). That is, in both the Baseline and the Cap-and-Trade scenarios, the model shows that Florida's economy will grow from $809 billion in 2008 to nearly $1.5 trillion in 2025. The difference in Florida's Gross State Product in 2025—that is, the difference between $1.472 trillion (Baseline) and $1.466 trillion (Cap-and-Trade)—is less than the Baseline state growth over two consecutive months.[13] In other words, even with a strong federal cap-and-trade regime, Florida's economy would achieve its climate action objectives by December 2025 and the same level of growth as the Baseline scenario only about 8 weeks later—by the end of February 2026.

TABLE 2

Macroeconomic effects for Florida in a national cap-and-trade scenario (percent change from baseline in 2025 unless otherwise indicated)

	Scenario		
	1	2	3
Real GSP	–0.3%	–0.4%	–0.4%
Personal income	–0.4%	–0.4%	–0.4%
Employment	–0.2%	–0.2%	–0.3%
Emissions	–22%	–34%	–43%
Emissions (MMTCO$_2$e)	321	273	235

2. Individual sector demand, output, and employment (economic structure) can change more significantly—but changes are still modest over two decades

Energy fuel and carbon-capped sectors can experience important adjustments, but these are offset by expansion elsewhere, including in the Services, Construction, and Consumer goods sectors. The Florida economy is seen undergoing an important structural adjustment, reducing aggregate energy intensity and increasing the labor-intensity of state demand and output. These shifts, masked at the aggregate level, may present opportunities for policy makers to mitigate adjustment costs. The task for Florida policy makers in the near term will be to design policies that fairly and efficiently distribute the costs of reducing greenhouse gas emissions.

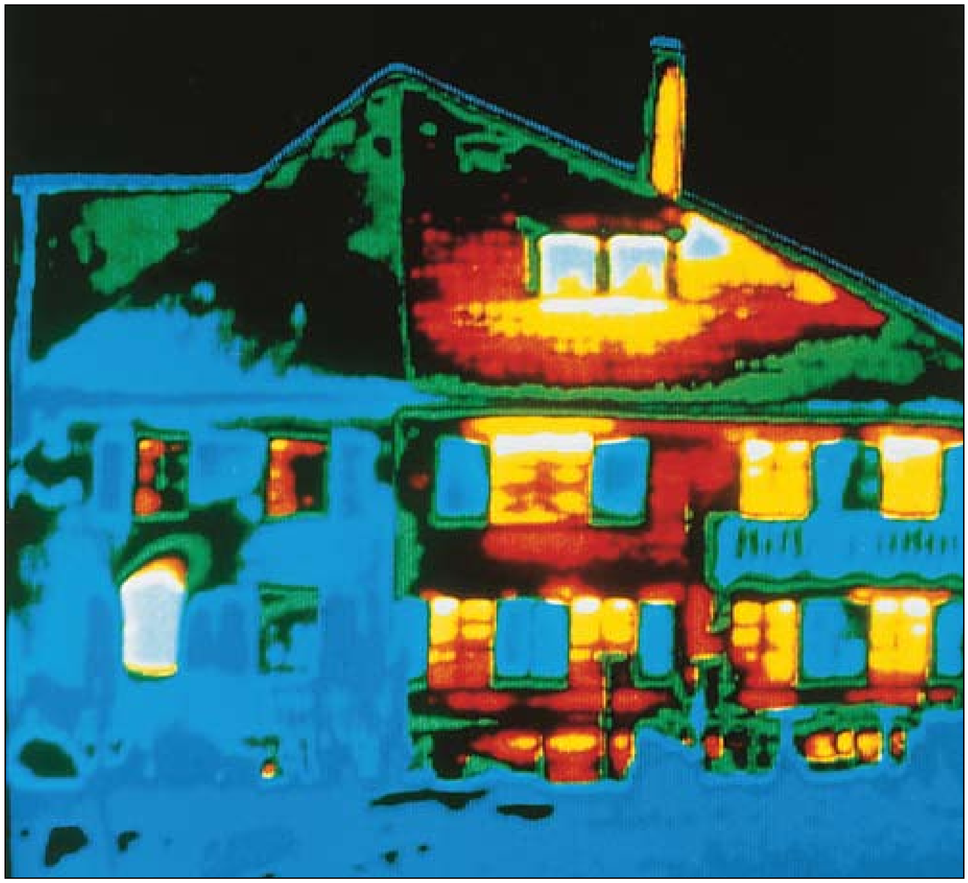
Sector adjustments are exemplified by the employment changes shown in Table 3 below. To put these effects in context, we include a fourth column showing baseline growth for each sector over the entire period examined. By comparison to the growth fundamentals of the Florida economy, the effects of climate action are quite small. If these effects were compared to the amount of climate damage, these effects would be far outweighed.

