Cascade Policy Institute
OREGON

4850 SW Scholls Ferry Road
Suite 103
Portland, Oregon 97225

t: 503.242.0900
f: 503.242.3822
info@cascadepolicy.org
www.cascadepolicy.org

Oregon Greenhouse Gas Reduction Policies: The Economic and Fiscal Impact Challenges

Prepared for the Cascade Policy Institute
September 2008

QuantEcon, Inc.

QuantEcon, Inc.

PO Box 280

Manzanita, Oregon 97130

Phone 503.368.4604

E-Fax 503.296.5495

Email RPOZDENA@QUANTECON.COM

This paper was prepared under a contract between the Cascade Policy Institute and QuantEcon, Inc., Randall J. Pozdena, PhD, President. The paper was co-authored by Eric Fruits, PhD, President of Economics International, under subcontract to QuantEcon, Inc.

Contents

Figures

Tables

1. Executive summary and conclusions

Policy initiatives to regulate greenhouse gas emissions are fast becoming a dominant feature of regional public policy. The initiatives commonly involve setting goals to reduce emissions below a baseline or business-as-usual level. The Western Climate Initiative is one such program, and has been subscribed to by Oregon and 10 other western states and provinces. Specifically, the WCI identifies emissions reduction targets and identifies cap-and-trade mechanisms as a way to achieve emissions reduction targets.

From an economics perspective, the initiatives ideally should strike the optimal balance between sacrifices that must be made in the near term and the benefits of avoiding future depression of economic well-being due to climate change. Unfortunately, the projections of future climate change are highly uncertain,[1] and the associated future economic benefits more uncertain still. Consequently, this paper does not engage that debate. Rather, it focuses on measurement of the short-run costs of certain, proposed aspects of the WCI, as we understand the Initiative today. Although only half of the equation, it is important to discuss what these costs may be, and what factors and policies might best mitigate these costs.

The paper first describes the nature of the WCI emissions goals and the cap-and-trade policy approach that is part of the Initiative. The paper then goes on to conduct an empirical investigation of the relationships among economic output, energy use and carbon dioxide emissions, and the links to the State's economic and fiscal condition.

The main findings of this paper are as follows:

- The notion of capping emissions and providing market signals through a cap-and-trade scheme is not conceptually unreasonable or without precedent.
- The WCI's empirical underpinnings are not transparently documented, making it difficult to evaluate whether the proposed trajectory of emissions reductions is at, below, or above a trajectory that optimally balances near-term costs against future benefits.
- The cap-and-trade mechanism has a history of implementation difficulties. This is due to the vulnerability of the caps and permit allocations to political influence and the tendency of permit values to be highly volatile – even in relatively flexible compliance settings. In the Oregon context, in which the portfolio of politically-acceptable, alternative energy sources is constrained, and the non-carbon technology options undeveloped, these problems may be aggravated.
- Economic vitality, energy use and carbon dioxide emissions have been tightly cointegrated historically, and energy strongly "causes" economic vitality. This is true both in studies over time and across countries. Of the OECD countries that display lower than average energy use relative to their economies, all have embraced nuclear power – a source that historically has been "off-the-table" in Oregon.
- Energy consumption and technology choices are strongly embedded in long-lived capital. This raises theoretical and practical obstacles to the economic development and adoption of carbon sparing technology. In addition, because of the existing carbon-intensity of the production of capital goods, too-rapid turnover of existing capital may actually accelerate atmospheric carbon accumulation.
- Absent adoption of silver-bullet, low cost/high effectiveness technological innovations, the cost to the Oregon economy of meeting the WCI emissions curtailment goal are large. Oregon's economic growth to 2020 would be approximately cut in half, and gross output per capita would be reduced by 20 percent relative to the baseline case.
- State and local revenues would be reduced by about 13 percent, relative to the baseline case.
- The measured impacts do not incorporate any deadweight losses imposed on the economy by inopportune technology-picking, subsidy schemes, misallocation of energy permit or tax revenues, and administrative overhead in both the public and private economies.
- Both cap-and-trade and carbon tax policies have theoretical justification, but implementation issues risk imposing costs greater than their benefits. Similarly, subsidizing accelerated adoption of energy-sparing technologies is of dubious net value when the risks of picking losers, instead of winners, is considered. Acceleration of the wrong technologies may actually aggravate atmospheric carbon levels.
- One policy that offers both economic benefits and carbon-emissions reductions is implementation of congestion pricing. Implementation of this policy resolves a pricing error on the highway system that wastes valuable time and fuel, and distorts land use and highway investment decisions – all to the disbenefit of the economy. Congestion pricing, by correcting this pricing error, thus is a carbon policy option that, perhaps uniquely, actually strengthens the economy while helping resolve carbon emissions problems associated with excess congestion, travel, and stop-and-go vehicle use.

From an economist's viewpoint, one intervenes in market processes only with great caution and an abundance of good homework. As the recent experience with ethanol subsidy policy suggests, the effects of well-meaning, but ill-conceived interventions can be costly. These authors believe that the benefits and costs of policy should be carefully calculated before imposing what otherwise will be a significant economic burden on economic activity.

2. Introduction

One of the fast-growing policy drivers in Oregon (and many other states) is climate change legislation. At the request of Cascade Policy Institute, the authors evaluate Oregon policy initiatives to regulate of greenhouse gas emissions. The goal of the evaluation is to estimate the challenge climate control initiatives pose in the form of economic and fiscal effects that may need to be offset by the benefits of climate policy. This information is provided to help inform the public and policy makers of the potential costs of these initiatives, to identify the potential stumbling blocks and help benchmark the scale of the benefits climate policy itself must bring.

Policy makers in several states have concluded that global warming is a crisis, that the human use of fossil fuels is the primary cause of such warming, and that state or regional policies must be enacted to stabilize the global climate. The authors do not challenge this conclusion here. We would only note that the types of models used to reach these conclusions are sensitive to specifications and assumptions. (A simple example of this sensitivity is presented in Figure 1.) This report focuses on the economic and fiscal impacts of state climate change policies rather than on potential climate change itself or issues of forecasting this change. Some of the policies under consideration by states will affect their economic performance and fiscal solvency.

FIGURE 1

Sensitivity of a Portland temperature trend and forecast model to order assumptions, 1871-2012

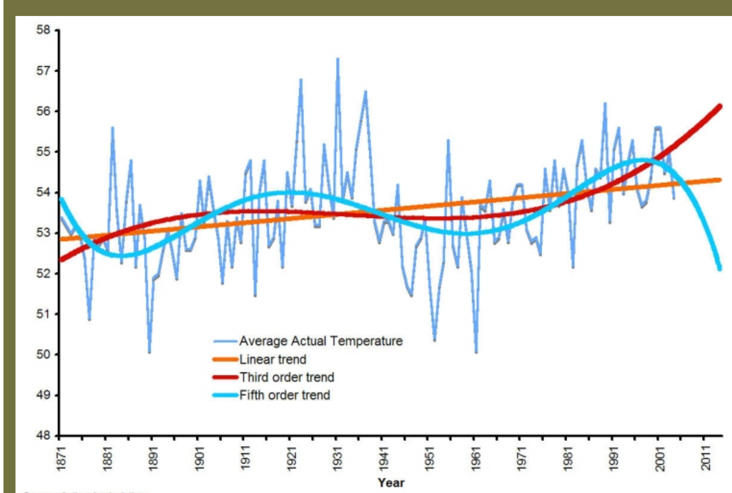


Figure 1 shows actual, historical temperatures for Portland, Oregon, and various time-series fitted trends and associated forecasts. The trends and forecasts vary only by the degree of the assumed polynomial form, yet the forecast implications are very different.

Oregon is a key state for such an analysis because the State is a leader in climate change legislation. Indeed, Oregon has adopted one of the most ambitious greenhouse gas emissions reduction goals in the world. However well-intentioned, such policies come with challenges in implementation and risks regarding their effect. This study reviews extant research and conducts original research. It focuses almost exclusively on carbon dioxide emissions, since the associated use of fossil fuels seems the greatest challenge at this time. The research is adapted to the Oregon context wherever possible, but necessarily relies on national and international studies.

The benefits of reduced emissions could include avoided economic damage that may result from changing climate conditions. On the other hand, actions to address climate change would impose costs because most emissions stem from the combustion of fossil fuels, which constitute the majority of the nation's energy supply. This study focuses on the potential costs of Oregon's greenhouse gas emissions reduction goals.

The focus on potential costs is not because we are uninterested in the benefits of a reduced carbon dioxide burden in the atmosphere. Rather, amongst economists there is greater potential to accurately measure costs associated with reduced fossil fuel energy use than the benefits. Indeed, in 2008, the GAO surveyed 18 expert economists on the potential costs and benefits of various climate policy options (United States Government Accountability Office, 2008). Overall, the panel rated estimates of costs as more useful than estimates of benefits for informing congressional decision making. Some panelists indicated that uncertainties associated with the future impacts of climate change as limitations to estimating benefits. Stavins et al. (2007) independently find that most studies tend to underestimate costs of emission reduction programs and overstate benefits. Thus, the greatest challenge of climate policy may be avoiding making matters worse.

3. Oregon's emissions goals

To be fair, Oregon's climate policies are not yet fully articulated. For purposes of benchmarking Oregon policy, therefore, we assume the State's commitment to the Western Climate Initiative (WCI) characterizes the broad features of Oregon's climate policy.

The Western Climate Initiative is a collaboration of 11 American states and Canadian provinces. Oregon was one of the founding states and is a full partner in the Initiative. The Initiative was formed to develop regional strategies to address potential climate change. Even though each partner sets its own emissions goals, through the Initiative, the partners set an overall regional goal for reducing greenhouse gas emissions. In July 2008, the partners issued a draft design of the regional cap-and-trade program (Western Climate Initiative, 2008).

