Chapter 5. The economic costs of climate change policy: an illustration

5.1 Abstract

Effort to develop a mandatory climate policy is accelerating and it seems likely that a national market-based strategy for dealing with climate change is on the near term horizon. Key provisions are likely to include a cap on selected greenhouse gas (GHG) emissions, an institutional framework for creating a nationwide emissions permit market, a welcoming integration of abatement opportunities from external domestic and international sources, and recognition of a broad range of features designed to soften economic impacts or promote economic efficiency. Prompted by a national sense of urgency, businesses, states and regions also are actively engaged in designing and implementing their own variations on these themes. Together, it is clear that there is growing support for a market-based complement to the technology orientation that characterizes current U.S. policy.

In the parlance of finance, climate change policy poses the ultimate present value problem. The benefits of current policy actions may not materialize for a very long time and discounting them to the present, even at very low discount rates, may not compensate today's costs. However, the continuing atmospheric accumulation of greenhouse gases is projected to have far reaching consequences for the earth's climate in coming decades. Although knowledge of the direct and indirect impacts of climate change is currently incomplete, damages to the environment and economy are inevitable, if not occurring already (Smith, J.B., 2004 and Jorgenson et al., 2004). This inevitability provides the ultimate justification for policy intervention.

There are two failures of the market economy that justify public initiatives on climate change. The first is a technological problem in that firms cannot capture all of the returns on their knowledge and technology investments which results in an economy-wide underinvestment in mitigation options. This underinvestment is compounded by the uncertainty that leads to thresholds on minimum financial performance or potential market size below which firms will not launch R&D or technological initiatives. The second problem arises from the divergence between "private" and "social" prices. Greenhouse gas emissions are related to the patterns of products and processes in production and consumption and these are strongly influenced by prevailing market

prices. Emissions are too high because market prices fail to internalize climate-related damages. When emissions-generating goods and services are priced properly, the benefits of avoided damages are reflected correctly in market prices and, so, reflect their social opportunity cost in use. The pricing arena calls for more direct emissions initiatives because the technology policies designed to remedy the first market failure are ill suited to address fully this second one (and vice versa). It is in dealing with this divergence in private versus social prices that the "cap and trade" mechanism gains its comparative advantage.

The suite of abatement remedies available will play a large part in just how large the ultimate cost of addressing climate change will be. This chapter joins a number of other economic analyses that have examined the pricing aspect of climate policy. It employs the Inter-temporal General Equilibrium Model (IGEM) of Dale Jorgenson Associates (DJA) to answer this question. While providing estimates of the economic costs of a market-based mitigation policy, there is an added and equally important objective of informing its actual design.

Climate change policy needs to be innovative and entrepreneurial. It needs a broad comprehensive vision. It needs to embrace all legitimate and measurable abatement strategies and all potentially competitive marketable options. It also needs to encompass complementary initiatives (tax policy, for example) that serve multiple objectives, perhaps, even beyond purely environmental concerns. Finally, it needs to succeed in achieving its ends with minimal economic consequence. By focusing on the interplay of policy and the economy, this effort identifies key provisional elements and adjustment mechanisms that serve this variety of needs.

The "policy" of this analysis approximates a modest first step at a comprehensive suite of provisions generally associated with cap and trade programs. After a voluntary and orderly phase-in, greenhouse gas (GHG) emissions are constrained to year 2000 emissions levels by 2010 and held there indefinitely. Not all emissions-generating activities are governed by this cap; households, small businesses and agriculture are exempt. The remaining so-called "covered" activities account for about 85% of all GHG emissions, a coverage level similar to recent proposals in the U.S. Senate. By today's standards, this is an extremely moderate cap in that the limit is fairly generous at the start and does not decline over time. In contrast, relative to their bases, the recent cap and trade proposals put forward in the U.S. Executive and Legislative branches are 25 to 100% more aggressive than the initiative analyzed here.

To facilitate compliance at the least possible cost in the scenario considered here, a national system of tradable emissions permits is established. Under the presumption of revenue neutrality, it is assumed that the allowances are auctioned to private industry with the proceeds then redistributed to households in lump-sum fashion. This is analytically equivalent to the other extreme in which all permits are distributed freely to the private sector with lump-sum taxes offsetting any losses in government revenues.

If marketable and verifiable compliance offsets exist beyond the "covered" processes and products, then up to 15% of the cap allowance can be met by these sources. This includes abatement offsets from households and small businesses, from forest-based domestic sequestration and from international permit trading with Canada, Japan, Australia, New Zealand, the European Union, Eastern Europe and the Former Soviet Union (the Annex I countries of the Kyoto Protocol). Like the allowance trading system, the inclusion of offsets reduces policy costs by recognizing and allowing the possibility of a broader array of lower cost abatement alternatives than is to be found within the scope of covered sources.[1]

Finally, the policy scenario allows the banking of permits with no limit on the amount of saving for future use.[2] Banking depends entirely on the time paths of permit prices, reflecting, as they do, present and future abatement costs, and interest rates. Of course, in reality, whether or not banking occurs also depends on uncertainty, which does not exist in the perfect foresight world of IGEM. In a policy without a safety valve (sometimes called a price cap), banking provides an opportunity to hedge against unexpected pricing surprises.[3] To isolate the pure effects of the emissions cap, permit

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[1] It is important to note that the data underlying the non-CO_2 abatement opportunities and the allowable external offsets from households, small businesses, domestic sequestration and international permit trading represent market-based emissions reductions from legitimate, verifiable sources – reductions which would not have occurred in the IGEM base case (without the policy scenario) and reductions that are additive to those from IGEM at a measurable opportunity cost in terms of the economy's productive resources.

[2] Borrowing is not considered in this analysis. It is assumed to be rendered uneconomic by reason of high borrowing costs and-or repayment penalties and by future permit price expectations.

[3] There are reasons why banking might not occur. Uncertainty about the future cost and availability of offsets or about a future change in emissions targets may eliminate the incentive to bank even if everything else is known and correct.

trading and alternative compliance opportunities, banking is considered only as a special case; all other model simulations are performed without banking.