TABLE 3

Sectoral employment changes (percent change from baseline in 2025)

	Scenario			Baseline
Sector	**1**	**2**	**3**	**2005–2020**
Agriculture	−1.32%	−1.32%	−1.33%	97%
Cattle and dairy	−0.93%	−0.93%	−0.93%	77%
Forestry	−0.60%	−0.54%	−0.50%	78%
Oil and gas	−2.19%	−2.40%	−2.60%	63%
Electric power	−1.10%	−1.26%	−1.40%	89%
LNG and gasoline	−0.82%	−0.97%	−1.09%	109%
Construction	−0.13%	−0.14%	−0.15%	59%
Food processing	−0.48%	−0.49%	−0.50%	71%
Oil refining	−0.80%	−0.88%	−0.95%	55%
Chemicals	−0.70%	−0.72%	−0.74%	75%
Cement	−3.91%	−4.10%	−4.28%	58%
Air conditioning and refrigeration	−0.18%	−0.09%	−0.02%	33%
Other industry	−0.36%	−0.32%	−0.29%	60%
Wholesale and retail trade	−0.21%	−0.24%	−0.27%	86%
Air transport	−3.80%	−4.05%	−4.30%	90%
Ground transport	−2.51%	−2.76%	−2.99%	102%
Water transport	−0.65%	−0.60%	−0.56%	79%
Truck transport	−0.87%	−0.97%	−1.06%	94%
Waste services	−4.36%	−5.90%	−7.21%	100%
Other private services	−0.10%	−0.13%	−0.15%	86%
Statewide	−0.22%	−0.25%	−0.27%	82%

Thermal image showing energy leakage from building.



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While total state employment changes by about the same magnitude as real GSP, some sectors are more strongly affected than others. In particular, sectors with high prior emissions, such as energy products, transportation, and waste services, all grow less quickly in the Cap-and-Trade scenario than in the Baseline scenario. Every sector expands over the time period considered, but the more emission-intensive sectors expand at a lower growth rate. Of course, this is precisely what is meant by a lower-carbon future, as aggregate GSP moves to lower emission intensity by shifting the composition of output.

Generally speaking, the Florida economy can reduce GHG emissions in three ways: reducing overall BAU growth (the least attractive option), shifting the structure of production toward less pollution-intensive activities (as observed here), or adopting new technologies to reduce emission intensity of existing activities. Because more than 80% of GHG emissions arise from energy use, energy efficiency is the most important form of technology adoption here.

Putting the results of the CGE model in perspective

What the economic model doesn't take into account (I): innovation spurred by price changes

Like mercury and sulfur dioxide, greenhouse gases such as carbon dioxide, methane, and nitrous oxide are pollutants. When firms can freely emit pollutants without regulation or penalties, the incentives to reduce these emissions are limited or non-existent. But once the government requires that the costs of pollution be internalized—such as through a cap-and-trade program—firms have a new set of incentives to reduce their emissions.

A substantial amount of literature suggests that the American economy is highly responsive to such incentives. Since enactment of the Clean Air Act in 1970, for example, U.S. utility and manufacturing companies have proven to be innovative in finding ways to reduce pollution without reducing productivity. In part as a result of such innovation, the total benefits of Clean Air Act programs from 1970 through 1990 were (according to a peer-reviewed study) between \$6 trillion and \$50 trillion, while the costs of achieving the pollution reductions were only \$523 billion.[14]

PHOTO COURTESY NASA

Hurricane Jeanne over Florida (2004).

Government-imposed limits on pollution have led the creation of entirely new industries, such as the firms that design and manufacture products like catalytic converters (to reduce automobile pollution) and scrubbers (to reduce industrial pollution). In addition, U.S. industry has proven responsive to "technological forcing" by the EPA under various provisions of the Clean Air Act.[15]

Although the current economic downturn is taking a serious toll on the economy, investment in "cleantech" has been among the fastest-growing targets of the U.S. venture capital industry. There is every reason to expect that private investment for this category of innovation will accelerate sharply once a price on carbon emissions has been established.

None of this "induced innovation" is reflected in the Cap-and-Trade scenario, which pessimistically assumes that firms required to purchase pollution allowances will make only the same very modest progress in reducing their GHG emissions (for example, by improving energy efficiency) that they have made in the past.

While we have conservatively elected not to assume that Cap-and-Trade will induce innovation over and above that experienced during the period when GHG emissions were unregulated, it is likely that innovation and entrepreneurship will lead to economic results better than those shown in the Cap-and-Trade scenario. However, CGE models are not set up to "guess" innovation rates and therefore any exogenous assumption on this issue could be seen as creating a bias in the model, which we seek to avoid here.