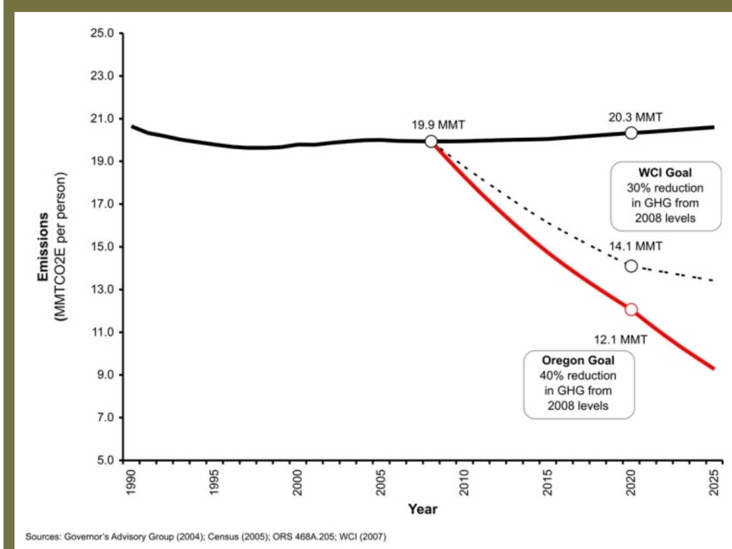
This study assumes that Oregon's climate policy embraces at least two, key features of the WCI:

1. **2020 Reduction Goal.** By 2020, Oregon aims to achieve greenhouse gas emissions that are 10 percent below 1990 levels.[2] By 2050, Oregon's goal is to achieve greenhouse gas emissions that are 75 percent below 1990 levels. The Western Climate Initiative regional greenhouse gas emission reduction goal is an aggregate reduction of 15 percent below 2005 levels by 2020 (Western Climate Initiative, 2007). Figure 2 shows that the Oregon goal represents a 40 percent reduction from 2008 levels in emissions per person. The Western Climate Initiative goal represents a 30 percent reduction from 2008 levels.

2. **Focus on cap-and-trade.** A focus on cap-and-trade schemes as a way to insert market incentives to conserve energy or switch fuels, or end-use technologies.

FIGURE 2

Oregon per capita greenhouse gas emissions, baseline and goals, 1990-2025



We do not know the origin of the 2020 Reduction Goal. As professional economists, we are reflexively suspicious of the seeming precision by which such goals are stated. Given the uncertainties involved, it is highly unlikely that the goal represents an accurately optimized net-benefit goal or climate management trajectory. Nonetheless, we take the goal as given since our focus is on the costs, rather than the benefits, of climate policy.

We turn first to a discussion of the cap-and-trade scheme before proceeding to the measurement of the impacts of Oregon's adopted goal, and the issues that are on the critical path to avoiding these costs.

4. Cap-and-trade programs

A cap-and-trade scheme is only one of many policy options to reduce greenhouse gas emissions. It is outside of the scope of this study to evaluate all of the policy alternatives. Section 8, however, discusses selected, other policies and their relationship to cap-and-trade programs.

The logic of cap-and-trade programs

Conceptually, cap-and-trade schemes create a market in emissions. Economists have long argued that environmental problems exist precisely because government has failed to create markets that individuals are inherently powerless to create. In contrast to the more commonly used regulatory compulsion approach (a form of so-called command and control), pricing schemes have lower societal costs. This is because those able to reduce emissions at the lowest cost are automatically encouraged to do so, whereas a pure regulatory scheme cannot make this differentiation and thereby imposes larger, dead-weight losses on the economy. Also unlike a pure, regulatory approach, cap-and-trade schemes generate revenue, which remains in the economy as a partial offset to the economic losses associated with adjusting equipment or business practices. For these reasons, virtually all economists support market-based solutions to environmental problems.

The basic operation of cap-and-trade program is relatively straightforward. The program "caps" total emissions at some arbitrary level and then issues permits, each of which allows a certain amount of emissions. The initial endowment of permits conceptually should total no more than the cap. The initial distribution of permits may require their purchase, or may be distributed without initial cost. In all the programs to-date, all or most of the permits have been issued for free to emitters based on their past emissions.

If a facility wishes to emit more than its endowed permits allow, the facility must purchase permits in the market. Sellers would be those facilities that emit less than their permits allow either because they have low cost ways of reducing emissions or reduce their products' output or choose to go out of business. The interaction of buyers and sellers yields a price for the emissions that clears the market for permits.

To the extent the permits have value, they provide an incentive to invest in mitigation technologies to reduce emissions. The capital costs of the investments would be offset by the value of permits that could be sold in the market. Over time the traded price of permits may rise or fall (under a fixed cap) depending upon the comparative trends in the need to emit versus trends in emissions abatement options.

The experience with cap-and-trade

In practice, with a few exceptions, cap-and-trade schemes have not been effective in reducing emissions – mainly because of implementation issues. A number of implementation problems plague cap-and-trade schemes:

1. **Political factors.** The allocation of the initial endowment of permits has often been plagued by special exemptions, political favoritism and (understandable) push-back by the industry(s) subject to the caps and adjustments to the caps. This has resulted in over-allotment of permits in almost every program. The result is that such programs do not impose binding caps. Permits, in turn, trade for nominal, low values.

2. **Price volatility.** In the real world, industries and firms regularly face volatility in their business activity. Spikes or depressions in activity are hard to accommodate with a permit scheme. Permits are, essentially, assets, analogous to stocks in that the buyer and seller must formulate expectations about their value far into the future. In a volatile world, permits – like stocks – are subject to sharp price movements with actual or expected changes in economic conditions. Orszag (2008) testified that experience with cap-and-trade programs have revealed this high price volatility. Indeed, Nordhaus (2007) found that the price of sulfur dioxide allowances under the U.S. Acid Rain Program was significantly more volatile than stock prices between 1995 and 2006.

3. **High administrative costs.** Monitoring emissions directly is costly in many settings. It is one thing to put monitors on a relatively small number of utilities' smokestacks. It is quite another to do so with motor vehicles, livestock, or individual businesses. Yet the potential for substitution across capped versus uncapped entities (across geographic boundaries, types of firms, etc.) may defeat the cap, or even breach the cap more than would have been the case without the cap-and-trade scheme.

4. **Differences in abatement potential.** Some gases are more amenable to cap-and-trade programs than others. Stavins (1998) observes that the number and diversity of sources of carbon dioxide emissions due to fossil fuel combustion are much greater than in the case of sulfur dioxide emissions. Ellerman and Buchner (2007) explain that there is a widely shared perception that the main difference between carbon dioxide and conventional pollutants – such as sulfur dioxide – is the abatement potential. For example, scrubbers were a demonstrated technology when the U.S. sulfur dioxide system was implemented. Moreover, substitution among coals of widely varying sulfur content was possible at the time. In contrast, for carbon dioxide associated with electricity generation or transportation, the extant opportunities for abatement potential are limited. In Oregon, for example, little coal is used and additional hydroelectric and new nuclear power are widely perceived as off-the-table. Hence, very little abatement is possible except by reducing output. Oregon is not alone in this.

   Ellerman and Buchner (2007) indicate that the perception of limited or costly abatement seems to have influenced both the ambition of the caps set in the EU Emissions Trading Scheme and several of the allocation choices. Even without a binding cap, emissions reduction programs have a small, negative net economic impact. It is due to the deadweight loss associated with administering the program and distributional costs. Binding caps, on the other hand, in a limited abatement setting, can have significant economic impacts as production costs increase and are passed through to households, businesses, and state and local governments.

5. **Misallocating the revenues generated.** Orszag (2008) suggests that the cost to the economy of an emissions reduction goal might be half as large if policymakers sold the allowances and used the revenue to lower current taxes on capital that discourage economic activity. These tax reductions would be instead of giving the allowances away to energy suppliers and energy-intensive firms or using the auction proceeds to reduce the costs that the policy could impose on low-income households. He warns, however, that using the allowances value to lower the total economic cost could exacerbate the regressivity of the cap-and-trade program.

It is worthwhile summarizing the effects of existing cap-and-trade schemes to evaluated the significance of these challenges.

Volatile organic materials (Chicago area)

The Emissions Reduction Market System ("ERMS") is a cap-and-trade emissions trading program operating in the Chicago area. The first permits were issued in 2000. Illinois was mandated to reduce volatile organic materials ("VOM") emissions by 3 percent a year through 2007.

Even though emissions have been declined while the program has been operating, Kosobud et al. (2004) and Evans and Kruger (2006) conclude that the Chicago VOM trading system has been ineffective because of an over-allotment of permits. Evans and Kruger (2006) attribute the over-allotment to three factors: (1) a baseline process/formula that inflated the cap; (2) federal and state regulations mandating emissions reductions that rendered the market redundant; and (3) economic losses due to numerous facility shutdowns. Kosobud (2007) finds that while emissions were reduced below benchmark, reductions cannot be attributed to the cap-and-trade program. Instead, traditional regulations and mandated emissions reductions drove down emissions (at an unknown cost in lost business activity) below allotments. This resulted in a surplus of permits, making the cap-and-trade program redundant and ineffective.

Nitrogen oxides and sulfur oxides (Southern California)

The Regional Clean Air Incentives Market ("RECLAIM") is a cap-and-trade emissions trading program operating in Southern California. The program began in 1994. Under the program, polluting facilities are required to cut their emissions of nitrogen oxides and sulfur oxides. The system was designed to reduce emissions of nitrogen oxides by 70 percent from 1994 to 2003. Emissions of sulfur oxides were to be reduced by 60 percent.

The emissions caps for each facility were too high to meet the emissions reduction goal. They were also too low – and inflexible – to respond to unanticipated shocks. The United States Environmental Protection Agency (2002) found that the rate of emissions decrease was less than half the initial projections. It concluded that initial allocations were excessively high. The initial allocations were approximately 4060 percent above actual emissions during the first two years (1994-1995).

Joskow (2001) concludes that the inflexibility of the cap-and-trade scheme contributed to California's energy crisis in the early 2000s. He notes that until early 2000, the market prices for permits were very low because the number of permits allocated to power plants generally exceeded their emissions. Between April 2000 and September 2000, the price of pollution permits required to cover nitrogen oxides emissions from power plants in the Los Angeles area increased by a factor of nearly ten. During this period, the demand for California-generated electricity increased rapidly. This, in turn, increased gas-fired generators' demand for permits. The supply of permits, however, continued its planned decline under the program. The result was a spike in the price of permits which (under limited technology options) hampered new capacity development and increased the cost of electricity generation and contributed to California's energy crisis.

Sulfur dioxide (multi-state)

The sulfur dioxide cap-and-trade scheme is often cited as the poster child for cap-and-trade.[3] However, it was introduced in a relatively ideal setting of readily-available technology and substitution opportunities. Phase I, 1995 through 1999, encompassed aggregate annual emissions from the 263 dirtiest large generating units. In Phase II, 2000 and beyond, almost all existing and new fossil-fueled electric generating units in the continental United States are subject to a tighter cap on aggregate annual emissions.