Foremost among the analytical findings is that the economic burden of mitigation policy, while measurable, is small. The U.S. economy easily can accommodate a modest policy; this is evidenced not only in the IGEM simulations but also in the results from the other modeling efforts. By 2020, permit prices in IGEM reach \$6[4] per metric ton carbon dioxide equivalent ($MTCO_2E$)[5] with international permit trading and \$10 per $MTCO_2E$ with only domestic offsets. There are corresponding reductions in real GDP of 0.5% and 0.7%, respectively. By 2040, permit prices are in the range of \$22 per $MTCO_2E$ with a GDP loss of 1.2%. And while a 1.2% impact on a trillion dollar economy is a large number, spread over thirty-four years, this loss entails an almost imperceptible slowdown in economic growth.

At the industry level, energy prices – coal, oil, gas and electricity – are most affected, with coal more so than any other commodity. This is not surprising in that 90% of the year 2000 covered emissions are related to the use of coal (35%), oil (39%) and gas (16%). Domestic crude oil and gas extraction prices decline following the declines in overall oil and gas demand. This occurs under the formulation in IGEM that approximates an upward sloping oil and gas supply curve. All non-energy prices increase. Some – chemicals, stone, clay and glass, primary metals, electrical machinery (semiconductors) and services (waste management) – are affected both directly and indirectly as their emissions are "covered" by the policy scenario. Others like agriculture, food, paper, plastics, motor vehicles, trade and finance are affected only indirectly.

The production side of the economy is affected adversely. With the exception of agriculture, food and related activities, all industries, especially those related to energy, experience declines in output volumes. This results from not only higher prices and declining demands throughout the economy but also from the limitations on supply that arise from changes in labor and capital availability and from productivity.

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[4] All cost references are in year 2000 constant dollars.

[5] All greenhouse gas prices and quantities are in metric tons of carbon dioxide equivalent ($MTCO_2E$). To covert to metric tons of carbon equivalent (MTCE) prices must be multiplied and quantities must be divided by 3.667 (or 44/12).

The reactions to mitigation policy do not significantly affect consumption. The proportional reductions in real household spending are much smaller than the effects on overall income, spending and production. By 2020, consumption foregone is in the range of 0.1 to 0.2% of baseline levels and, by 2040, the loss increases to 0.5%. In dollar terms, policy costs are $33 per household in 2010, $158 per household in 2020 and $672 per household in 2040. If there is no possibility of foreign permit purchases, these per household costs rise to $84, $313 and $677, respectively. Nevertheless, at their worst in 2040, foregone consumption is less than the additional amounts households spent in 2007 relative to 2006 on gasoline, heating oil and natural gas due to their rising prices.

Overall, the estimated economic impacts of mitigation policy are small. They could be made even smaller through judicious use of complementary fiscal policies. All simulations in this exercise involve lump-sum transfers of permit and tax revenues. It is well-known that this is the least efficient recycling mechanism and, thus, the outcomes above are potentially larger than would be the case if another more efficient mechanism were employed. While the existence of a so-called "double dividend" is controversial, there is broad consensus that there are better and worse ways to redistribute permit revenues. Mitigation policies such as this ***can*** serve to alleviate even greater distortions elsewhere, for example, in labor and capital taxation. The end result may not be "win-win" for the environment and the economy but almost certainly further lowers the overall costs of mitigation policy.

Likely the second most significant analytical finding from this effort is that the benefits of competitive offsets from external sources are large. Their presence reduces significantly the already small costs and limits on them should not be developed independently from overall cost-benefit considerations. This conclusion also is robust across all the modeling efforts. Allowing the use of offsetting emissions from sources outside the cap – that is, households, small businesses, domestic sequestration and international permit purchases – substantially reduces the economic costs of the mitigation policy. In the longer term (2025-2040), the lower cost abatement options provided by the first 15% of these offsets more than halve the adverse policy impacts. For example, the 1.2% losses in GDP would be more than twice as large were it not for the 15% offsets. Nearer term (2010-2025), if international permit trading is allowed to compete with abatement from households, small businesses and domestic sequestration, the 15% offsets reduce policy costs by more than two-thirds as compared to the halving observed when only domestic alternatives are permitted.

Extending the use of offsets to 50% of the emissions cap even further reduces policy costs. The magnitude of these savings depends on the time horizon and the mix of external abatement options. The contributions of more generous offsets always begin small and increase with time. Offsets from international permit trading are, from the data provided, the cheapest and most plentiful of the external sources. With such trading, the 15% offset limit is reached prior to 2020 after which additional offsets begin to prove beneficial. Extending the offset limit from 15 to 50% reduces the policy scenario costs by an additional 30%, 2010-2025, and by an additional 50%, 2025-2040. If the additional offsets arise solely from domestic sources, these additional savings fall to 3% and 12%, respectively. This is because the external domestic options are only slightly less expensive than the internal compliance alternatives they displace but are much more expensive than abatement "purchased" from overseas.

The evidence indicates that there are diminishing net benefits associated with increasing the level of offsets from external sources. However, arbitrarily limiting their potential contribution below that economically justified only raises overall policy costs. Equally problematic is further restricting, in percentage or absolute terms, the role of these or any other competitive alternatives as the emissions constraint becomes more severe. In a series of simulations in which allowable emissions, post 2020, are reduced below 2000 levels and limits on external offsets follow the new cap, the benefits of more generous allowances diminish, not unexpectedly, as the emissions target is lowered and becomes more severe. If policy costs are a major concern, then any limits on potentially competitive abatement alternatives should be developed in the full context of policy costs and benefits. Holding such limits constant or reducing them clearly only raises the economic costs of mitigation policy and in fact suggests that an expansion of an offsets program might be justified over time (assuming that the offsets represent real, measurable, sustainable and incremental emissions reductions).

Finally, the benefits from external offsets increase as baseline emissions increase. Under higher base case emissions, the reductions in policy costs from the first 15% and the next 35% of these offsets exceed the gains observed under lower base case emissions. This too suggests that such limits should be determined by their economically competitive positions rather than by arbitrary restrictions.

Third, the findings of this analysis support more extensive near-term policy actions. The economic costs of modest emissions reduction policies are small and easily absorbed. Costs are substantially higher and less readily absorbed when policies become more aggressive, either by intent or by necessity due to higher baseline emissions. The benefits from input substitution, induced technical change and the development of new abatement opportunities such as those envisioned from external offsets materialize only gradually and only in the presence of recognizable market-based incentives. By extension, these signals are best generated by policies that directly affect prices and, thereby, permanently internalize the pricing externalities of climate change. Cap and trade policies, thus, are deemed essential complements to the technology initiatives that target underinvestment in R&D and productive capital.