What the economic model doesn't take into account (II): losses caused by climate change

In this report, we compare the projected economic outcomes of a business-as-usual scenario and a Cap-and-Trade scenario. But the scenarios are inaccurate in at least one important sense: they do not factor in the economic impact of the effects of climate change over the period being modeled.

An emerging body of literature indicates that these costs are likely to be substantial. In particular, a 2007 report by Elizabeth Stanton and Frank Ackerman of Tufts University, *Florida and Climate Change: The Costs of Inaction*,[16] contains the following estimates for net economic costs to Florida from climate change over the coming decades:

TABLE 4

The costs of inaction (in billions of 2006 dollars, except percentages)

	2025	2050	2075	2100
Tourism	$ 9	$40	$ 88	$167
Hurricanes	$ 6	$25	$ 54	$104
Electricity	$ 1	$ 5	$ 10	$ 18
Real estate	$11	$23	$ 33	$ 56
Summary: costs of inaction	**2025**	**2050**	**2075**	**2100**
in billions of 2006 dollars	$27	$92	$184	$345
as % of projected Florida GSP	1.6%	2.8%	3.9%	5.0%

Sum of entries may differ slightly because of founding

These substantial net harms to the Florida economy from climate inaction are *not* included in the Baseline model. To that extent, the CGE model we use here overstates the net difference between the Baseline and Cap-and-Trade model.

Of course, many impacts of increased greenhouse gas concentrations in the atmosphere take years or decades to have their full effect. As a result, for relatively short time periods—such as through 2025—some of the harmful impacts of climate change are likely to occur even if a federal cap-and-trade program were to be adopted immediately. It would therefore be inappropriate to attribute all of the economic costs of climate change during the period in question (through 2025) to the Baseline scenario, and none to the Cap-and-Trade scenario. The *Costs of Inaction* report takes this point into account by assuming that there will be substantial costs from climate change even in the "rapid stabilization" scenario, and by estimating the *net* difference between the two policies.

Conclusion

Florida has made ambitious commitments to greenhouse gas mitigation, and this initiative has helped to sustain momentum for a national cap-and-trade system of tradable pollution rights. Using a state-of-the-art economic forecasting model, this study examines the effects of Florida's participation in such a national carbon trading scheme. Generally speaking, we find that for the projected range of national permit prices, Florida can achieve its GHG mitigation goals at very modest or even negligible growth cost. In particular, our results suggest that using national cap-and-trade to reduce its emissions would sacrifice less than 0.5% real GSP growth by 2025. This means that Florida's economy would hit its baseline growth targets about eight weeks later than expected, after 18 years. Considering the potential climate damage to this vulnerable state, Florida can easily afford to support an effective national or international agreement to avert more serious climate change.

Looking more deeply at the state's adjustment experience, we see that carbon pricing will shift the state's economic structure toward a lower carbon future, reducing relative growth rates for carbon-intensive activities. All sectors expand substantially compared to present day output and employment levels, but carbon prices do provide important market incentives for greening Florida's economy.

APPENDIX A

Overview of the economic model and data resources

The Berkeley Energy and Resources (BEAR) model is a suite of research tools designed to elucidate economy-environment linkages in Florida. The schematics in Figures A.1 and A.2 describe the four generic components of the modeling facility and their interactions. This section provides a brief summary of the formal structure of the BEAR model.[17] For purposes of this report, the 2003 Florida Social Accounting Matrix (SAM) was aggregated along certain dimensions. The current version of the model includes 50 activity sectors and 10 households aggregated from the original Florida SAM. The equations of the model are completely documented elsewhere (Roland-Holst, 2005), and for now we discuss only its salient structural components.

Structure of the calibrated general equilibrium model

Technically, a CGE model is a system of simultaneous equations that simulate price-directed interactions between firms and households in commodity and factor markets. The role of government, capital markets, and other trading partners are also specified, with varying degrees of detail and passivity, to close the model and account for economy-wide resource allocation, production, and income determination.

The role of markets is to mediate exchange, usually with a flexible system of prices, which are the most important endogenous variables in a typical CGE model. As in a real market economy, commodity and factor price changes induce changes in the level and composition of supply and demand, production and income, and the remaining endogenous variables in the system. In CGE models, an equation system is solved for prices that correspond to equilibrium in markets and satisfy the accounting identities governing economic behavior. (For example, the price paid by a purchaser in a transaction must be the same as the price accepted by the seller in that transaction.) If such a system is precisely specified, equilibrium always exists and such a consistent model can be calibrated to a base period data set. The resulting calibrated general equilibrium model is then used to simulate the economy-wide (and regional) effects of alternative policies or external events.