Stavins (1998) concludes that the trading program performed successfully. Targeted emissions-reductions were achieved and exceeded. Estimated cost savings are up to $1 billion annually, compared with the cost of command-and-control regulatory alternatives that were considered by Congress in prior years. However, there are several unique features to this program:

1. As Stavins (1998) points out, there were both input and process substitutions available. The permit system was based on emissions of sulfur dioxide rather than the sulfur content of fuels. In this way the available scrubbing and fuel-switching were both feasible options.
2. Monitoring was relatively straightforward. The major emitters in the sulfur dioxide market were coal burning electric utilities. For these utilities there were reliable continuous electronic monitoring sensors in smokestacks to record emission volumes. The EPA could record these emissions in real time and deduct a tradable permit for each ton of the sulfur dioxide emitted. Permits had, in principle, an infinite life and were allocated free of charge. (Kosobud 2007)
3. Fuel switching was possible at low cost. Schmalensee et al. (1998) find, for example, that declines in rail transportation rates lowered the cost of low-sulfur, Powder River Basin coal. Indeed, in hindsight, emitters overinvested in scrubbers relative to the costs of low-sulfur coal. The combination of scrubber technology and low-sulfur coal resulted in relatively steep declines in emissions.

Even in this idealized environment, however, the Nordhaus (2007) finding of volatile allowances suggests the program produced repeated, and unexpected, shocks and the associated efficiency losses.

Nitrogen oxides (multi-state)

Nitrogen oxides (NOx) are prime ingredients in the formation of ground-level ozone (smog), a pervasive air pollution problem in many areas of the eastern United States. The NOx Budget Trading Program ("NBP") and the NOx SIP Call program are cap-and-trade programs. They were created to reduce emissions of nitrogen oxides from power plants and other large combustion sources in the eastern United States. The programs were designed to reduce NOx emissions during the warm summer months, referred to as the ozone season, when ground-level ozone concentrations are highest.

The market has been marked by price fluctuations and uncertainties regarding whether certain states would participate in the programs (Burtraw et al., 2005). Because of a multiplicity of confounding legal, participatory, and economic factors, no rigorous examination has been published on the economics of the programs. It serves as a nascent case study of the complexity of implementing cap-and-trade schemes.

Carbon dioxide (EU)

The European Union Greenhouse Gas Emissions Trading Scheme ("EU ETS") is a cap-and-trade program that began trading in 2005. It is closest to the notions being advanced regionally by the WCI and Oregon policymakers. The program has relatively modest goals:

1. The Kyoto agreement requires EU countries by 2012 to reduce their greenhouse gas emissions by an

average of 8 percent below 1990 emissions levels.

2. The EU Emissions Trading Scheme exempts emitters of less than 10,000 tons of carbon dioxide per year and thereby only covers about 50 percent of the EU's emissions (Metcalf et al., 2008).

3. Because it is implemented at an EU level, evasion through geographic substitution is relatively limited.

Even with its relatively modest goals, most observers do not consider the EU's emissions reduction programs to be a success.

1. **No meaningful reductions in emissions have been achieved.** Indeed, Stagnaro (2008) finds that since the EU's adoption of the Kyoto Protocol, the European Environmental Agency cannot attribute changes in carbon emissions from 1999 to 2005 to any policies or regulations. Indeed, variations in greenhouse gas emissions are better explained by variations in weather and the business cycle than by emissions reduction policies.

2. **Political conditions resulted in an over-allotment of permits.** Smith and Swierzbinski (2007), studying the United Kingdom's experience, conclude that an inflated baseline for individual firms exposed the system to an over-allotment of permits. The result is an emissions cap that requires little additional abatement effort, and low permit values. Ellerman and Buchner (2007) report that the number of allowances distributed to installations in the first year of the EU Emissions Trading Scheme exceeded those installations' emissions by about four percent of the total EU cap. Convery and Redmond (2007) identify several factors that created pressure for member states of the Emissions Trading Scheme to be generous with their allowances. Because the allowances are allocated for free, there is a strong competitive incentive for companies in the trading sectors to press to maximize the quantity of their allowances. Countries with less generous allocation run the risk of slowing or stifling investment and capacity expansion.

3. **Price volatility.** Hepburn et al. (2006) and Convery and Redmond (2007) report that prices in the EU's Emissions Trading Scheme have had periods of volatility and one or more price crashes. The authors conclude that the fundamental cause for the volatility is that the projections upon which allocations were based embodied far greater uncertainty than was acknowledged at the time the allocations were made. Ellerman and Joskow (2008) suggest that higher than expected prices in 2005 and early 2006 were due to a cold late winter in early 2005, a dry summer in southern Europe, and high natural gas and oil prices that made coal more attractive. Convery and Redmond (2007) attribute a sharp fall in price experienced in the spring of 2006 to the release of actual carbon dioxide emissions data for 2005. The actual emissions data indicated that the market was "long" by a substantial number of permits. That is, emissions were much lower than the number of permits issued. As a result, permit prices plummeted.

4. **Increases in power costs.** Despite little or no carbon impact, the scheme affected power prices. Sijm et al. (2006) conclude that power prices increased significantly in the face of carbon dioxide emissions trading. They estimate pass-through rates of 60-100 percent of the carbon dioxide costs. Pass-through rates are lowest in France in which more than 75 percent of its electricity is generated from nuclear power (Nuclear Energy Institute, 2008). This is disputed by Anger and Oberndorfer (2008). They conclude that because of the over-allotment of permits, the EU's Emissions Trading Scheme did not impose a cost burden on emissions management and should not have raised costs.

The practical experience with cap-and-trade is not encouraging for its cost-effectiveness in the Oregon setting. Oregon has a more aggressive emissions reduction goal than most of the earlier programs and seemingly also a more restrictive portfolio of compliance alternatives. With a large share of Oregon's energy either coming already from relatively clean sources (hydroelectric power and natural gas facilities), its fuel-switching and scrubbing options are relatively limited. Hence, even if applied to public utilities first – to reduce monitoring and administration costs – its practical options are few in this regard.

The other main uses of energy, transportation, residential and industrial uses, pose administrative challenges and greater difficulties in adjusting for the users. There is current public and/or policy skepticism about hydroelectric or nuclear capacity, importation of natural gas, and use of wave energy, and there are load management issues with wind and solar power. Consequently, it is clear that squeezing reductions in carbon emissions with a cap-and-trade scheme may be difficult without reducing total energy usage.

We now turn to measurement of the economic impacts which it appears may be a major channel of reaction to Western Climate Initiative policy.

5. The relationship among dioxide emissions, energy consumption, and economic activity

Both over time and across countries, changes in national income is associated with changes in energy consumption and carbon emissions. Figure 3 shows a positive relationship between per capita energy consumption and per capita national income. The relationship is approximately one-to-one: a one percent increase in energy consumption is associated with a one percent increase in national income (Table 1).

Similarly, lower energy consumption is associated with lower national income. OECD countries have some of the highest energy consumption and the highest national income.[4]

FIGURE 3

Relationship between per person energy consumption and national income, by country, 1980-2004

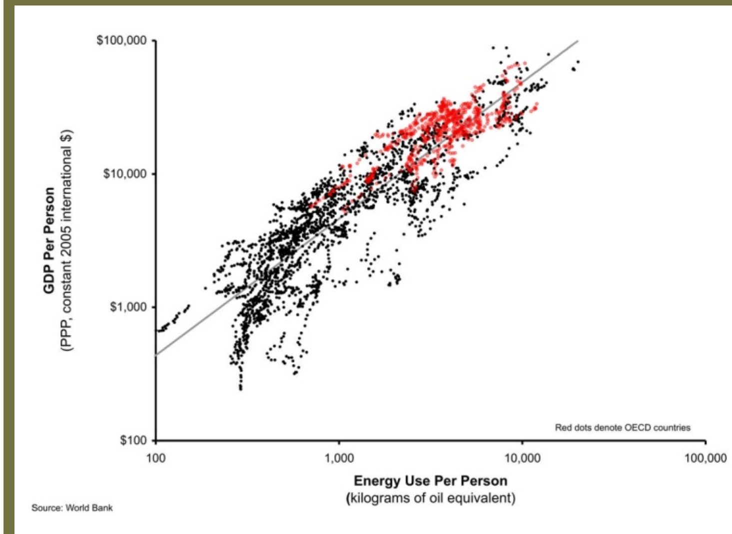


TABLE 1

Regressions of gross domestic product, energy consumption, and carbon dioxide emissions, country cross-section, natural logarithms, 2003

Dependent Variable: GDP per capita based on PPP

Variable	Coeff.	Std. Err.	t-stat.	P-value
Intercept	1.36	0.07	19.54	0.00 ***
Total energy consumption per capita (kgoe / person)	1.02	0.01	106.36	0.00 ***
Adjusted R-squared	0.80			
Observations	2,829			

Dependent Variable: Carbon dioxide per capita in metric tons of carbon

Variable	Coeff.	Std. Err.	t-stat.	P-value
Intercept	-8.67	0.08	-108.14	0.00 ***
Total energy consumption per capita (kgoe / person)	1.32	0.01	119.81	0.00 ***
Adjusted R-squared	0.84			
Observations	2,829			

Dependent Variable: Total energy consumption per capita (kgoe / person)

Variable	Coeff.	Std. Err.	t-stat.	P-value
Intercept	6.65	0.01	716.78	0.00 ***
Carbon dioxide per capita in metric tons of carbon	0.63	0.01	119.81	0.00 ***
Adjusted R-squared	0.84			
Observations	2,829			

Dependent Variable: GDP per capita based on PPP

Variable	Coeff.	Std. Err.	t-stat.	P-value
Intercept	8.12	0.01	699.57	0.00 ***
Carbon dioxide per capita in metric tons of carbon	0.71	0.01	107.47	0.00 ***
Adjusted R-squared	0.80			
Observations	2,829			

Figure 4 shows a positive relationship between per capita energy consumption and per capita carbon dioxide emissions. The estimated elasticity is approximately 1.32: a one percent increase in energy consumption is associated with a 1.32 percent increase in carbon dioxide emissions (Table 1). Conversely, a one percent decrease in carbon dioxide emissions would be associated with a 0.63 percent reduction energy consumption. For countries that produce nuclear energy, increases in energy consumption are associated with smaller increases in carbon dioxide emissions than for non-nuclear countries.