Gradually more decisive steps, dual pronged and adopted early, prod market systems and behavior in the "right" direction; required actions will become more obvious and urgent as the damages from climate change increase and become more readily identified with their source.. A comprehensive climate change policy, crafted today with little or no cost to the overall economy, offers a valuable head start on the path to securing more substantial future payoffs from innovation, technical change and the creation of new, market-based alternatives. With costs as small as those determined here, there is no compelling reason to delay these future benefits or forcibly compress the schedule of their arrival.

In summary, this report offers a comprehensive analysis of a suite of climate policy initiatives associated with a cap and trade program with the goal of identifying those empirical and design issues that most influence the economic consequences of their enactment. Empirically, present-value policy costs heavily depend on the actual outcomes of household consumption-saving and labor-leisure decisions, the magnitudes of and any induced changes in sectoral demand elasticities and technological trends, and the resulting time paths of permit prices and market interest rates. From a design perspective, mitigation policies can be made much less costly if they jointly promote environmental and economic successes, if all legitimate and verifiable emissions-reducing alternatives are allowed to compete, and if the only limits on the use of competing abatement options are those arising from the marketplace. While these are the important conclusions from the present exercise, the more valuable next step is to place these policy costs within the context of the benefits they are purchasing.

5.2 Introduction

In facing the challenges of global climate change, the United States has yet to embrace any mitigation policy that involves a so-called “cap and trade” mechanism in which there is a constraint on allowable greenhouse gas (GHG) emissions along with a system of tradable emissions allowances. The reasons for this are numerous and varied (see, for example, McKibbin and Wilcoxen, 1997). Prominent among them is the notion that the nearer term economic costs associated with the imposition of a given “cap” are less than fully compensated by economic benefits occurring in the distant future; that is, the constraint is socially inefficient and sub-optimal. Add to this the complication that the nearer term costs are more readily identified and quantifiable while the longer term benefits are more ambiguous and uncertain and hesitancy on policy action becomes inevitable.

There are two failures of the market economy that justify public initiatives on climate change (Goulder, 2004). To the extent that the anthropogenic portion of climate change is a technological problem, the fact that firms cannot capture all of the returns on their knowledge and technology investments results in an economy-wide underinvestment in mitigation options. This underinvestment is compounded by the presence of uncertainties that give rise to thresholds on minimum financial performance or potential market size below which firms do not launch R&D or technological initiatives. To date, this market failure remains the primary focus of national climate change policy with technology-push being the order of the day.

But climate change is also a problem of the divergence between “private” and “social” prices. Past, present and future GHG emissions are related to the patterns of products and processes in production and consumption and these are strongly influenced by prevailing market prices. Emissions are too high (from, for example, over reliance on fossil fuels and the current mix of energy-consuming technologies) because market prices fail to internalize climate-related damages. When emissions-generating goods and services are priced properly, the benefits of avoided damages are reflected correctly in market prices and, so, reflect their social opportunity cost in use. The pricing arena calls for more direct emissions initiatives because the technology policies designed to remedy the first market failure are ill suited to address this second one (and vice versa). It is in dealing with this divergence in private versus social prices that the "cap and trade" mechanism gains its comparative advantage.

While no one denies the technological aspects of climate change, there is growing awareness of the need for a dual approach with technology-push on the one hand and emissions limits on the other. Businesses, localities, states and regions increasingly are engaged in the design and implementation of emissions control policies that complement their ongoing R&D and technology efforts. Among other things, these involve voluntary or mandatory emissions targets, performance incentives featuring both rewards and penalties and the beginnings of a network of interdependent allowance (permit) and offset markets (see, for example, www.pewclimate.org). These leading-edge policies are extremely well intentioned and, undoubtedly, will yield significant and measurable abatement leading to climate change benefits in the coming years. Still, climate change remains a global problem requiring national and international action and cooperation. It is into this larger framework that these sub-national components need be woven.

Although U.S. policy makers chose not to endorse the Kyoto Protocol, many legislators recognize the merits of a dual approach and the incremental value afforded by U.S. participation in an international "cap and trade" system. As such, several states (including ten in the northeast and six in the west) have initiated cap and trade proposals and at the national level there have been numerous greenhouse gas cap and trade proposals put forward in the 110^{th} and 111^{th} Congresses.

This analysis joins a small family of analyses that have analyzed U.S. cap and trade proposals. Each of these employs a unique model or model system to estimate their policy's impact on the U.S. economy, in general, and on its consumers, in particular. The emphasis in these analyses is on the economic outcomes of a mitigation initiative, components of it and variations in it.

This analysis follows a similar pattern but with a different focus. Here, the Intertemporal General Equilibrium Model (IGEM) of Dale Jorgenson Associates (DJA) is used to simulate the economy's reaction to the introduction of a cap and trade system. In this regard, the analysis is like those cited above. However, unlike earlier efforts, the experimental design in these simulations emphasizes the mechanisms of adjustment with particular attention devoted to important empirical questions and broader policy decisions that affect both the nature and magnitude of the observed outcomes. ***It must be recognized that this effort considers only the direct and indirect costs of mitigation policy. The estimated benefits of the avoided damages from climate change policy are not incorporated into the model simulations.*** Moreover, analytical choices in the data and operating assumptions of these simulations are intentionally conservative and are believed by these authors to establish an upper bound on IGEM's estimated policy costs.

The remainder of chapter is organized as follows. Section 5.3 presents the policy and data considerations for the IGEM simulations. Section 5.4 provides an overview of the effects of two pairs of variations on main policy themes – international permit trading and external offset opportunities. Section 5.5 explores, in detail, the mechanisms of adjustment common to all the model runs. Sections 5.6 compares key results from this exercise to those obtained from other models developed by Charles River Associates (Smith et al., 2003), the U.S. Energy Information Administration (EIA, 2003 and 2004), the Massachusetts Institute of Technology (Paltsev et al., 2003) and the Research Triangle Institute International (Ross et al., 2008). Section 5.7 focuses on two issues with potentially longer-run implications; these are banking and policy options beyond 2020. Section 5.8 revisits the details of Section 5.4 for a base case that entails higher energy and emissions growth over the period 2010-2025. Finally, Section 5.9 offers a series of conclusions derived from the above for the design and timing of cap and trade policies.

