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William C. Whitesell
Excerpt
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Introduction

This book is intended to offer value to anyone interested in the science and economics of climate change. The text is suitable for use in an interdisciplinary course on climate science and economics. The comprehensive framework presented here could also provide value for scientists, economists, and policy analysts who already have a thorough knowledge of some aspects of climate issues. The work incorporates a survey of the latest journal articles, working papers, and books on climate change issues as of the time of writing. For anyone who has tried to absorb the thousands of pages written by the Nobel-prize winning Intergovernmental Panel on Climate Change, the presentation below will hopefully be seen as mercifully concise yet still informative.

The analysis also reflects a unique perspective of the author. Although I have long been deeply interested in earth sciences, I worked full time on climate issues only in the last several years. For nearly two decades prior to that, I held a day job as an economist at the Federal Reserve Board – an officer responsible for some of the staff work on interest rate management. The history of the Federal Reserve and of central banking around the world holds important lessons for climate policy. Communicating those lessons is one key motive for writing this book.

Since its creation early in the twentieth century, the Federal Reserve has made numerous mistakes in the conduct of monetary policy. A failure to understand the role of the financial sector of the economy contributed to the Great Depression of the 1930s. A misunderstanding of the causes of inflation led to the Great Inflation of the 1970s. In other countries, the framework for money policy was inappropriate because central banks lacking independence tended to generate inflationary extremes. More recently, though not entirely the responsibility of central banks, inadequate regulation of complex new financial instruments and markets helped generate the financial collapse of 2008.

Central banks have adjusted their policies and procedures substantially over the years in response to improved understanding of the economy and of the role of monetary policy. Since the early 1980s, inflation has been reduced to modest levels in most countries around the world. Periods of economic expansion have lasted far longer than was the case in times past. Although lessons regarding the recent financial crisis and economic downturn have yet to be fully digested, the forceful and comprehensive responses of policy makers have averted the worst of the possible outcomes.

Undoubtedly, errors will be made in climate policy as well, especially in the early years of policy formulation and implementation. Unless timely adjustments are made to correct such errors when they become evident, the consequences could be harrowing. On one hand, weak and ineffective policies could mean extreme climate change in the future and great damage to society. On the other hand, poorly designed climate policies could cause an enormous waste of resources and substantial impairment of economic prospects.

Although climate issues are different in many respects from those affecting monetary policy, the similarities are also numerous. Comparable concerns arise regarding the organizing frameworks for climate and monetary policy, including a trade-off between long-range goals and the short-run flexibility needed to avoid economic harm. In monetary policy, the long-run goal is avoiding inflation. In climate policy, the long-run goal is avoiding climate damage. In the short run of a year or two, a central bank's behavior can alter the amplitude of a business cycle for better or worse. An inflexible climate policy can cause unnecessary short-run economic harm, but a well-designed policy can smooth out its effects on the economy over time.

In the face of such trade-offs, the frameworks for monetary and climate policy each need to wrestle with issues regarding the independence and discretionary authority of the implementing agencies, and also the accountability mechanisms. In addition, the conduct of each type of policy involves a balancing of inherent two-sided risks. Many central banks now characterize their conduct of monetary policy as a process of risk management. Probabilities that the policy setting is too easy or too tight must be assessed, and the consequences of an error in either direction must be weighed. To understand the nature and magnitude of the risks, a central bank must learn all it can about the economy. It must also have complete information about the financial sector – the key channel through which monetary policy affects the economy.

Climate policy also is essentially risk management. Just as a central banker studies the economy, a climate policy maker must assess possible future climate outcomes. As a central bank must predict how its policies are transmitted through the financial sector, climate policy must assess its effects on the economic sectors that emit greenhouse gases. An understanding of climate history and of the prospects for emitting sectors, covered in Part One of the book, is essential for making informed decisions regarding the framework and conduct of climate policy.

A risk management approach includes a sense of humility about the state of our knowledge. Economic and climate models have become increasingly sophisticated and as a result, forecasting has improved dramatically. However, we need to remain suspicious about model predictions and sensitive to the underlying assumptions that could dramatically alter the outlook. Like the economy, the climate system is enormously complex and difficult to forecast. Fundamental uncertainties remain about key scientific parameters affecting those projections. We should also expect to be surprised about climate outcomes, just as we have often been surprised about the economy.

Uncertainties about climate science can be exaggerated, however, and uncertainty is no excuse for policy paralysis. The scientific enterprise always involves challenges to conventional understandings, but a policy maker need not give equal weight to all minority points of view that lack the evidence to gain general acceptance. Alternative perspectives do need to be considered, and some important issues remain controversial even within the scientific mainstream. However, the increasing scientific consensus about the risks in the climate outlook should not be taken lightly.