FIGURE 4

Relationship between per person energy consumption and carbon dioxide emissions, by country, 1980-2004

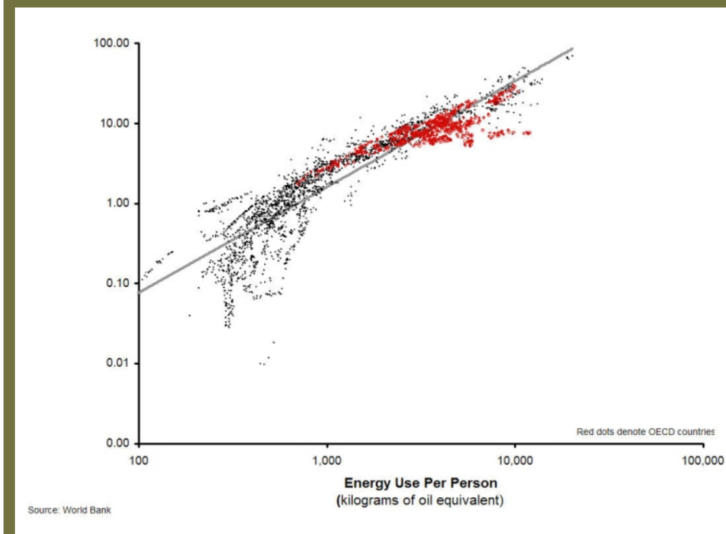


Figure 5 shows a positive relationship between per capita carbon dioxide emissions and per capita national income. The estimated elasticity is approximately 0.71: a one percent increase in carbon dioxide emissions is associated with a 0.71 percent increase in national income (Table 1). Similarly, lower energy carbon dioxide emissions are associated with lower national income.

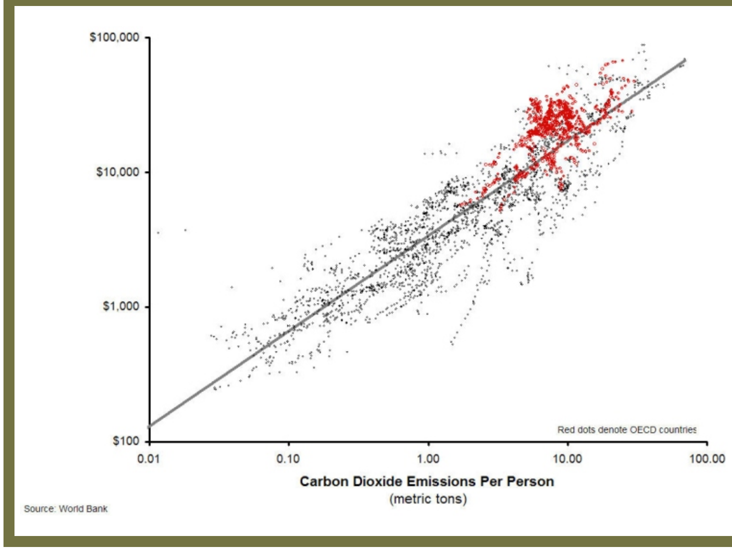
Causation Evidence

A correlation between two variables does not imply that one event causes the second to occur. For example, a third factor could be causing both variables in the same direction. Policy cannot be based on simple correlations. One must be sure that a change in one variable, through policy, will "cause" the desired change in outcomes.

There are several methods for evaluating the relationships among economic activity, energy consumption and carbon emissions. One approach involves simulation modeling. Under this approach, the modeler develops a best guess of how each sector of the economy responds to changes in energy markets and to changes in each of the other sectors of the economy.

FIGURE 5

Relationship between per person carbon dioxide emissions and national income, by country, 1980-2004



This is the basis of the impact framework developed for the Western Climate Initiative.[5] Thus, implicitly, the WCI framework assumes causality, even if no such causal relationship has been demonstrated.

Many simulation models are not well documented and difficult to evaluate. For example, as far as we can discern, there is no publicly available technical documentation for the ENERGY 2020 model employed by the Western Climate Initiative. This makes it impossible to evaluate independently the validity of the model. In addition, simulation models are presumptive in their structure and content, calling into question whether the relationships and associated predictions are reliable and unbiased.

Econometric analysis is a statistical approach for developing the relationships among income, energy consumption and carbon emissions. Rather than assuming a relationship, econometric techniques use real-world data to test whether a relationship exists and whether forecasts reliably predict actual outcomes. The econometric approach also permits testing for causality. A variable is said to "cause" another if movements in one economic variable consistently precede movements in a second variable. Since an omitted, third common variable can be responsible for this pattern of precedence, defining causality in this way (referred to as Granger causality) is more reliable than simple correlative studies.

Econometric studies that have found that there are such strong inter-relationships among economic activity, energy consumption, and emissions that it is hard to separate their mutual influences. This notion, that is called "cointegration" means that, in the historical context at least, one cannot expect to be able to influence economic activity without having associated changes in energy and emissions. The studies reviewed below discuss these causality studies.

Numerous studies have found that energy "causes" economic activity or that there is a symbiotic or "bi-directional" effect whereby each affects the others. See the summary of energy and economic activity studies in Pozdena (forthcoming, 2008). Although more sophisticated theoretically than the simple, correlative studies, these studies show a very persistent effect of energy on economic activity, even in the very long run.[6] The most recent peer-reviewed published research concludes, for example, that a 10 percent decrease in energy would result in a decrease in long-run real GDP by 1.2 percent to 3.9 percent (Narayan and Smyth, 2008).

Thus, historical relationships suggest that policies to reduce energy consumption in the U.S. will have a negative impact on economic activity in the long run. This should come as no surprise since, if there were inexpensive ways of conserving energy or cost-effective technologies to reduce the cost of their use, they would have been adopted by the market.

Even though one can argue that fossil fuels have provided a too-cheap means of producing energy, that alone does not explain energy trends. Consumption of energy is not a goal in itself; it is a cost imposed on other activities. At all times, in all economies, therefore, there is an incentive to reduce the use of energy in general, but that is balanced against the benefits it provides. That benefit is economic activity, and our interest in economic vitality has dominated the market cost implications of energy consumption. The implication for the future is that the cost of conservation and production of energy by other means should not be assumed to be trivial, nor the desire for economic vitality weak.

Carbon dioxide emissions are not a necessary consequence of energy production and consumption. However, under historical technology and market conditions, carbon emissions have been tightly integrated with economic activity. Coondoo and Dinda (2006), for example, evaluate the causal association between emissions and economic activity and finds the same, high level of cointegration others find for energy itself. Since the study is a panel of different countries at different times, it demonstrates the pervasiveness of this cointegration even among economies of different composition and levels of energy consumption. This, in turn, suggests that it is going to be hard, at the margin, to influence emissions without adversely affected economic activity.

6. Technology to the rescue?

Historical studies give us a picture of cause and effect under historical conditions. The great prayer of climate change policy, therefore, must be that novel technology – that was not a choice or not available in the past – will evolve rapidly to break the tight entanglement of energy, emissions, and economic activity. This section explores the potential for heroic technological fixes to the cointegration dilemma.

Changes in technology can take many forms. Technological change can take the form of novel mechanical or chemical processes to produce or consume energy. Energy conservation within existing technical constraints, however, also is a form of technological change because it involves individuals and firms rearranging the way they do things. Economists view technological change as a factor that evolves under the combined influence of serendipity and market conditions. Exactly how technology will evolve is uncertain, difficult to predict, and limited by market forces. Bretschger (2005) puts the challenge of resource-sparing technological change succinctly:

> *[T]echnological change has the potential to compensate for natural resource scarcity, diminishing returns to capital, poor input substitution, and material balance restrictions, but is limited by various restrictions like fading returns to innovative investments and rising research costs.*

Increasing scarcity of some resources and the associated rising prices should stimulate creation and adoption of new, energy sparing technologies. Indeed, the logic of cap-and-trade and other efforts to create markets in carbon emissions is to stimulate adoption of carbon-sparing technologies and behaviors. However, penetration of new technology can be expected to be slow and costly, for several reasons.

1. Even if the carbon-sparing technology already exists, capital market forces will stymie penetration. The reason is that most technology is embedded in durable, physical capital of come kind, such as industrial plant and equipment, vehicles, housing type or location, etc. If a new technology comes along that is energy-sparing, the owner of the existing capital will suffer reduced value of that capital. Specifically, if asset markets work efficiently, the value of the "old" capital will fall by an amount equal to the relative energy cost savings offered by the "new" capital – everything else being equal. Thus, owners of old capital will be, at best, indifferent to the existing or new technology. Indeed, if the new technology has high, front-end costs (of acquisition, conversion, etc.), it may make more sense to hold on to the old technology (which has low market value) until other factors make replacement cost-effective. This is likely why Newell (2004) and others have observed that making the replacement technology cheaper accelerates adoption faster than a higher cost of energy.

2. If carbon-sparing alternative technology is not currently available, the only effect of higher energy input prices is to reduce consumption and production of the associated products or services and/or depress the wealth of those who hold the old capital. This is problematic because it results in reduced economic activity hand-in-hand with any reduction in energy use and carbon emissions. Reduced private income and wealth may limit the resources available to develop new technologies. Liddle (2007), in his study of cointegration of vehicle travel, the economy, fuel costs, and fuel efficiency, concluded that it may be very costly to use pricing mechanisms to improve fleet fuel efficiency. He looks to technological changes to resolve the challenge.

3. Wholesale replacement of energy-consumptive capital is itself energy consumptive. For example, photovoltaic panels manufactured in the 1990s used more energy in their manufacture than they produced over their lifetimes. In essence, subsidizing their adoption above the market level thus increased, rather than decreased, fossil fuel use.[7] The latest panel technologies may be less wasteful, but often, energy-efficiency calculations do not incorporate the cost of converting existing systems, developing storage facilities, etc. through the entire supply chain.[8] When such calculations are made, the total energy budget of adopting new technology can be surprisingly high. Consider, for example, the energy cost of manufacturing new cars with greater energy efficiency. The full, supply-chain budget can be approximated from national, input output information linked to sectoral energy consumption data.[9] When all of the supply-chain energy demands are considered, it requires approximately 7.6 terajoules (7.6×10^{12} joules) to manufacture one million dollars of cars or light trucks. Converted to BTUs and equivalent gallons of gasoline, enough energy thus is used to manufacture a $20,000 car to propel an existing-efficiency vehicle over 100,000 miles. The point of such energy-accounting exercises is simply to highlight the challenge of technology transition. The transition to carbon-sparing energy or transportation technologies typically will initially accelerate climate carbon accumulation, since these energy demands are front-loaded. (In climate policy parlance, there is a negative time shift in the carbon emission burden.)

In summary, it is difficult to project the development timing, cost and penetration rate of new, carbon-sparing technology. More importantly, it is hard to know whether the rate of adoption of new technology is, or is not, adequately captured in the historical record used to develop causality models. If it is, then the implications of those models are sufficient to provide insights into the economic effects of climate policy in Oregon.

In what follows, we take the conservative position that technological change may be unable to fully offset the impact of the WCI initiatives on the Oregon economy.