5.3 Policy considerations and marginal abatement costs

5.3.1 Policy considerations

Like any model, IGEM can only approximate the details of a complex and comprehensive cap and trade proposal. There are simply not enough "hooks" and "levers" in IGEM to accurately capture the many fine specifics that are conceivable in policy design. As a result, these simulations consider a variety of key provisions included in many of the proposals put forward to-date. These include the emissions constraint in relation to base case emissions growth, the allocation of emissions permits, compliance alternatives to these permits, namely domestic offsets and international credits, and the possibilities for banking of emissions permits.

The analysis assumes a modest cap on GHG emissions at 2000 levels beginning in the year 2010. It is assumed that the policy is announced in 2005 with an ensuing orderly and voluntary transition to the constrained level of emissions beginning in 2006. The cap references the emissions of six greenhouse gases – carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) – as measured by their global warming potential (GWP). It is based on the totality of 2000 GHG emissions less non-transportation exemptions for the direct emissions from the residential and agriculture sectors and small businesses emitting less than 10,000 metric tons of carbon dioxide equivalent ($MTCO_2E$). For the purposes of identification, these exemptions are considered as ***non-covered*** (by policy) sources of GHG emissions while the emissions-generating activities of all other entities are considered as ***covered*** sources.

Based on the U.S. Environmental Protection Agency's (EPA's) 2004 emissions inventory (EPA, 2004) and assuming that activities in the commercial sector are a reasonable proxy for small business enterprises in the commercial *and* industrial sectors, GHG emissions from 2010 forward are constrained not to exceed 5,945 million metric tons of carbon dioxide equivalent ($MMTCO_2E$). This is just over 84% of the 7,039 $MMTCO_2E$ of total GHG emissions occurring in 2000 but is greater than the 5,673 $MMTCO_2E$ of GHG emissions arising from 2000's fossil fuel use.

Table 5.1 shows IGEM's base case emissions and energy growth through 2040 while Figure 5.1 graphically depicts the magnitude of the emissions constraint. Inputs and outputs in IGEM increase at a decreasing rate in base case simulations as the model tracks toward a zero-growth, steady state post 2060.[6] Emissions from covered sources

[6] In order to solve numerically, IGEM requires a terminal, steady-state condition for the economy toward the end of a base-case or policy simulation. Zero growth for emissions and the overall economy in the long run is part of the model's structure rather than an arbitrary assumption or a belief that emissions will stabilize or decline in the future.

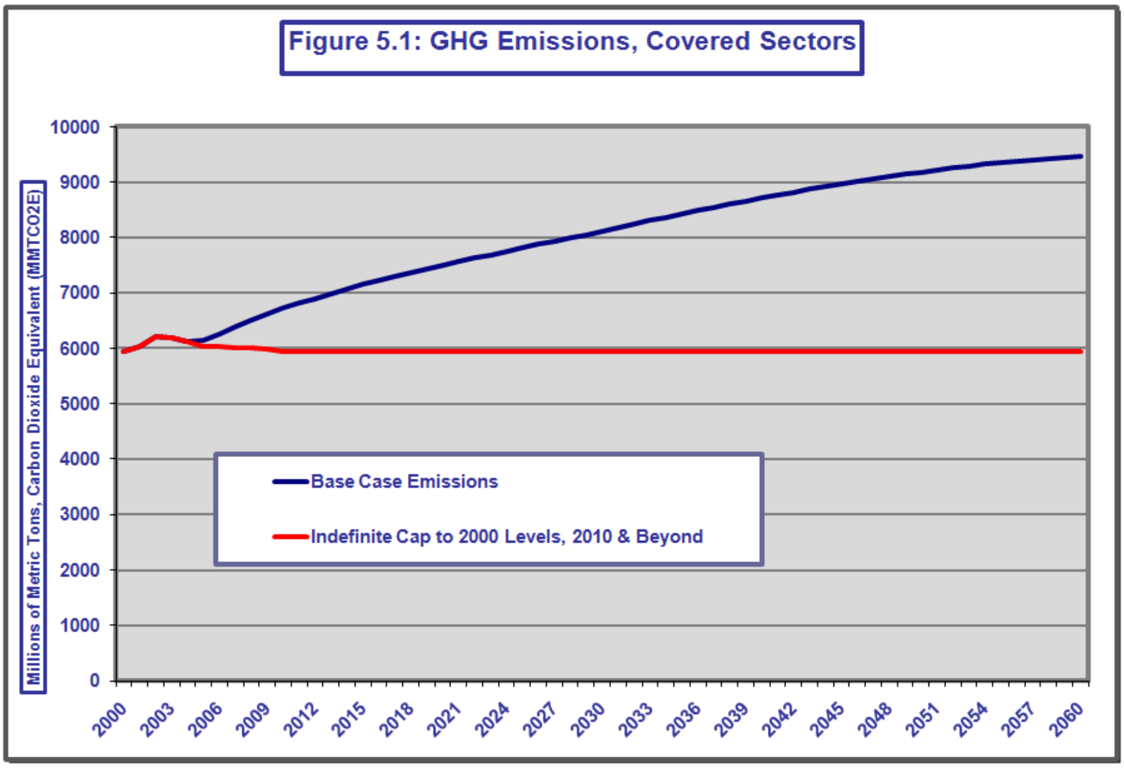
reach 6,724 $MMTCO_2E$ by 2010, 7,500 $MMTCO_2E$ by 2020, 7,815 $MMTCO_2E$ by 2025 and 8,712 $MMTCO_2E$ by 2040. At 5,945 $MMTCO_2E$, the constraint implies abatement in these respective years of 779 (11.6%), 1,555 (20.7%), 1,870 (23.9%) and 2,767 (31.8%) $MMTCO_2E$. (In steady state, abatement is 3,544 $MMTCO_2E$ or 37.4% of covered emissions).

Under the cap and trade proposals currently being considered, allowances are either distributed freely to individual emissions sources or auctioned. If auctioned, the proceeds can fund desirable initiatives, provide transition assistance to heavily affected groups and sectors and, or otherwise ease the economic burden through ear-marked capital grants or direct transfers.