The distinguishing feature of a general equilibrium model, applied or theoretical, is its closed-form specification of all activities in the economic system under study. This can be contrasted with more traditional partial equilibrium analysis, in which linkages to other domestic markets and agents are deliberately excluded from consideration. A large and growing body of evidence suggests that indirect effects (e.g., upstream and downstream production linkages) arising from policy changes are not only substantial, but may in some cases even outweigh direct effects. A model that consistently specifies economy-wide interactions can best assess the implications of economic policies or business strategies. In a multi-country model like the one used in this study, indirect effects include the trade linkages between countries and regions, which themselves can have policy implications.

The model we use for this work has been constructed according to generally accepted specification standards, implemented in the GAMS programming language, and calibrated to the new Florida SAM estimated for the year 2003.[18] The result is a single economy model calibrated over the eighteen-year time path from 2007 to

2025.[19] Using the very detailed accounts of the Florida SAM, we include the following in the present model:

Production

All sectors are assumed to operate under constant returns to scale and cost optimization. Production technology is modeled by a nesting of constant-elasticity-of-substitution (CES) functions. See Figure A.1 for a schematic diagram of the nesting.

In each period, the supply of primary factors—capital, land, and labor—is usually predetermined.[20] The model includes adjustment rigidities. An important feature is the distinction between old and new capital goods. In addition, capital is assumed to be partially mobile, reflecting differences in the marketability of capital goods across sectors.[21] Once the optimal combination of inputs is determined, sectoral output prices are calculated assuming competitive supply conditions in all markets.

Consumption and closure rule

All income generated by economic activity is assumed to be distributed to consumers. Each representative consumer allocates optimally his or her disposable income