Policy makers need to consider the appropriate emphasis on the objectives of commitment and flexibility in climate policy frameworks. It may be hubris to lock into place the detailed specification of climate policy for decades to come. Risk management cannot be aptly conducted on automatic pilot. In the conduct of monetary policy, central bankers need continuous updates of their knowledge of the economy and the financial sector. In the conduct of climate policy, provision should also be made for policy to adjust to new information about the climate and emitting sectors.

The risks for climate policy seem asymmetric, and this imbalance in risks has important implications for the choice of policy instruments. In both monetary and climate policy, trade-offs exist between the use of quantity and price instruments. Central bankers have wrestled with the issue of whether to try to control the economy using the quantity of money or the level of short-term interest rates (a price measure). An assessment of uncertainties plays a key role in determining the appropriate choice between these two types of policy instruments. The presence of uncertainty alone does not determine the choice. Rather, the result depends on the consequences of uncertainty. A classic paper in monetary theory recommended the use of a quantity instrument (the money supply) if uncertainty about the demand for money was relatively small and uncertainty about the effects of interest rates on the economy was large (Poole, 1970).[1] In modern economies, uncertainty about the demand for money has increased and uncertainty about the effects of interest rates has declined. Financial innovations have created numerous close substitutes for holding deposits, adding to the uncertainty about money demand. Also, deregulation and integration of financial markets have increased the reliability of the interest rate instrument. Largely for these reasons, most central banks now implement monetary policy by setting targets for short-term interest rates rather than the quantity of money.

As discussed in Part Two of the book, climate policy also faces a trade-off between quantity and price instruments. A price instrument could be a carbon tax. A quantity instrument could be a hard limit on the quantity of greenhouse gas (GHG) emissions. A seminal paper on uncertainty in environmental policy found a result resembling that for monetary policy instruments (Weitzman, 1974). In the context of air pollution, this result argues that it is preferable to use a price instrument if the incremental benefit of reducing emissions is about the same across the range of possible emissions (a flat marginal climate damage curve). A price instrument then avoids paying too much when emission reduction costs are greater than expected and it avoids high-cost environmental damage when emission reductions are cheaper than expected. However, if incremental environmental damage rises steeply with each extra unit of emissions (an upward-sloped marginal damage curve), the quantity instrument of an emission limit is preferable.

The presence of climate tipping points is often cited as a rationale for quantity rather than price controls. Indeed, on reaching a tipping point, the environmental damage curve would begin to rise steeply. As discussed in Chapter 1 of this book, Earth's history has demonstrated an extraordinary range of global average temperatures and climate outcomes well before any influence from human activities. A rapid shift to a dramatically different climate than the fairly stable one we have enjoyed over the last 10,000 years would not be harmful to the planet but could impose catastrophic costs on human society. A careful look at the current level of scientific

[1] References are given at the end of the book. Most are peer-reviewed journal articles, but several textbooks and popular books are also mentioned. For convenience, the text mentions only the first name of coauthored papers.

understanding, however, indicates that we do not have a good idea about when a global tipping point may occur.

Nevertheless, the structure of risks around potential climate outcomes is unbalanced in a way that gives an advantage to a quantity instrument over a price instrument. Consider the potential consequences of a climate policy that is wrong in either direction. On one hand, an overly strict policy would impose higher-than-necessary costs on the economy. On observing those high costs, the policy could be reversed before too long, if necessary through legislative action. The economy would likely recover several months after the policy setting was loosened. On the other hand, consider a climate policy that fails to do enough. The evidence that policy action is insufficient may remain ambiguous for some years, because the climate system responds to a new stimulus with considerable delays. Nevertheless, once climate change begins, it develops some momentum on its own. Feedback mechanisms amplify the initial movement. By the time it is certain that policy is too weak, it will be too late to make an effective adjustment; further damage from climate change will be inevitable. The costs to society could then be many times more than the costs of earlier effective action. Thus, the consequences of an insufficient climate policy are more severe than those of a policy error on the other side. A quantity instrument provides greater assurance of controlling the risk of unexpectedly large climate change. A price instrument, by contrast, adds uncertainty about the responses of individuals and businesses to the price signal.

On practical political grounds also, a pure price policy, such as a carbon tax, may be unrealistic. In addition, international agreements on climate policies have focused on a quantity instrument in the form of emission reduction commitments. The international dimension is particularly important in the case of GHGs that mix fairly quickly throughout the world's atmosphere and remain aloft for decades and centuries. Other pollutants that have more localized effects can be addressed adequately with domestic policies, but GHGs cannot be controlled unless all countries with substantial emissions participate in the effort.