7. The economic and fiscal impacts of Oregon's greenhouse gas reduction goals

This section evaluates the economic and fiscal effects Oregon's proposed greenhouse gas emissions reduction goal. This study focuses on the economic and fiscal impacts of climate change policies rather than on potential climate change itself. Some of the policies under consideration by states will affect their economic performance and fiscal solvency.

It should be noted that the impact estimates presented in this section are not "best-case" estimates – though there is some risk they may prove to be that. They are based on long term and/or widespread historical behavioral relationships. As noted elsewhere in this report, technological change offers the greatest potential to mitigate some portion of the impacts of achieving the stated, Oregon reduction goals. However, patterns of energy use are embedded in huge stocks of commercial, industrial and residential capital, and producing new, more efficient capital itself is energy-consumptive and carbon-emissive.

Liddle (2007) and Pozdena (2008, forthcoming) have studied the long-term revealed relationships among energy use, travel activity and progress in fuel efficiency in transportation. They found low responsiveness of either technical change or travel behavior to price changes alone. If more generally applicable, these findings suggest that the there may be slow development and adoption of technology and/or backward shifting (near-term acceleration) of the atmospheric carbon burden. Thus, there are considerable hurdles to development and deployment of new technologies such that the current relationships are altered significantly. Hence, it is relevant to appraise economic and fiscal impacts under conservative assumptions, since to do otherwise may assume away an important cost of producing greenhouse gas benefits.

Baseline forecasts of greenhouse gas emissions, employment, income, and state and local government revenues

Both over time and across countries, changes in Oregon state income and employment are correlated with changes in population. The State of Oregon (2008) provides actual and forecast population over the period 1990-2015. The United States Census Bureau (2005) forecasts state population through 2030.

Greenhouse gas emissions

The Oregon Governor's Advisory Group on Global Warming (2004) forecasts what it calls the "business as usual" amount of greenhouse gas emissions through 2025. This study adopts the Advisory Group's "business as usual" scenario as a baseline level of annual emissions. "Business as usual" assumes that the state continues present activities (including those that now restrain greenhouse gas emissions), but takes no additional special actions to reduce emissions. Under the "business as usual" scenario, the Advisory Group predicts that by 2025 Oregon's total greenhouse gas emissions would be 61 percent higher than 1990 levels. Much of the growth in greenhouse gas emissions can be attributed to population growth. Indeed, the Advisory Group's projections suggest that 2025 "business as usual" per capita emissions would be almost identical to 1990 levels.

Gross domestic product

The United States Bureau of Economic Analysis (2008) provides Oregon's gross domestic product over the period 1997-2007. Table 2 shows estimates of the relationship between Oregon population and GDP. The data indicate an elasticity of 3.23: a one percent increase in population would be associated with a 3.23 percent increase in Oregon's gross domestic product. This elasticity estimate is applied to the Census Bureau's population projections to forecast employment through 2020 and converted to 2008 dollars using the gross domestic product deflator provided by the State of Oregon (2008).

TABLE 2

Regressions of gross domestic product, employment, and state and local government own source revenues, natural logarithms

Dependent Variable: GDP (millions $2000)

Variable	Coeff.	Std. Err.	t-stat.	P-value
Intercept	7.61	0.17	45.60	0.00 ***
Population (millions)	3.23	0.13	24.33	0.00 ***
Adjusted R-squared	0.98			
Observations	11			

Dependent Variable: Employment (millions)

Variable	Coeff.	Std. Err.	t-stat.	P-value
Intercept	-2.49	0.45	-5.52	0.00 ***
GDP (millions $2000)	0.25	0.04	6.58	0.00 ***
Adjusted R-squared	0.81			
Observations	11			

Dependent Variable: State & local own source general revenue (millions $2008)

Variable	Coeff.	Std. Err.	t-stat.	P-value
Intercept	0.77	1.34	0.58	0.58
GDP (millions $2008)	0.77	0.11	6.76	0.00 ***
Adjusted R-squared	0.85			
Observations	9			

Dependent Variable: Employment (millions)

Variable	Coeff.	Std. Err.	t-stat.	P-value
Intercept	-1.00	0.05	-20.38	0.00 ***
Population (millions)	1.17	0.04	30.02	0.00 ***
Adjusted R-squared	0.97			
Observations	26			

Employment

Economics recognizes the interrelationship between gross domestic product and employment.[10] Table 2 shows estimates of the relationship between Oregon gross domestic product and employment. The elasticity of employment with respect to gross domestic product is 0.25: a one percent increase in gross domestic product is associated with a 0.25 percent increase in employment. This elasticity estimate is applied to gross domestic product projections to forecast employment through 2020.

State and local government revenues

The United States Census Bureau (2008) provides Oregon's state and local governments' own-source revenues for each of the fiscal years 1995-96 through 2005-06, with the exception of fiscal years 2000-01 and 2002-03 for which state-level data is not available.[11] Revenues are converted to 2008 dollars using the gross domestic product deflator provided by the State of Oregon (2008). Table 2 shows estimates of the relationship between Oregon gross domestic product and state and local governments' own source revenues. The data indicate an elasticity of 0.77 with respect to gross domestic product: a one percent increase in gross domestic product would be associated with a 0.77 percent increase in Oregon's state and local government revenues. The elasticity estimate is applied to the employment and gross domestic product projections to forecast state and local governments' own-source revenues through 2020.

Oregon's greenhouse gas reduction goals relative to the baseline

Figure 2 shows Oregon's greenhouse gas emissions goal relative to actual and baseline projected emissions provided by the Oregon Governor's Advisory Group on Global Warming (2004). It assumes that policies will be in place by the end of 2008 to achieve Oregon's 2020 reduction goal. Given current projections of Oregon's population growth, the state's 2020 reduction goal can be attained if per capita emissions decline by a little more than four percent per year continuously between 2008 and 2020.

Impacts on state income

The estimated elasticity of gross domestic product with respect to carbon dioxide emissions under historic conditions is approximately 0.71. In other words, a one percent reduction in per capita carbon dioxide emissions is associated with a 0.71 percent decrease in per capita gross domestic product (Table 1). The estimated elasticity is applied to the reduction in emissions relative to the baseline. For example, Oregon's 2020 reduction goal would result in emissions that are 40.7 percent lower than baseline. Applying the estimated elasticity indicates that state per capita gross domestic product would be 28.9 percent lower than baseline.

FIGURE 6

Oregon actual and forecast gross domestic product per person, baseline and greenhouse gas emissions reduction goal, 1990-2025

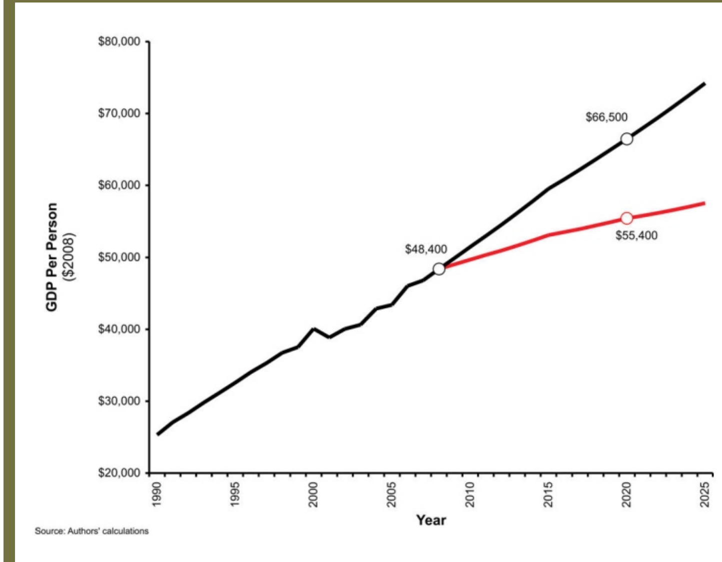
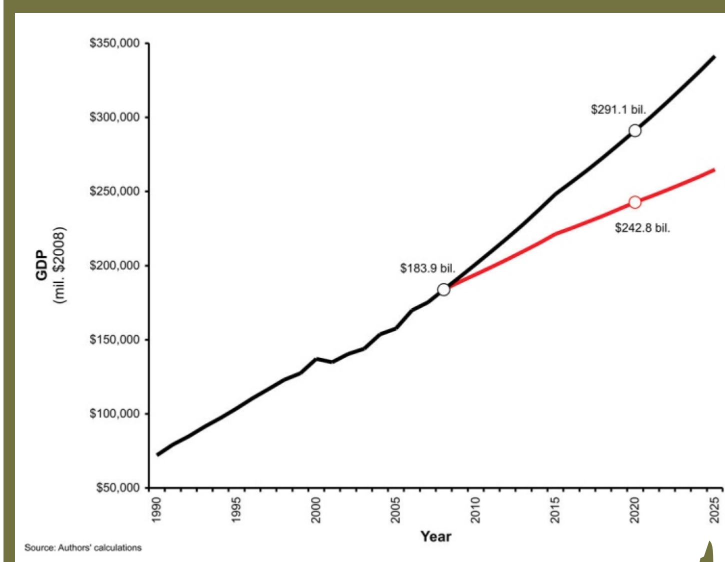


Figure 7 shows that 2020 baseline gross domestic product is projected to be $291.1 billion. With the greenhouse gas reduction goal, 2020 gross domestic product would be $242.8 billion, or $48.3 billion lower than baseline projections. Between 2008 and 2020, the sum of foregone income would be $301.0 billion. At a discount rate of 7 percent, the present value of the foregone income is $173.3 billion.

FIGURE 7

Oregon actual and forecast gross domestic product, baseline and greenhouse gas emissions reduction goal, 1990-2025



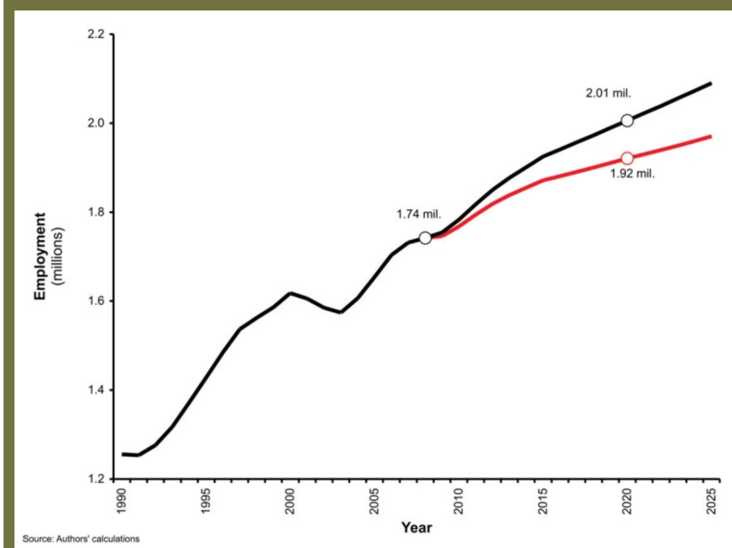
Impacts on state employment

Table 2 estimates the relationship between Oregon gross domestic product and employment. The estimated elasticity is applied to Oregon's gross domestic product under the greenhouse gas emissions reduction goal.