FIGURE A.1
Component structure of the modeling facility

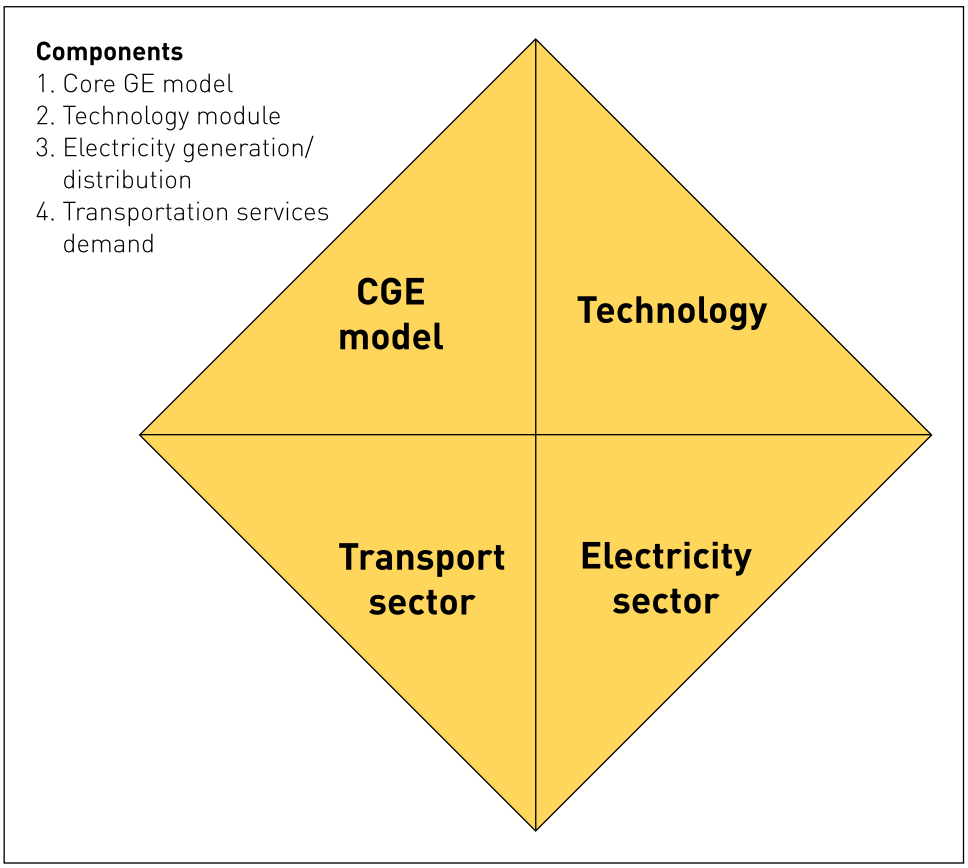
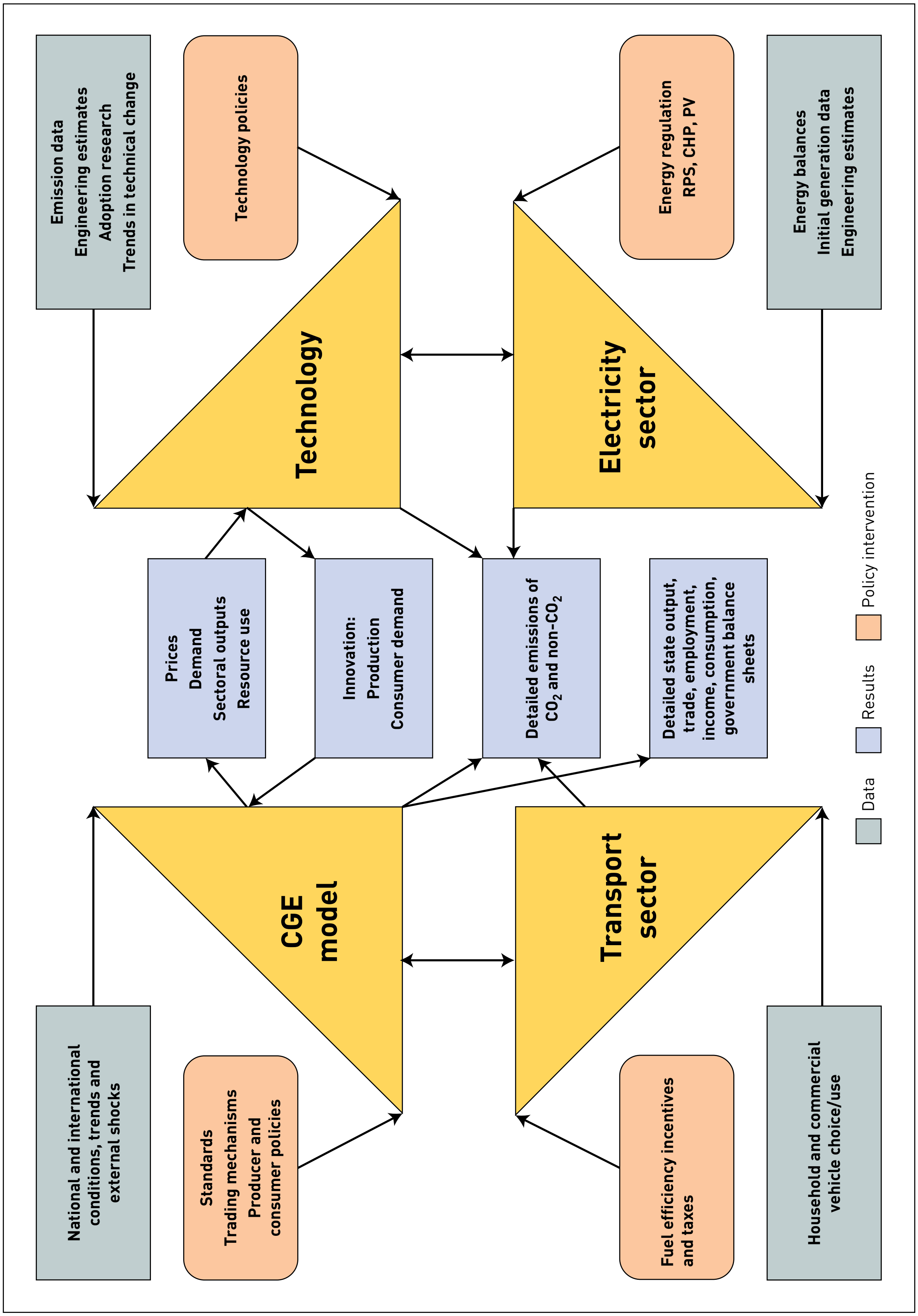


FIGURE A.2
Schematic linkage between model components



among the different commodities and saving. The consumption/saving decision is completely static: saving is treated as a "good" and its amount is determined simultaneously with the demand for the other commodities, the price of saving being set arbitrarily equal to the average price of consumer goods.

The government collects income taxes and indirect taxes on intermediate inputs, outputs, and consumer expenditures. The default closure of the model assumes that government deficit/saving is exogenously specified.[22] The indirect tax schedule will shift to accommodate any changes in the balance between government revenues and government expenditures.

The current account surplus (deficit) is fixed in nominal terms. The counterpart of this imbalance is a net outflow (inflow) of capital, which is subtracted (added to) the domestic flow of saving. In each period, the model equates gross investment to net saving (equal to the sum of saving by households, the net budget position of the government, and foreign capital inflows). This particular closure rule implies that investment is driven by saving.