Table 5.1: Base Case Emissions and Energy Growth

		Average Annual Growth Rates in Percent						
	2000 Levels	**2005-2010**	**2010-2015**	**2015-2020**	**2020-2025**	**2025-2030**	**2030-2035**	**2035-2040**
GHG Emissions - Covered Sectors	**5945**	1.786%	1.244%	0.952%	0.826%	0.754%	0.757%	0.670%
Carbon Emissions from Fossil Fuel Use	**5673**	2.047%	1.353%	1.044%	0.852%	0.777%	0.767%	0.687%
Total GHG Emissions - All Sectors	**7039**	1.681%	1.201%	0.898%	0.792%	0.716%	0.730%	0.648%
Energy Consumption								
Coal	**22.6**	1.198%	0.695%	0.504%	0.410%	0.421%	0.442%	0.436%
Refined Petroleum Products	**38.4**	2.647%	1.811%	1.510%	1.302%	1.186%	1.105%	0.929%
Natural Gas	**23.9**	2.276%	1.486%	0.971%	0.650%	0.508%	0.563%	0.551%
Fossil Fuel Use	**84.9**	2.156%	1.431%	1.096%	0.886%	0.797%	0.788%	0.704%
Energy Production								
Crude Oil and Gas Extraction	**34.6**	1.099%	0.832%	0.771%	0.755%	0.796%	0.836%	0.743%
Electricity Generation	**3802**	2.448%	1.802%	1.490%	1.257%	1.127%	1.026%	0.869%

Emissions levels in millions of metric tons of carbon dioxide equivalent. Fossil fuel levels in quadrillion Btu. Electricity generation level in billions of kilowatt hours.



In IGEM, private sector permit revenues accrue to employee-shareholder households while auction revenues flow to the U.S. government. Demographic details enter into the patterns of consumer commodity demands; at the level of goods and services, there are differing estimated expenditure effects among households but common price responses. At higher levels in IGEM's modeling of the household sector, all effects are common. As there are only "representative" consumers, there are no distinguishing behaviors among IGEM's employee-shareholders who, in the "real" world, would differ by reasons of occupation, industry of employment and corporate ownership. This means that the inter-temporal choices of households (i.e., present versus future spending on consumption *and* leisure) followed by their consumption-versus-leisure decisions are unaffected by the initial allocations of permits to specific stakeholders in specific industries. Put differently, the estimated market outcomes in these simulations are independent of the initial allocation of emissions permits or, equivalently, are invariant among alternative initial allocation schemes.

Under the condition that the scenario is both deficit *and* revenue neutral with respect to the fiscal positions of federal, state and local governments, the following two allocation options yield identical market outcomes in IGEM. In one scheme, all allowances are distributed freely to covered emissions sources. Motivated by economic self interest, these entities use, buy or sell these allowances as market conditions dictate. Governments are assumed to adjust their tax policies through changes in personal exemptions (i.e., through lump-sums) so as to preserve pre-policy deficit and spending levels. There is no presumption that these levels are somehow preferable to any others only that their preservation avoids the complications over what to do with new permit revenues or about any tax losses.

In the alternative scheme, all permits are auctioned with the proceeds flowing to the U.S. Treasury. These revenues are redistributed to households in lump-sums but only to the extent that government deficit and spending levels are maintained. Admittedly, lump-sum redistributions are the least favorable means of revenue recycling and such an assumption begs additional considerations of possible joint tax reforms and even the "double dividend." While the existence and magnitude of a double dividend remain unsettled empirical questions, there is broad agreement that there are better and worse ways to recycle permit revenues (see, for example, Goulder 1994, Jorgenson and Yun 1991, Jorgenson et al. 2000, and Tuladhar and Wilcoxen 1999). Adopting the assumption of lump-sum transfers in this analysis helps insure the upper-bound nature of the policy cost estimates. It simultaneously suggests that modest changes in government tax policies, though beyond the analytical scope of this effort, can serve to ameliorate these costs.

Since these two schemes lead to identical economic impacts, any combination of the two also has these effects. With no behavioral differences among employee-shareholder households and given deficit and revenue neutrality, the estimated market outcomes in these simulations are independent of both the initial allocations of permits among private sector recipients and the initial allocation of permits between the private and public sectors.

In addition to tradable allowances, the scenario evaluated here allows covered sources to meet their compliance obligations by purchasing abatement offsets from "outside" the system. As the "economics" warrant, emissions reductions can be acquired from households and small businesses, from new opportunities for domestic sequestration in agriculture and from participating in enforceable and verifiable international permit trading. While recognizing the likely availability of "cheaper" compliance options, abatement from these alternative sources is limited to 15% of the emissions cap or 892 $MMTCO_2E$. (It is assumed that the permit market will be sufficiently well developed so that the 15% holds for individual entities as well as in aggregate.) However, because of the ameliorative power of finding less expensive compliance opportunities wherever they occur, this analysis also considers a scenario which raised this limit to 50% of the cap or 2974 $MMTCO_2E$. For the intermediate term, this more generous offset allowance is never binding so that all abatement choices are made strictly on a least-cost basis.

The role of emissions offsets in mitigation policy is more solid in theory than it is in practice. In theory, offsetting reduces policy costs by allowing those for whom emissions reduction is cheapest and easiest to "sell" their achievements, beyond compliance, to those for whom the requisite reductions are too expensive or technologically difficult. In practice, GHG offsets need to reduce GHG emissions, efficiently, measurably, permanently and additionally. Efficiency and measurability, however, involve institutional obstacles to accessing offsets. Such things as informational asymmetries between buyers and sellers, the lack of standards and contractual transaction costs are not trivial hurdles to overcome. The permanence issue concerns the sustainability of "today's" offset actions. For example, reforestation counters the effects of deforestation but there is no guarantee of its permanence; newly planted forests eventually can burn, decay naturally or be harvested. The problem of offsets contributing "additionally" is important for policy so that these only count when the reductions would not have occurred anyway and, for modeling, to assure that emissions reductions are not being double counted. That there is, in advance of formal policy, an infant, but rapidly growing, private world market with widely varying offset "prices" is testimony that some offsets are better than others and that market solutions offer the best paths to resolution. (*The Economist*, 2006.)