Figure 8 shows that 2020 baseline employment is projected to be 2.01 million, or 45.8 percent of projected population. Under Oregon's greenhouse gas reduction goal, 2020 employment would be 1.92 million, or 90,000 less than baseline projections. If state population growth continues at the rate projected by the United States Census Bureau (2005), then only 43.9 percent of the population would be employed.

FIGURE 8

Oregon actual and forecast employment, baseline and greenhouse gas emissions reduction goal, 1990-2025



Impacts of Oregon's greenhouse gas reduction goals on state and local government revenues

Table 2 estimates the relationship between Oregon state and local government own source revenues as a function of the state's gross domestic product and employment. The estimated elasticity estimates are applied to Oregon's gross domestic product and employment under the greenhouse gas emissions reduction goal.

Figure 9 shows that 2020 baseline state and local revenues are projected to be $34.1 billion. With the greenhouse gas reduction goal, 2020 state and local own source revenues would be $29.7 billion, or $4.4 billion lower than baseline projections. The lower employment from meeting the emissions goals will also increase the demand for state and local government expenditures.

FIGURE 9

Oregon actual and forecast state and local government own source revenues, baseline and greenhouse gas emissions reduction goal, 1990-2025

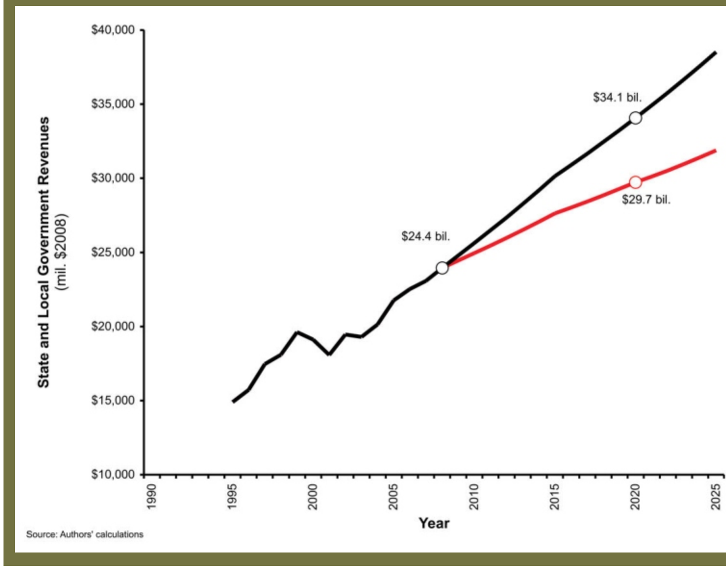
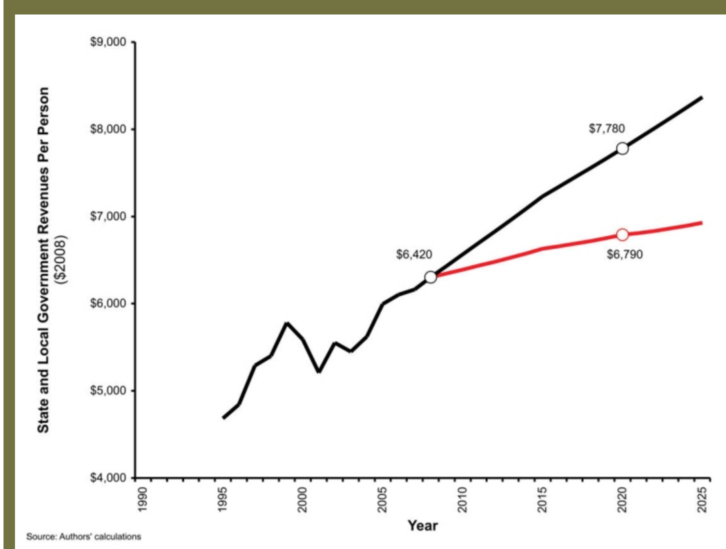


Figure 10 shows that 2020 baseline state and local revenues per capita is projected to be $7,780. Under Oregon's greenhouse gas reduction goal, 2020 state and local revenues per capita would be $6,790, or $990 lower than baseline projections.

FIGURE 10

Oregon actual and forecast state and local government own source revenues per capita, baseline and greenhouse gas emissions reduction goal, 1990-2025



8. Alternative carbon dioxide emissions management options

As the discussion above has made clear, the cap-and-trade approach is a means of creating a market in emissions, but often stumbles over implementation problems in practice. If there are economic externalities to the emission of carbon dioxide, creating markets in these emissions is an important thing to do. It serves as a means of efficiently guiding the burden of adjustment to climate policy to those who can adjust at least cost. However, the cap-and-trade approach has been problematic, historically, and seems particularly difficult, in our opinion, to accommodate to the comprehensive capping of carbon dioxide emissions.

In this section, we discuss selected, alternative mechanisms of managing carbon emissions.

Carbon tax

An alternative to cap-and-trade schemes is a carbon tax applied to the per unit carbon content of fossil fuels. The advantages of a carbon tax approach over a cap-and-trade scheme include the following:

1. A carbon tax is paid in proportion to the amount of fuel used, allowing the burden on the payor to vary more closely with the variations in industrial and other energy use. In economics parlance, a carbon tax is a flow-based pricing scheme rather than a stock-based scheme as with the cap-and trade permits. The permits, being long-lived assets, require speculation about future values of the permits on the part of market participants. The uncertainty of future conditions makes such speculation a proximate cause of the volatility and inequity observed in other permit programs.

2. A carbon tax prices the marginal use of fossil fuel directly. Permit schemes do so only if the permits are traded in a highly liquid and high volume setting. Specifically, to preserve marginal-cost signaling, small increments of permit quantities will have to be bought and sold.

3. A carbon tax approach also is more easily extended to commercial, residential and transportation settings where fuel use is already extensively metered. Thus, it can more easily be a comprehensive program.

4. It is inevitable, in the uncertain world of climate and economic modeling, that changes in carbon pricing policy will have to be made. With a carbon tax, these changes are transparent and, when coupled with the return of revenues to payors (see below), changes in incentives can be implemented with relatively little relative equity impacts. In the case of permit schemes, however, changes in the cap or quantity of permits will create a patchwork of changes in wealth positions of the various holders.

This is not to say that there are no issues associated with implementing a carbon tax. Some of the challenges include the following:

1. First and foremost, the collected revenues need to be deployed in a way that minimizes the impact on the economy. Use of the revenues to reduce other tax obligations, as in the British Columbia implementation, is particularly attractive. It makes the overall program more politically palatable while preserving the marginal incentive to conserve fuel use. Proper implementation, of course, requires that there not be a one-for-one refund of carbon taxes paid, or the marginal incentives will be dulled.

2. It is often argued that the certainty of meeting emissions goals is lower than with a specific cap-setting scheme. This is true, since with carbon taxation, one must wait to observe the market reaction before knowing what amount of emissions reduction that will occur. However, from our perspective, this is an advantage in that the risks to the economy of an overly aggressive cap are more easily avoided. Put differently, cap-and-trade schemes, relative to a carbon tax, enjoy greater certainty of emissions reduction at the expense of greater uncertainty about the scale of adverse economic impacts.

3. If fuels produce differing quantities of offending greenhouse gases according to their use, the carbon tax scheme will have to be made technology sensitive if it is to encourage scrubbing, sequestration, and other post-combustion adjustments. This complicates the implementation.

A challenge that faces any emissions rationing or pricing scheme is whether emissions management technology will evolve quickly enough to meet emissions reduction goals without impairing economic activity by more than the value of economic gains purported to be associated with emissions reductions. With both the long-term effect of climate change uncertain and its economic impact less certain still, it is hard to set either emissions quantities or prices with any confidence.

European Union countries have also adopted ambitious goals, but have been unsuccessful in attaining them. Indeed, Stagnaro (2008) finds that since the EU's adoption of the Kyoto Protocol, the European Environmental Agency does not attribute changes in carbon emissions from 1999 to 2005 to any policies or regulations. Except for one case, the variation in emissions is not attributed to specific policies. Rather, variations in greenhouse gas emissions are better explained by variations in weather and the business cycle than by emissions reduction policies.

Technology acceleration

An economically efficient carbon policy maximizes the present value of expected, economic well-being. The trade-off of present prosperity against the risks of future, negative economic impacts of climate change may be very harsh. Indeed, in the extreme hypothetical case that there are no better carbon-sparing technologies than those available today, the picture is dire. The only way to avoid the impacts of climate change over time would be to shrink the current economy drastically.

Rapid technological change is the means by which current output and income trends potentially could be maintained while reducing negative impacts of climate change. This makes it important to determine if there are cost-effective means of accelerating the development and adoption of carbon-sparing technologies.

There are three, basic ways of achieving this acceleration: pricing of carbon emissions, subsidy of new technology adoption, and subsidy of basic research.

Pricing of Emissions

One prices carbon emissions to reflect their economic burden. That is the goal, of course, of cap-and-trade and carbon tax policies. By raising the cost of burning carbonaceous fuels, incentives are created that will encourage conservation through reduction in carbon-intensive activities. This conservation necessarily implies some loss in current economic well-being. The prospect of this loss, however, in turn creates incentives to avoid these losses, motivating profit-seeking innovators to develop cost-effective, carbon-sparing technology.

Economic history is full of examples of profit-motivated innovation springing from the desire to spare a costly input. Thus, we know that influencing the price of carbon will stimulate innovation and adoption of carbon-sparing technology. In addition, the incentive will be strongest to develop cost-effective innovations since only these will be adopted in the market place.

Thus, there is no reason to doubt the effectiveness of the invisible hand of the marketplace. However, as discussed earlier in this paper, technology embedded in long-lived capital will be absorbed slowly due to the offsetting price changes in old technologies. This raises the question of whether additional policies to accelerate technological change are warranted.

Subsidy of new technology adoptions

A common, existing policy is to subsidize the capital cost of new technologies. The rationale for such subsidies include the following:

1. **The market needs to be exposed to the new technology in order to embrace it.** This is the learning or market-transformation argument for technology subsidies. The difficulty with this logic, however, is that it is not clear that market transformation is necessary if the benefits of the innovation are clear. The booms in personal computers, mobile phones, iPods, and other technology all occurred with great rapidity, despite high capital costs, without public subsidy. On the other hand, publicly mandated innovations rarely – if ever – successfully take off. For example, the switch to digital over-the-air television broadcasting has been subsidized by the giveaway of broadcast spectrum and hardware subsidies. Nevertheless, the switch over has been delayed by several years because consumers have not been convinced that the innovation represents an improvement over the status quo.