Trade

Goods are assumed to be differentiated by region of origin. In other words, goods classified in the same sector are different according to whether they are produced domestically or imported. This assumption is frequently known as the *Armington* assumption. The degree of substitutability, as well as import penetration shares, are allowed to vary across commodities. The model assumes a single Armington agent. This strong assumption implies that the propensity to import and the degree of substitutability between domestic and imported goods is uniform across economic agents. This assumption reduces tremendously the dimensionality of the model. In many cases, this assumption is imposed by the data. A symmetric assumption is made on the export side where domestic producers are assumed to differentiate the domestic market and the export market. This is modeled using a *Constant-Elasticity-of-Transformation* (CET) function.

Dynamic features and calibration

The current version of the model has a simple recursive dynamic structure as agents are assumed to be myopic and to base their decisions on static expectations about prices and quantities. Dynamics in the model originate in three sources: (i) accumulation of productive capital and labor growth; (ii) shifts in production technology; and (iii) the putty/semi-putty specification of technology.

Capital accumulation

In the aggregate, the basic capital accumulation function equates the current capital stock to the depreciated stock inherited from the previous period plus gross investment. At the sectoral level, however, the specific accumulation functions may differ because the demand for (old and new) capital can be less than the depreciated stock of old capital. In this case, the sector contracts over time by releasing old capital goods. Consequently, in each period, the new capital vintage available to expanding industries is equal to the sum of disinvested capital in contracting industries plus total saving generated by the economy, consistent with the closure rule of the model.

The putty/semi-putty specification

The substitution possibilities among production factors are assumed to be higher with the new than the old capital vintages—that is, technology has a putty/semi-putty specification. Hence, when a shock to relative prices occurs (e.g., the imposition of an emissions fee), demands for production factors adjust gradually to the long-run optimum because the substitution effects are delayed over time. The adjustment path depends on the values of the short-run elasticities of substitution and the replacement rate of capital. As the latter determines the pace at which new vintages are installed, the larger the volume of new investment, the greater the possibility to achieve the long-run total amount of substitution among production factors.

Dynamic calibration

The model is calibrated on exogenous growth rates of population, labor force, and GDP. In the so-called Baseline scenario, the dynamics are calibrated in each region by imposing the assumption of a balanced growth path. This implies that the ratio between labor and capital (in efficiency units) is held constant over time.[23] When alternative scenarios around the baseline are simulated, the technical efficiency parameter is held constant, and the growth of capital is endogenously determined by the saving/investment relation.

Modeling emissions

The BEAR model captures emissions from production activities in agriculture, industry, and services, as well as in final demand and use of final goods (e.g., appliances and autos). This is done by calibrating emission functions to each of these activities that vary depending upon the emission intensity of the inputs used for the activity in question. We model both CO_2 and the other primary greenhouse gases, which are converted to CO_2 equivalent.

Following standards set in the research literature, emissions in production are modeled as factor inputs. The base version of the model does not have a full representation of emission reduction or abatement. Emissions abatement occurs by substituting additional labor or capital for emissions when an emissions tax is applied. This is an accepted modeling practice, although in specific instances it may either understate or overstate actual emissions-reduction potential.[24] In this framework, emission levels have an underlying monotone relationship with production levels, but can be reduced by increasing use of other, productive factors such as capital and labor. The latter represent investments in lower intensity technologies, process cleaning activities, and the like. An overall calibration procedure fits observed intensity levels to baseline activity and other factor/resource use levels. In some policy simulations, we evaluate sectoral emissions-reduction scenarios, using specific cost and emissions reduction factors, based on our earlier analysis (Hanemann and Farrell, 2006).

The model has the capacity to track 14 categories of individual pollutants and consolidated emission indexes, each of which is listed in Table A.1 below. Our focus in the current study is the emission of CO_2 and other greenhouse gases, but the other effluents are of relevance to a variety of environmental policy issues. For more detail, please consult the full model documentation.

An essential characteristic of the BEAR approach to emissions modeling is endogeneity. The BEAR model permits emission rates by sector and input to be exogenous or endogenous, and in either case the level of emissions from the sector in question is endogenous unless a cap is imposed. This feature is essential to capture structural adjustments arising from market-based climate policies, as well as the effects of technological change.