The data employed in these simulations to portray non-CO_2 abatement opportunities and the allowable external offsets from households, small businesses, domestic sequestration and international permit trading were obtained from analyses in which the issues above were of primary concern. The abatement opportunities external to

IGEM represent ***additional*** emissions reductions from legitimate, verifiable sources at measurable costs in terms of the diversion of productive economic resources to these ends.

As IGEM is nationally focused, modeling U.S. participation in a global system of permit trading involves numerous external assumptions with only limited guidance from the literature on world models and assessments. To ascertain the availability of international permits to the U.S. requires answers to the following questions.

1. What is each country's policy with respect to the sales of allowances domestically versus internationally?
2. What is to be assumed about emissions targets beyond current commitment periods?
3. What limits will potential consuming nations place on purchases of other nations' excess emissions capacity or, so-called, "hot air?"
4. What behavior will the owners of "hot air" exhibit (e.g., withholding, banking, etc)?
5. What relationship will emerge between and among the developed and developing nations with respect to offsets available from investments in Clean Development Mechanisms (CDMs)?

Even with answers to these, the directions of international permit trading need not always be constant. It is generally predicted that market conditions initially result in the U.S. becoming a net purchaser of international permits. However, it is quite plausible that emerging conditions among Annex I countries (U.S., Canada, Japan, Australia, New Zealand, the European Union, Eastern Europe and the Former Soviet Union) favor the U.S. as a net seller of permits (McKibbin et al., 1998). This opportunity arises because U.S. differentials in baseline conditions, future rates of growth, substitution possibilities and available technological alternatives may allow it to achieve targeted emissions reductions at a lower comparative cost.

With consensus unlikely, adopting any one set of assumptions regarding global permit trading focuses undo attention on market outcomes that potentially are not robust. Accordingly, IGEM simulations are prepared under two extremes. In one case, the U.S. can buy as many permits as are economically justified from those that are available from other Annex I countries. At the other extreme, the U.S. does not engage in international permit purchases because they are either too expensive or not available. In this instance, households, small businesses and domestic sequestration are the only sources of external compliance offsets.

Finally, the analysis does examine the implications of unlimited banking of permits for future use. IGEM, however, is a perfect foresight model, meaning that economic agents have perfect foresight about future policy, technology and their consequences that, in reality, exists only with a great deal of uncertainty. This is coupled with an eventual, long-run, zero-growth steady state requirement for CGE type of economic models. It is unclear whether perfect-foresight banking toward this steady state is a particularly informative assumption given a primary focus on the magnitude of pure, near-term policy costs. Furthermore, whether banking does or does not occur is all about uncertainty. For example, in a policy without a capped allowance price (i.e., safety valve), banking provides an opportunity to hedge against unexpected surprises. Alternatively, there are plenty of reasons why banking might not occur. For example, any future uncertainty about the cost and availability of offsets or a future change in the emissions target would virtually eliminate the incentive to bank even if everything else in the model's outlook were exactly right. Thus, unlike the other model assessments, the IGEM simulations are conducted in the absence of banking assuming this to be just as plausible an outcome. This isolates the pure effects of the policy's main provisions unencumbered by the consequences of financial arbitrage. Banking and its implications for abatement, permit prices and the economy as a whole are thus considered only as a special case.

5.3.2 Marginal abatement costs

Chapter 4 discussed the role of marginal abatement cost (MAC) schedules in climate change policy assessments and the delineation between internal and external abatement sources. Accordingly, we begin this exercise by analyzing each GHG and each economic activity and identifying those mitigation possibilities are that are likely to be adequately represented by IGEM's response to a given policy initiative. These are considered internal to IGEM as are the economic costs associated with their implementation. All other possibilities are external to IGEM and require external abatement cost schedules. Currently, all foreseeable abatement opportunities related to the carbon emissions from covered sources are viewed as internal. This means the marginal abatement cost schedules implicit in IGEM simulations accurately portray all the economic costs of intermediate-term carbon mitigation. External to IGEM are judged to be those abatement opportunities related to household and small business mitigation strategies, non-CO_2 greenhouse gases, domestic sequestration and international permit trading.

The MAC information for residential and small business abatement is based on IGEM simulations. Here, the opportunities for emissions reductions at every possible permit price are adjusted proportionally downward to reflect the perceived difficulty of bringing these small scale operations into the market system. The details for domestic sequestration are developed from the "The Cost of U.S. Forest-based Carbon Sequestration" (Stavins and Richards, 2005). The MAC schedules for non-CO_2 greenhouse gases and international permit trading are from efforts internal to or sponsored by the U.S. Environmental Protection Agency (EPA). Underlying the non-CO_2 aggregate estimates are the analyses of methane and nitrous oxide (Delhotel et al., 2005, and Scheehle and Kruger, 2005) and of HFCs, PFCs and SF_6 (Ottinger-Schaefer et al., 2004). The international abatement opportunities are based on data from global models and assessments adopted by EPA for their use in first approximation, partial equilibrium analyses of climate change policies (Smith, 2005). It must be emphasized these MAC schedules are constructed to avoid the recognized shortcomings of potential offsets. To this end, the non-CO_2 abatement opportunities and the allowable external offsets from households, small businesses, domestic sequestration and international permit trading represent emissions reductions from legitimate, verifiable sources. Equally important, abatement amounts are additive to those from IGEM at measurable costs in terms of the diversion of the economy's productive inputs.

5.4 The impacts of mitigation policy

The capping of covered-sector GHG emissions is packaged with combinations of offset assumptions to create four scenarios – a 15% limit on external offsets both with and without international permit trading and a 50% limit with and without international trading. The focus here is on evolving permit prices and the structure of abatement and, in turn, their effects on the overall economy. The period of interest is the intermediate term from 2010 through 2040.

Table 5.2 shows the permit prices for these four simulations expressed in terms of year 2000 GDP purchasing power The sources and the external costs of abatement are summarized for these same years in Tables 5.3 and 5.4, respectively.

Table 5.2: GHG Permit Prices

	15% Limit on Alternative Compliance Options		**50% Limit on Alternative Compliance Options**	
	With International	**Domestic Only**	**With International**	**Domestic Only**
2010	$2.1	$5.8	$2.1	$5.8
2015	$3.6	$8.0	$3.7	$8.0
2020	$5.8	$9.9	$5.1	$9.9
2025	$9.8	$11.8	$6.1	$11.8
2040	$22.2	$22.3	$8.7	$17.2

Dollars per metric ton of carbon dioxide equivalent.
Dollars in terms of GDP's purchasing power in the year 2000.