2. **Fledgling or "orphan" technologies need bootstrapping in order to be able to scale up production sufficiently.** This "critical mass" argument is a variation of the market-transformation argument, and suffers from the same defects. Decades of subsidies provided to solar power installations have yet to transform the industry into one that can survive without the subsidies. Indeed, one could argue that the subsidies have served to sustain a moribund technology that was not providing energy in excess of the energy embedded in the product. It will take a major, persistent change in fossil fuel prices to improve the pace of innovation in this technology.

3. **Subsidies are required to accelerate conversion of durable "old" capital.** Some studies have observed that subsidies to reduce purchase costs are more effective in technology adoption than the prospect of equal savings in use. See Newell (2004). This likely is due to the uncertainty of future energy cost savings relative to a definitive subsidy. Often times, however, the uncertainty of savings in use is warranted because technologies do not operate as efficiently in real-world environments as they do in the lab. Newell observes that energy savings from higher efficiency levels routinely have been overestimated. New technologies often involve overstatements of savings by 20 percent to 100 percent, and overestimation of internal rates of return by factors of five. Thus, the fact that subsidizing capital costs can accelerate adoption does not necessarily make it a cost- or energy-effective mechanism.

In our view, none of these reasons is per se a justification for subsidizing adoption of new technologies. The only real justification is in those cases in which the private market would "underpurchase" new technology because it does not perceive the social externality associated with climate change effects. By pricing those externalities directly, however, (via a cap-and-trade or carbon tax) private decisions will properly incorporate this consideration. Hence, at a minimum, subsidies are duplicative of an emissions-pricing program.

There are other problems with subsidy programs directed at technology adoption. The most important one is that policy makers have to "pick the winners" to subsidize. Even with unbiased professional advice, one has to have great faith in policy makers' prescience in technology and market trends. In fact, the track record in this regard is poor. The nearly wholesale abandonment of nuclear power, for example, has traded local environmental risks for what some say will be a global climate change catastrophe due to fossil fuel use. In addition, the subsidy has to be paid by someone, potentially diverting funding of beneficial activities to non-cost-effective ones.

Subsidy of basic research

The one area that most economists might argue deserves public subsidy is basic research. The difference between basic and applied research is that the former may be more expensive than any one market innovator could afford, and does not typically enjoy the profit prospects of the latter.

In summary, acceleration of technological innovation seems best served by levying charge on carbon emissions. Most subsidies are either likely to be ineffective (inherently, or due to incompetence in picking winners), or duplicative of the incentives provided by pricing emissions externalities. There may, however, be some justification for subsidizing basic research that bears upon carbon technology.

Congestion Pricing

Congestion pricing is a policy that economists have advocated for many over 50 for reasons other than climate change considerations. This author has studied and advanced the notion of congestion pricing for over 30 years. Economists believe that such pricing better reflects the impact of additional vehicles on the speed of the traffic stream under high volume conditions. Current mechanisms of road pricing (the gas tax, primarily) are insensitive to the scarcity of peak road capacity. This under-pricing of scarce peak roadway capacity distorts trip making, location decisions, and roadway authorities' tendencies to add new capacity. All of these effects have an adverse effect on the carbon footprint of travel and dissipate valuation time resources of regional labor.

Thus, a side effect of congestion pricing would be reduction in low-value trip making, and encouragement of time-, fuel- and carbon sparing travel and mode choice behavior. Vehicle miles traveled (VMT) would be reduced, especially in the peak period, but likely also in daily traffic. In addition, reducing turbulence of traffic ("stop-and-go conditions") reduces both fuel consumption and emissions.

The results of a regional implementation experiment in the Puget Sound Region (for which this author was a principal investigator) suggest that pricing for congestion alone on the region's road network would reduce total VMT by about six to seven percent, and generate economic benefits of $28 billion over a thirty-year period in present value terms. Relative to the costs of implementing the strategy, the economic benefits are dramatic: the estimated benefit-cost ratio is over six-fold, suggesting that the effects on the regional economy would be unusually potent (Puget Sound Regional Council, 2008).

Congestion pricing should be implemented on its own merits. However, because it actually generates *positive* economic benefits by sparing another, valuable resource (travelers' time) its economic footprint may be positive, rather than negative. Hence, it is one of the few carbon-sparing policies that actually improves, rather than degrades, economic welfare.

Whereas carbon taxes, set at a level that emulates the social cost of carbon emissions, would be on the order of a fraction of a cent to a cent or so per VMT, peak period congestion levies may easily be in the 25 to 65 cents per VMT on congested facilities. Thus, congestion pricing may be a case where doing something to generate economic benefits may indirectly be a good first step in managing carbon emissions.

TABLE 3

Summary of energy-economy causation research

		Causality Finding		
Author	Country Studied	Energy causes GDP	GDP causes Energy	No Causality
Stern (1993)	US	X	X	
Stern (2000)	US	X	X	
Lee (2006)	US	X	X	
Abosedra and Baghestani (1989)	US		X	
Akarca and Long (1980)	US			X
Yu and Choi (1985)	US			X
Yu and Hwang (1984)	US			X
Cheng (1995)	US			X
Erol and Yu (1987)	Japan	X	X	
Erol and Yu (1987)	Canada	X		
Erol and Yu (1987)	Italy		X	
Erol and Yu (1987)	West Germany		X	
Erol and Yu (1987)	France			X
Erol and Yu (1987)	UK			X
Yu and Choi (1985)	UK			X
Ghali and El-Sakka (2004)	Canada	X	X	
Soytas and Sari (2003)	Italy		X	
Soytas and Sari (2003)	France	X		
Soytas and Sari (2003)	Germany	X		
Soytas and Sari (2003)	Japan	X		
Lee (2006)	Canada	X		
Lee (2006)	France		X	
Lee (2006)	Italy		X	
Lee (2006)	Japan		X	
Soytas and Sari (2006)	Canada	X	X	
Soytas and Sari (2006)	Italy	X	X	
Soytas and Sari (2006)	Japan	X	X	
Soytas and Sari (2006)	UK	X	X	
Soytas and Sari (2006)	France	X		
Soytas and Sari (2006)	US	X		
Soytas and Sari (2006)	Germany		X	
Narayan and Smyth (2008)	G-7 Panel	X		

Endnotes

1. See Keenlyside (2008), for example, who most recently raised a furor the journal *Nature* amongst climate management advocates with his prediction of decadal cooling.

2. Oregon Revised Statutes §468A.205. Oregon's statute identifies a greenhouse gas as any gas that contributes to anthropogenic global warming including, but not limited to, carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

3. The dominant precursor of acid rain in the U.S. is sulfur dioxide from coal-fired power plants in the northeast and midwest. These emissions are the focus of the acid rain program created by Title IV of the Clean Air Act Amendments of 1990 that created a cap-and-trade program. Title IV created a cap on utility sulfur dioxide emissions from electric generating units, to be implemented in two phases.

4. The Organisation for Economic Co-operation and Development (OECD) is an international organisation of thirty countries that accept the principles of representative democracy and free-market economy. OECD members are considered to be the most economically advanced countries in the world.

5. This reflects the authors' understanding of the Western Climate Initiatives' potential framework to estimate economic impacts. The Initiative has not published any estimates of economic impacts associated with its reduction goals and its cap-and-trade scheme. To date, it has published a framework document that describes the inputs, assumptions, and modeling approach it intends to use to estimate impacts (ICF Consulting Canada, 2008). The Initiative's potential approach uses an energy market model to simulate changes in the supply and demand for different sources of energy in response to different policy scenarios. The simulation model uses ENERGY 2020, an integrated multi-region energy model that provides detailed all-fuel demand and supply sector simulations. ENERGY 2020 can be linked to a detailed macroeconomic model to determine the economic impacts of energy/environmental policy and the energy and environmental impacts of national economic policy.

6. Most studies that have found causality have found that changes in energy consumption cause changes in income (Narayan and Smyth, 2008; Soytas and Sari, 2006; Thoma, 2004; Stern, 2000, 1993). (For the U.S., results from Soytas et al. (2007) suggest Granger causality from energy consumption to real GDP. While the authors fail to reject the hypothesis at a 10 percent level of confidence, the p-value (0.1599) suggests that Granger causality is more likely than not.) Earlier studies have found causation going the other way (Abosedra and Baghestani, 1991; Kraft and Kraft, 1978). One study has found bi-directional causality (Lee, 2006).

7. Energy payback is the recovery (period) of the energy spent for manufacturing of the respective technical energy systems, also called harvesting ratio (ISO 13602).

8. See, for example, United States Department of Energy (2004).

9. Carnegie Mellon University Green Design Institute (2008).

10. See, for example, Zhang et al. (2006) and Sawtelle (2007).

11. Own source revenues are the total taxes, charges and fees raised at the state and local level, excluding utility, liquor store, and insurance trust fund revenues. Total revenues are equal to own source revenues plus federal funds.

Sources

Abosedra, S. and Baghestani, H. (1991). New evidence on the causal relationship between United States energy consumption and gross national product. Journal of Energy and Development, 14(2):285292.

Akarca, A.T., Long, T.V., 1980. On the relationship between energy and GNP: a re-examination. Journal of Energy and Development 5, 326331.

Anger, N. and Oberndorfer, U. (2008). Firm performance and employment in the EU emissions trading scheme: An empirical assessment for Germany. Energy Policy, 36(1):1222.

Bretschger, L. (2005). Economics of technological change and the natural environment: How effective are innovations as a remedy for resource scarcity? Ecological Economics, 54(23):148163.

Burtraw, D., Evans, D. A., Krupnick, A., Palmer, K., and Toth, R. (2005). Economics of pollution trading for SO2 and NOx. Annual Review of Environment and Resources, 30:253289.

Carnegie Mellon University Green Design Institute (2008). Economic input-output life cycle assessment (EIO-LCA), US 1997 industry benchmark model. http://www.eiolca.net, accessed September 15, 2008.

Cheng, B.S., 1995. An investigation of cointegration and causality between energy consumption and economic growth. Journal of Energy and Development 21, 7384.

Convery, F. J. and Redmond, L. (2007). Market and price developments in the European Union emissions trading scheme. Review of Environmental Economics and Policy, 1(1):88111.

Coondoo, D. and Dinda, S. (2002). Causality between income and emission: A country group-specific econometric analysis. Ecological Economics, 40(3):351367.