TABLE A.1
Emission categories

1.	Carbon dioxide	CO_2
	Criteria pollutants	
2.	Suspended particulates	PART
3.	Sulfur dioxide (SO_2)	SO_2
4.	Nitrogen dioxide (NO_2)	NO_2
5.	Volatile organic compounds	VOC
6.	Carbon monoxide (CO)	CO
7.	Toxic air index	TOXAIR
8.	Biological air index	BIOAIR
	Water pollutants	
9.	Biochemical oxygen demand	BOD
10.	Total suspended solids	TSS
11.	Toxic water index	TOXWAT
12.	Biological water index	BIOWAT
	Land pollutants	
13.	Toxic land index	TOXSOL
14.	Biological land index	BIOSOL

TABLE A.2
Florida social accounting matrix for 2000—structural characteristics

1.	20 production activities
2.	20 commodities (includes trade and transport margins)
3.	3 factors of production
4.	2 labor categories
5.	Capital
6.	Land
7.	10 household types, defined by income tax bracket
8.	Enterprises
9.	Federal government (7 fiscal accounts)
10.	State government (27 fiscal accounts)
11.	Local government (11 fiscal accounts)
12.	Consolidated capital account
13.	External trade account

TABLE A.3
Aggregate accounts for the prototype Florida CGE

A. Production sectors and commodity groups		
The following sectors are aggregated from the IMPLAN scheme of 524 sectors/ commodities.		
	Label	**Description**
1	DistElec-A	Electric power
2	OilRef-A	Oil refining
3	Cement-A	Cement
4	Agric-A	Agriculture
5	Cattle-A	Cattle and dairy
6	Forest-A	Forestry
7	OilGas-A	Oil and gas
8	DistGas-A	LNG and gasoline
9	Constr-A	Construction
10	Chemicl-A	Chemicals

continued on next page

continued from previous page

11	AirCon-A	Air conditioning and refrigeration
12	FoodPrc-A	Food processing
13	OthInd-A	Other industry
14	AirTrns-A	Air transport
15	GndTrns-A	Ground transport
16	WatTrns-A	Water transport
17	TrkTrns-A	Truck transport
18	Trade-A	Wholesale and retail trade
19	WstServ-A	Waste services
20	PrivServ-A	Other private services
B. Labor categories		
	Label	**Description**
1.	Skilled	
2.	Unskilled	
C. Capital		
D. Land		
E. Natural resources		
F. Household groups (by income)		
	Label	**Description**
1.	HOUS0	(←$0k)
2.	HOUS1	($0-12k)
3.	HOUS2	($12-28k)
4.	HOUS4	($28-40k)
5.	HOUS6	($40-60k)
6.	HOUS8	($60-80k)
7.	HOUS9	($80-200k)
8.	HOUSH	($200+k)
G. Enterprises		
H. External trading partners		
	Label	**Description**
1.	ROUS	Rest of United States
2.	ROW	Rest of the world

These data enable us to trace the effects of responses to climate change and other policies at unprecedented levels of detail, tracing linkages across the economy and clearly indicating the indirect benefits and tradeoffs that might result from cap-and-trade policies, pollution fees, or trading systems. As we see in the results section, the effects of climate policy can be quite complex. In particular, cumulative indirect effects often outweigh direct consequences, and affected groups are often far from the policy target group. For these reasons, it is essential for policy makers to anticipate linkage effects like those revealed in a general equilibrium model and data set like the ones used here.

The SAM used with BEAR departs in a few substantive respects from the original 2003 Florida SAM. The two main differences have to do with the structure of production, as reflected in the input-output accounts, and with consumption good aggregation. To specify production technology in the BEAR model, we rely on both activity and commodity accounting, while the original SAM has consolidated activity accounts. We chose to maintain separate activity and commodity accounts to maintain transparency in the technology of emissions and patterns of tax incidence. The difference is non-trivial and considerable additional effort was needed to reconcile use and make tables separately. This also facilitated the second SAM extension, in which we maintained final demand at the full 119 commodity level of aggregation, rather than adopting six aggregate commodities as in the original SAM.

APPENDIX B
Notes on policy interaction

Sectoral rates will differ according to many factors, including how they participate in emissions trading, indirect linkage effects, and relative adjustment costs. These can vary in the BEAR model because emission levels are endogenous (that is, determined through the operation of the simulated economic system, not by an external constraint). Three primary forces are at work here:

1. Policy interaction: In some cases, policies have interactive direct and indirect effects. The former are more deterministic ex ante, and are simply additive. The latter can be quite complex and require detailed inspection to identify positive and negative synergies.

2. Technical substitution: As discussed above, the tested scenarios do not take account of the potential for climate policies to induce innovation, but the BEAR model does allow for technical substitution. In response to price changes, individual sectors can be expected to substitute fuels, other inputs, and/or factors of production to achieve greater cost effectiveness.

3. Indirect price effects: Sometimes referred to as rebound effects, these price responses will create a second round of demand adjustments in sectors with partially offsetting or reinforcing price changes.

Examples

1. With fuels, efficiency or carbon-price-induced demand reductions may be somewhat offset by induced falling market prices. Likewise, rising demand for construction services (e.g., building standards) may be partially attenuated by price increases.

2. Standards-induced acceleration of hybrid vehicle adoption may lower prices of less efficient used cars, offsetting their fuel-inclusive operating cost and encouraging higher VMT.