Table 5.3: Sources of Emissions Abatement

In millions of metric tons, carbon dioxide equivalent ($MMTCO_2E$)

	Covered and unlimited		Non-covered and limited				
	Internal to IGEM	External to IGEM					
	IGEM	Non-CO2 GHG	Non-covered Res.&Comm.	International Trading	Stavins-Richards Sequestration	Total Offsets	Total
15% Limit, With International							
2010	195	107	15	464	0	479	781
2020	516	147	31	861	0	892	1555
2025	802	176	31	861	0	892	1870
2040	1603	274	31	861	0	892	2768
15% Limit, Domestic Only							
2010	479	151	40	0	111	152	781
2020	787	179	59	0	531	590	1555
2025	926	191	67	0	685	752	1870
2040	1603	274	75	0	817	892	2768
50% Limit, With International							
2010	194	107	15	465	0	480	781
2020	454	139	33	928	0	962	1555
2025	544	148	39	1072	68	1178	1870
2040	790	167	51	1407	353	1811	2768
50% Limit, Domestic Only							
2010	479	151	40	0	111	152	781
2020	787	179	59	0	531	590	1555
2025	926	191	67	0	685	752	1870
2040	1338	253	93	0	1085	1177	2768

Notes:

The 15% limit on alternative compliance options is 892 $MMTCO_2E$ and is always reached in these simulations.

The 50% limit on alternative compliance options is 2974 $MMTCO_2E$ and is never reached in these simulations.

Table 5.4: Abatement Costs External to IGEM
In millions of $(2000)

	Covered and unlimited	Non-covered and limited				
		Non-covered	International	Stavins-Richards	Total	
	Non-CO2 GHG	Res.&Comm.	Trading	Sequestration	Offsets	Total
15% Limit, With International						
2010	-$70	$21	$319	$0	$339	$269
2020	$39	$56	$1,217	$0	$1,272	$1,311
2025	$220	$56	$1,217	$0	$1,272	$1,492
2040	$1,400	$56	$1,217	$0	$1,272	$2,672
15% Limit, Domestic Only						
2010	$58	$97	$0	$546	$643	$701
2020	$235	$219	$0	$3,244	$3,462	$3,698
2025	$347	$293	$0	$4,575	$4,868	$5,214
2040	$1,399	$364	$0	$5,795	$6,159	$7,559
50% Limit, With International						
2010	-$70	$21	$320	$0	$341	$271
2020	$7	$66	$1,518	$0	$1,584	$1,591
2025	$43	$89	$2,132	$334	$2,555	$2,598
2040	$157	$164	$4,136	$2,032	$6,331	$6,488
50% Limit, Domestic Only						
2010	$58	$97	$0	$546	$643	$701
2020	$235	$219	$0	$3,245	$3,463	$3,699
2025	$349	$296	$0	$4,607	$4,902	$5,251
2040	$1,057	$572	$0	$8,989	$9,561	$10,618

Note:
These costs represent the cumulative abatement costs derived from the external MAC schedules adopted for this analysis.

Several conclusions emerge from these results. First and most obvious, permit prices in all cases continue to rise as the constraint becomes more stringent or, equivalently, as the gap widens between the cap and what covered-source emissions would have been in its absence. Constraints beyond a policy's terminal year need to be explicit because they clearly matter for the permit market and, indeed, for the economy as a whole.

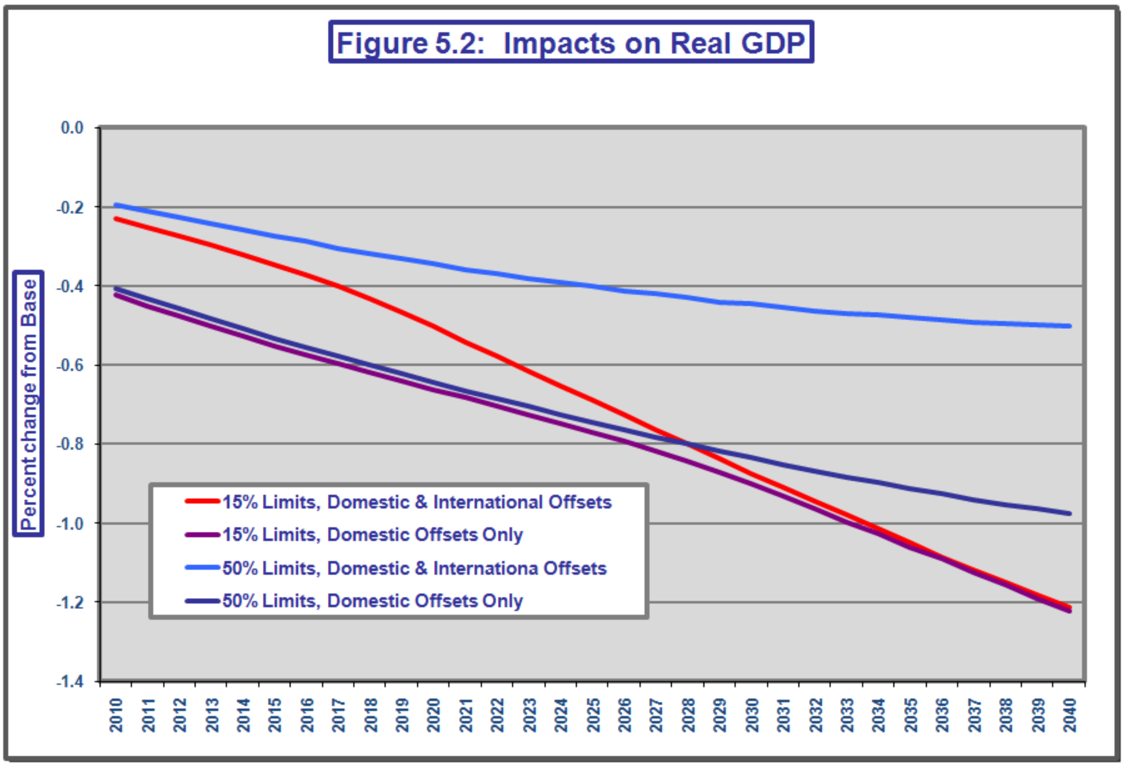
Second, economic agents choose the least expensive portfolio of abatement options subject to their individual availability. Given the MAC schedule for abatement opportunities from non-U.S. Annex I countries and under the condition that the U.S. can acquire whatever abatement is economically justified from this market, abatement overall is cheaper with international permit trading than it is without it. If, for whatever reason, international trading is ruled out (not allowed, not available, not competitive, etc.), the household-small business and domestic sequestration options are more expensive and less competitive. This conclusion, of course, is generic to the availability or lack thereof of any lower cost compliance offset; it is simply that, here, international permit trading is the low cost source.