Coondoo, D. and Dinda, S. (2006). Income and emission: A panel data-based cointegration analysis. Ecological Economics, 57(2):167181.

Ellerman, A. D. and Buchner, B. K. (2007). The European Union Emissions Trading Scheme: Origins, allocation, and early results. Review of Environmental Economics and Policy, 1(1):6687.

Ellerman, A. D. and Joskow, P. L. (2008). The European Union's emissions trading system in perspective. Pew Center on Global Climate Change. http://www.pewclimate.org/docUploads/EU-ETS-In-Perspective-Report.pdf, retrieved September 11, 2008.

Erol, U., Yu, E.S.H., 1987. On the relationship between electricity and income for industrialized countries. Journal of Electricity and Employment 13, 113122.

Evans, D. A. and Kruger, J. A. (2006). Taking up the slack: Lessons from a cap-andtrade program in Chicago. Resources for the Future. http://www.rff.org/rff/Documents/RFF-DP-06-36.pdf, retrieved July 16, 2008.

Ghali, K.H., El-Sakka, M.I.T., 2004. Energy use and output growth in Canada: a multivariate cointegration analysis. Energy Economics 26, 225238.

Hepburn, C., Grubb, M., Neuhoff, K., Matthes, F., and Tse, M. (2006). Auctioning of EU ETS Phase II allowances: How and why? Climate Policy, 6(1):137160.

ICF Consulting Canada (2008). Economic analysis and modeling support to the Western Climate Initiative: ENERGY 2020 model inputs and assumptions. Western Governor's Association, July 15, 2008 draft. http://www.westernclimateinitiative.org/ewebeditpro/items/O104F18738.pdf, retrieved August 12, 2008.

International Monetary Fund (2008). World economic outlook database. April.

Joskow, P. L. (2001). California's electricity crisis. Oxford Review of Economic Policy, 17(3):365388.

Keenlyside, N. S. et al., (2008). Advancing decadal-scale climate prediction in the North Atlantic sector, Nature 453, 84-88 (1 May 2008)

Kosobud, R. F. (2007). Trading or taxes in the regulatory control of air polluting emissions. Dialogue, 15(1):1215.

Kosobud, R. F., Stokes, H. H., Tallarico, C. D., and Scott, B. L. (2004). The Chicago VOC trading system: The consequences of market design for performance. Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research. http://tisiphone.mit.edu.proxy.lib.pdx.edu/RePEc/mee/wpaper/2004-019.pdf, retrieved July 16, 2008.

Kraft, J. and Kraft, A. (1978). Relationship between energy and GNP. Journal of Energy Development, 3(2):401403.

Lee, C.-C. (2006). The causality relationship between energy consumption and GDP in G-11 countries revisited. Energy Policy, 34(9):10861093.

Lee, C.C., 2006. The causality relationship between energy consumption and GDP in G-11 countries revisited. Energy Policy 34, 10861093.

Liddle, B. 2007, 'Long-Run Relation among Motor Fuel Use, Vehicle Miles Traveled, Income, and Gas Price for the US', paper presented at the 27th USAEE/IAEE North American Conference 'Developing and Delivering Affordable Energy in the 21st Century, Houston, Texas, 16-19 September.

Metcalf, G. E., Paltsev, S., Reilly, J., Jacoby, H., and Holak, J. F. (2008). Analysis of U.S. greenhouse gas tax proposals. National Bureau of Economic Research. Working Paper 13980.

Narayan, P. K. and Smyth, R. (2008). Energy consumption and real GDP in G7 countries: New evidence from panel cointegration with structural breaks. Energy Economics, 30(5):23312341.

Newell, Richard G. (2004). “Energy Efficiency Challenges and Policies,” The Pew Center on Global Climate Change and the National Commission on Energy Policy, The 10-50 Solution: Technologies and Policies for a Low-Carbon Future, Workshop Proceedings, Chapter 17.

Nordhaus, W. D. (2007). To tax or not to tax: Alternative approaches to slowing global warming. Review of Environmental Economics and Policy, 1(1):2644.

Nuclear Energy Institute (2008). World nuclear power generation and capacity, 2007. http://www.nei.org/filefolder/World Nuclear Power Generation and Capacity 2.xls, retrieved August 13, 2008.

Oregon Governor's Advisory Group on Global Warming (2004). Oregon strategy for greenhouse gas reductions. State of Oregon. http://www.oregon.gov/ENERGY/GBLWRM/docs/GWReport-FInal.pdf, retrieved August 26, 2008.

Orszag, P. R. (2008). Containing the cost of a cap-and-trade program for carbon dioxide emissions. Testimony before the Committee on Energy and Natural Resources United States Senate, Congressional Budget Office. http://energy.senate.gov/public/files/OrszagCBOTestimony052008.pdf, retrieved August 12, 2008.

P.K. Narayan, R. Smyth, 2008. Energy consumption and real GDP in G7 countries: New evidence from panel cointegration New evidence from panel cointegration with structural breaks, Energy Economics 30 (2008) 23312341

Pozdena, Randall (2008). Vehicle Miles Traveled and the Economy: The Challenge for Climate Policy, Bi-Partisan Policy Commission, forthcoming.

Puget Sound Regional Council, Traffic Choices StudySummary Report, April 2008. http://psrc.org/projects/trafficchoices/summaryreport.pdf, accessed September 2008.

Sawtelle, B. (2007). Analyzing the link between real GDP and employment: An industry sector approach. Business Economics, 42(4):4654.

Schmalensee, R., Joskow, P. L., Ellerman, A. D., Montero, J. P., and Bailey, E. M. (1998). An interim evaluation of sulfur dioxide emissions trading. Journal of Economic Perspectives, 12(3):5368.

Sijm, J., Neuhoff, K., and Chen, Y. (2006). CO2 cost pass-through and windfall profits in the power sector. Climate Policy, 6(1):4972.

Smith, S. and Swierzbinski, J. (2007). Assessing the performance of the U.K. Emissions Trading Scheme. Environmental and Resource Economics, 37(1):131158.

Soytas, U. and Sari, R. (2006). Energy consumption and income in G-7 countries. Journal of Policy Modeling, 28(7):739750.

Soytas, U., Sari, R., 2003. Energy consumption and GDP: causality relationship in G7 countries and emerging markets. Energy Economics 25, 3337.

Soytas, U., Sari, R., 2006. Energy consumption and income in G7 countries. Journal of Policy Modeling 28, 739750.

Soytas, U., Sari, R., and Ewing, B. T. (2007). Energy consumption, income, and carbon emissions in the United States. Ecological Economics, 62(34):482489.

Stagnaro, C. (2008). Europe 2020: An alternative proposal. Istituto Bruno Leoni. http://brunoleonimedia.servingfreedom.net/Papers/IBL_Report_CarbonTax_eng_print.pdf, retrieved July 16, 2008.

State of Oregon (2008). Historical annual and quarterly data tables, other, 19902015. Office of Economic Analysis. http://www.oregon.gov/DAS/OEA/docs/economic/econdata/other-annual.xls, retrieved August 12, 2008.

Stavins, R. N. (1998). What can we learn from the grand policy experiment? Lessons from SO2 allowance trading. Journal of Economic Perspectives, 12(3):6988.

Stavins, R. N., Jaffe, J., and Schatzki, T. (2007). Too good to be true? An examination of three economic assesssments of California climate change policy. AEI-Brookings Joint Center for Regulatory Studies. http://www.reg-markets.org/publications/abstract.php? pid=1151, retrieved September 11, 2008.

Stern, D. I. (1993). Energy and economic growth in the USA: A multivariate approach. Energy Economics, 15(2):137150.

Stern, D. I. (2000). A multivariate cointegration analysis of the role of energy in the US macroeconomy. Energy Economics, 22(2):267283.

Stern, D.I., 1993. Energy and economic growth in the USA. Energy Economics 15, 137150. Stern, D.I., 2000. Multivariate cointegration analysis of the role of energy in the US macroeconomy. Energy Economics 22, 267283.

Thoma, M. (2004). Electrical energy usage over the business cycle. Energy Economics, 26(3):463485.

United States Bureau of Economic Analysis (2008). Gross domestic product by state.

United States Census Bureau (2005). State interim population projections by age and sex, 20042030; Table 1: Ranking of census 2000 and projected 2030 state population and change. http://www.census.gov/population/projections/PressTab1.xls, retrieved August 26, 2008.

United States Census Bureau (2008). Federal, state, and local governments: State and local government finances.

United States Department of Energy (2004). PV FAQs. Office of Energy Efficiency and Renewable Energy. http://www.nrel.gov/docs/fy05osti/37322.pdf, retrieved September 10, 2008.

United States Environmental Protection Agency (2002). An evaluation of the South Coast Air Quality Management District's Regional Clean Air Incentives Marketlessons in environmental markets and innovation. http://www.epa.gov/region09/air/reclaim/reclaim-report.pdf, retrieved September 11, 2008.

United States Government Accountability Office (2008). Climate change: Expert opinion on the economics of policy options to address climate change. GAO-08-605.

Western Climate Initiative (2007). Statement of regional goal. http://www.westernclimateinitiative.org/ewebeditpro/items/O104F13006.pdf, retrieved August 12, 2008.

Western Climate Initiative (2008). Draft design of the regional cap-and-trade program. http://www.westernclimateinitiative.org/ewebeditpro/items/O104F18808.PDF, retrieved July 23, 2008.

Yu, E.S.H., Choi, J.Y., 1985. The causal relationship between energy and GDP: an international comparison. Journal of Energy Development 10, 249272.

Yu, E.S.H., Hwang, B.K., 1984. The relationship between energy and GDP: further results. Energy Economics 6, 186190.

Zhang, M., Gourley, S., and Soriano, F. (2006). Analysing the terms of trade effect on GDP and employment in the presence of low real unit labour costs. Australian Bureau of Statistics. http://www.pc.gov.au/data/assets/pdf file/0019/61066/zhang2.pdf, retrieved September 10, 2008.

About Cascade Policy Institute: *Founded in 1991, Cascade Policy Institute is Oregon's premier policy research center. Cascade's mission is to explore and promote public policy alternatives that foster individual liberty, personal responsibility and economic opportunity. To that end, the Institute publishes policy studies, provides public speakers, organizes community forums and sponsors educational programs.*

Cascade Policy Institute is a tax-exempt educational organization as defined under IRS code 501(c)(3). Cascade neither solicits nor accepts government funding and is supported by individual, foundation and business contributions. Nothing appearing in this document is to be construed as necessarily representing the views of Cascade or its donors. The views expressed herein are the author's own.