3. To the extent renewable energy is deployed in response to rising carbon costs, indirect price effects could be extensive and difficult to predict, including agro-food costs (biofuel), home prices (solar), and land use (wind).

All the effects in this category are secondary, however, and very unlikely to reverse aggregate outcomes.

Notes

1 Executive Orders 07-126, 07-127, and 07-128.

2 Florida's Energy and Climate Change Action Plan, Appendix B, Cap and Trade, at B-3 (Oct. 15, 2008), available at http://www.dep.state.fl.us/climatechange/files/action_plan/app_b_cap_trade.pdf (emphasis added). In addition, in 2008, the Florida legislature passed, and Governor Crist signed, the Energy, Climate Change, and Economic Security Act of 2008, which created a variety of new programs and incentives to address global warming.

3 Florida's Energy and Climate Change Action Plan, Appendix B, Cap and Trade, at B-10.

4 Nathaniel Keohane and Peter Goldmark, *What Will It Cost to Protect Ourselves from Global Warming? The Impacts on the U.S. Economy of a Cap-and-Trade Policy for Greenhouse Gas Emissions* (2008), available at http://www.edf.org/documents/7815_climate_economy.pdf.

5 Executive Summary, Florida's Energy and Climate Change Action Plan, at 16-17 (2008).

6 See Roland-Holst (2005) for a complete model description.

7 Specifically, we use a moving average of historical Florida GSP growth over the period 2003–2007, combined with BEA forward projections for U.S. GDP to 2025. Taking a five-year moving average forward, these are averaged so that Florida's baseline growth rate converges to the national rate by 2025.

8 Although carbon dioxide is the most significant greenhouse gas, other gases, such as methane and carbon dioxide, also contribute to the greenhouse effect. Because these other gases are more potent than carbon dioxide in terms of global warming potential, all types of greenhouse gases are expressed in the form of carbon dioxide equivalents.

9 These prices are from the EPA's Preliminary Analysis of the Waxman-Markey Discussion Draft—The American Clean Energy and Security Act of 2009, in the 111th Congress (April 20, 2009), available at www.epa.gov/climatechange/economics/pdfs/WM-Analysis.pdf. When the sponsors of the bill released a revised version, the EPA did a second analysis, concluding that the revisions would lead to somewhat lower allowance prices. EPA, Ways in Which Revisions to the American Clean Energy and Security Act Change the Projected Economic Impacts of the Bill (May 17, 2009), available at http://energycommerce.house.gov/Press_111/20090515/hr2454_epaestimate.pdf. In this study, we conservatively use the somewhat higher prices that the EPA estimated based on the original (March 31, 2009) draft bill.

10 In California, for example, it is estimated that energy efficiency measures over the last three decades have saved households $56 billion and created over 1.4 million additional jobs (Roland-Holst, 2008).

11 This finding is quite consistent with national-level climate research (e.g., Keohane and Goldman, 2008), which suggests very low aggregate economic costs for GHG abatement.

12 In these three scenarios, carbon prices are from the low, medium, and high estimates in Table 1 above.

13 The $1.464 trillion figure is the average of the 2025 Florida GSP figures for the three Cap-and-Trade scenarios.

14 U.S. Environmental Protection Agency, *Benefits and Costs of the Clean Air Act*, www.epa.gov/oar/sect812/index.html. This site includes both a retrospective study of the period 1970 to 1990 (published in 1997) and a (partially) prospective study of the period 1990–2010 (published in 1999).

15 U.S. Environmental Protection Agency, Advance Notice of Proposed Rulemaking: *Regulating Greenhouse Gas Emissions under the Clean Air Act*, www.epa.gov/climatechange/anpr.html.

16 The *Costs of Inaction* report is available at www.ase.tufts.edu/gdae/Pubs/rp/Florida_lr.pdf.

17 See Roland-Holst (2005) for a complete model description.

18 See, e.g., Meeraus et al. (1992) for GAMS.

19 The present specification is one of the most advanced examples of this empirical method, already applied to over 50 individual countries or combinations thereof.

20 Capital supply is to some extent influenced by the current period's level of investment.

21 For simplicity, it is assumed that old capital goods supplied in secondhand markets and new capital goods are homogeneous. This formulation makes it possible to introduce downward rigidities in the adjustment of capital without increasing excessively the number of equilibrium prices to be determined by the model.

22 In the reference simulation, the real government fiscal balance converges (linearly) towards zero by the final period of the simulation.

23 This involves computing in each period a measure of Harrod-neutral technical progress in the capital-labor bundle as a residual. This is a standard calibration procedure in dynamic CGE modeling.

24 See, e.g., Babiker et al. (2001) for details on a standard implementation of this approach.

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