Our alternatives, however, are not limited to a stark choice between a carbon tax and an inflexible limit on GHG emissions. A variety of measures can be used to ensure that cumulative emissions of GHG remain contained while the costs of controlling emissions are also kept within some bounds. A cap-and-trade program is a market-based policy approach with differing design options that adjust the emphasis between the predictability of prices and the predictability of quantities. Similar to a carbon tax, cap-and-trade uses a price signal to motivate a broad range of possible emission reduction activities, thereby reducing the cost of achieving environmental goals compared with the more narrowly targeted "command-and-control" approaches.

With cap-and-trade, the overall emissions of economic sectors included in the program are subject to a limit, or cap. The government distributes emission allowances (for free or through auctions) up to the cap level. The allowances (or permits) can be traded among firms, which limits costs relative to a mandate requiring each firm to reduce emissions: Firms that find it expensive to reduce emissions can instead buy an allowance from firms having cheaper emission abatement opportunities. Offset credits (emission reductions achieved in projects outside the cap-and-trade system) can also be used to lower compliance costs within the system.

Unlike a carbon tax, a cap-and-trade program creates new markets for allowances and offsets. A large, new carbon market entails risks of manipulation and excess speculation. Dramatic fluctuations in carbon prices, similar to the booms and busts in energy markets in recent years, would undermine the incentive for investments in emission reduction. Large price swings would cause errors in investment choices, with some firms implementing emission abatement projects that are too expensive whereas others fail to proceed with lower-cost projects that should go forward. Moreover, wide fluctuations in prices could provide cover for manipulative activities or at least raise suspicions that might undermine political support for the program.

A carbon market, created by regulation, need not have prices as volatile as those in an ordinary commodity market. With careful design, opportunities for manipulation and excess speculation can be avoided while incentives for emission reductions are still maintained. One option to achieve that result is a managed price approach that borrows from the procedures that the Federal Reserve and other central banks use to manage interest rates. Central banks announce a target interest rate that guides private trading in a huge overnight loan market. In addition, they use auctions to adjust the supply of money in that market, which helps achieve the target interest rate. Through these procedures, central banks are quite successful at managing interest rates. Trading rarely occurs very far from the target rate, despite the limited government interventions through auctions, the diverse group of market participants, and the enormous volume of private trading (several hundred billion dollars a day in the United States). Because interest rates are kept close to the announced target, there is virtually no opportunity for manipulation of the market and no opening for the speculative bubbles that characterize other financial and commodity markets.

A similar approach could be used to manage prices in a large new carbon market. The government could choose an emission goal several years ahead (e.g., 2020). It could then publish a forecast of gradually rising allowance prices designed to achieve a smooth path of reductions in emissions toward the achievement of the intermediate-term emissions goal. In a given year, the government could announce a hard price target and adjust the supply of allowances in auctions as needed during the year to help achieve that target. At the end of the year, the government could make adjustments in its price forecast as needed to ensure achievement of the intermediate-term emissions goal. Prices would adjust, relative to expectations, from one year to the next, but not because of temporary factors affecting emissions only in a given year, such as fluctuations in the weather. The forecast path for prices would be adjusted only if persistent factors threatened achievement of the intermediate-term emission goal.

Several other design options could be considered for a cap-and-trade program, or for dynamically adjusting carbon taxes, that would also provide some balance between the predictability of prices and the predictability of emissions. Even though cap-and-trade systems have been operational in the United States and Europe for some time now, the experience with different design options in a large, actively traded market is actually rather limited. We do not as yet know what is the best-practice approach for such systems. In those circumstances, it is advisable for legislation to allow mid course corrections to be made in program design. If so, a managed price approach may be an apt choice for the early years of the program because it would allow a new market to develop without the risks of manipulation and excess speculation.

Careful design of a domestic carbon market will not be sufficient to ensure that environmental goals are met; instead, a global effort is needed. Domestic climate policies therefore should have one eye on the international arena. Incentives need to be created for other countries to make substantial efforts, particularly for developing countries struggling to catch up to the living standards of richer nations. Today's advanced economies chose the cheapest path of development, without awareness of the effects on the climate of high emissions of GHG. The world community needs to find a strategy for today's developing countries to raise their living standards as well, but without repeating the errors of high-emission growth. Advanced economies have a responsibility, recognized in a framework treaty ratified by most countries, to assist developing countries in achieving low-carbon growth and adapting to climate change.

International mechanisms were established under the Kyoto Protocol to begin accomplishing these goals. They included enforceable emission reduction commitments by advanced economies and offset projects to be purchased from developing countries. A new international agreement is under negotiation to take effect after the Kyoto Protocol expires in 2012. The Copenhagen Accord of December 2009 brought agreement on a global temperature goal, strengthened reporting from developing countries, and increased financial aid from advanced economies. However, considerable further work is needed to complete the details of the international climate framework for the post-2012 period. Under the Kyoto Protocol and the Copenhagen Accord, individual countries can choose national climate programs from a wide variety of options. Many countries are now considering the implementation of domestic cap-and-trade systems. Given the limited experience to date with such systems, there are advantages of allowing experimentation with alternative designs. Eventually, however, greater harmonization of cap-and-trade programs would allow the systems to be linked, which could result in a unified world price for carbon. A common price signal would provide an incentive for all lower-cost emission abatement projects around the world to be implemented, while higher cost projects are avoided. The global emission reduction goal could then be achieved at the lowest possible cost. International coordination of climate policies is essential to work toward achieving that outcome. Coordination is also likely needed to help spur stronger actions and to address concerns regarding the effects of differing climate policies on the competitiveness of industries in different countries.

Controlling emissions of GHG is not the only possible way to prevent global warming. A variety of geo-engineering options have also been suggested for further investigation, including measures to shield the planet from some solar radiation and methods for enhancing the natural sequestration of GHG. As of now, none of these proposals can be counted on as a panacea. Considerable further research is required to assess the prospects of such schemes and the risks that they could inadvertently cause other types of environmental damage.

Finally, although a variety of adverse scenarios need to be contemplated while studying climate policy, we need not be motivated only by fear. We can allow ourselves to be fascinated by the story of our planet's wild climate history. We can deepen awareness of how human activities affect the climate. With objectivity, we can weigh the economic realities of climate policy options. And we can share a vision of the extraordinary and positive role humans can play in the planet's future. Never before in the nearly 4 billion years of life on Earth has a species arisen with the ability to take conscious control of the climate. Whether we like it or not, we are now the managers of the planet's future.

PART ONE

EARTH'S CLIMATE HISTORY AND OUTLOOK

A study of climate history is an essential foundation for climate policy. Earth's history gives us an appreciation of the wide swings in the types of climate that are possible. It informs us of the forces that have generated those fluctuations and have stabilized the planet's temperature at very different levels for long periods of time. It provides estimates of the temperatures associated with much greater or much less planetary ice cover than we have today. And it offers case studies of episodes of climate change that bear an eerie resemblance to scenarios that could characterize our future.

A sense of the limits of our scientific knowledge is also essential. Uncertainties about the science place extra burdens on the design of policy. We cannot merely implement what "science" tells us to do, because the science itself is evolving and controversial. To make wise policy, we need to assess what is known with confidence and what remains highly speculative. Our uncertainty will condition the degree of flexibility we should build into the framework for policy.

ONE

Salient Events of Climate History

THE FIRST 4 BILLION YEARS

In its long history, Earth has seen extremes of fire and ice that would have made human life impossible. The planet was born in a cauldron of volcanic eruptions and million-megaton impacts from outer space. Any hydrogen or helium in the early atmosphere soon escaped into space. In time, only heavier molecules remained, including nitrogen and the greenhouses gases: water vapor, carbon dioxide, methane, and ammonia. No free oxygen was present.

A gas is called a greenhouse gas (GHG) because it lets sunlight through but absorbs outgoing heat radiation from the surface of the Earth. The absorbed heat energy is reradiated in all directions. Because some of it returns to the surface, the GHG boosts the planet's temperature. If no GHG were present in the atmosphere, the world's current average temperature would be about 0°F rather than the actual level of 58°F (14.5°C).

About half a billion years after its formation as a planet, Earth had cooled enough for rain to fall and the oceans to form. Life emerged soon – in geological terms – thereafter. The Sun was weaker back then, emitting only about 70% of the radiation of today. The Earth would have frozen solid were it not for the high concentrations of GHG in the atmosphere. The Sun was less radiant than today largely because it had less helium. As with any star, nuclear fusion in the core of the Sun converts hydrogen into helium. Because helium is heavier than hydrogen, the density of the Sun gradually increases, boosting the gravitational pull at its core and consequently making it contract and intensifying its radiant output.

Although the planet was warmed by its GHG, no stratospheric ozone layer had formed to provide protection from the Sun's ultraviolet rays. Therefore, although bacteria thrived on the plentiful organic molecules in the ocean,