Third, in these simulations, the limits on external offsets are longer-term considerations. With 15% offsets and international permit trading, the limit is not reached until 2019. With only domestic offsets available, the 15% limit is not binding until 2030. Under the more generous 50% allowances and given the projected growth in baseline emissions, use of these compliance alternatives is unlimited in these simulations.

The importance of these allowable external alternatives cannot be overemphasized. In their absence, long-run permit prices (not shown) would be more than twice as high, as would their economic consequences. Statutory limits on their use also forces more expensive alternatives. Once these limits are reached, there are no period-to-period changes in their utilization or their cost. Permit prices then rise at a more rapid rate as abatement becomes ever more costly. Even the distinction between the lower cost international and higher cost domestic alternatives blurs in the presence of these limits. The convergence of the permit prices in the two cases with 15% limits shows the combination of only domestic options to be competitive with that involving trade *because* these limits were reached. Only much more and now more equally expensive alternatives across the two scenarios remain.

However, with unlimited external offsets over this period, businesses choose the lowest cost options available to them. In both cases, permit prices again are lower because the limits are raised on lower cost options. In addition, the cost differential that initially characterizes the two 50% cases persists. The time paths of permit prices no longer converge because there are no binding limits on any of their underlying abatement options. The availability of only domestic abatement options remains more expensive than when lower cost international permits also can be purchased.

The consequences for the overall economy correspond to the patterns of permit prices and abatement costs. Figure 5.2 shows the effects on real GDP. Clearly, the economy absorbs this constraint on emissions with relative ease. By 2020, economic losses range from 0.3 to 0.7% of the baseline estimate. By 2040, this range expands to 0.5-1.2%. A 1.2% reduction in GDP over the next thirty-four years involves an almost imperceptible 0.035 percentage point reduction in annual growth. At the lower end of these ranges are simulations in which larger proportions of abatement are provided by lower cost sources. At the upper end, these sources are not available by either statute or assumption. Under the 15% limits, convergence occurs in the GDP changes as offset possibilities are exhausted and only higher cost options remain. Under the 50% limits, the economy definitely benefits from these more generous offsets but the paths diverge as the 50% limits are not binding. Allowing only domestic offsets becomes increasingly expensive over time because international permit purchases serve almost as a "backstop" in insulating the economy from the costs of mitigation.



As discussed below, the impacts on GDP are spread across all its components with the effects on household spending being proportionally among the smaller. Table 5.5 shows the effects on real consumption, both in aggregate and per household. The proportional reductions in consumption are, ultimately, less than half of those of GDP.

By 2020, the consumption loss is just over 0.1% when trading allows international purchases and just over 0.2% when international trading is not allowed. By 2040, the losses are just over 0.5% when external offsets are limited to 15% of the cap. Under more the more generous offset provision that allow up to 50% of compliance to come from offsets, the losses in consumption range from just under 0.3% to just under 0.5%.

Table 5.5: The Impacts on Real Consumption				
Percent Change from Base	**2010**	**2020**	**2025**	**2040**
15% Limit, With International	-0.03%	-0.12%	-0.21%	-0.52%
15% Limit, Domestic Only	-0.07%	-0.24%	-0.31%	-0.53%
50% Limit, With International	-0.03%	-0.13%	-0.18%	-0.29%
50% Limit, Domestic Only	-0.06%	-0.23%	-0.31%	-0.49%
Change Per Household in $(2000)	**2010**	**2020**	**2025**	**2040**
15% Limit, With International	-$33	-$158	-$270	-$672
15% Limit, Domestic Only	-$84	-$313	-$410	-$677
50% Limit, With International	-$35	-$166	-$236	-$372
50% Limit, Domestic Only	-$77	-$302	-$402	-$626

A better perspective on the impact on consumers is provided by spending losses, in 2000 dollars, on a per household basis. By 2010, the average cost borne by an estimated 119 million households is around $35 when international permits are allowed and around $80 when only domestic offsets are allowed. By 2020, the average burden on the 134 million households rises to around $160 and $310, respectively. By 2040, the average cost per household range from $370 to $680 spread over 162 million households. The higher figures occur under the 15% limitations on offsets while the lower figures occur when these limitations are relaxed. As before, the smallest impact occurs when international permits are available under more generous allowances.

Traditionally, changes in GDP are viewed from the demand side as policies affect overall spending and its components. However, in CGE models, it is equally appropriate to focus on aggregate supply and, in particular, capital and labor inputs. Table 5.6 shows these for the four simulations. Like GDP and consumption, the capital stock and labor demand are less affected with international trading and with more relaxed constraints on the use of external offsets. As the 15% offset limit is reached, there is supply-side convergence reflected both in the accumulation of capital and in labor supply-demand equilibria. By 2040, the least favorable outcomes indicate declines in capital and labor availability of 1.4 and 0.8%, respectively. Under the most favorable conditions, these reductions are more than halved, to 0.6 and 0.3%, respectively.

Table 5.6: The Impacts on Capital and Labor				
Percent Change from Base				
Capital Stock	**2010**	**2020**	**2025**	**2040**
15% Limit, With International	-0.25%	-0.55%	-0.77%	-1.43%
15% Limit, Domestic Only	-0.45%	-0.75%	-0.89%	-1.44%
50% Limit, With International	-0.21%	-0.39%	-0.47%	-0.62%
50% Limit, Domestic Only	-0.43%	-0.73%	-0.86%	-1.18%
Labor Demand and Supply	**2010**	**2020**	**2025**	**2040**
15% Limit, With International	-0.20%	-0.41%	-0.53%	-0.79%
15% Limit, Domestic Only	-0.38%	-0.48%	-0.53%	-0.81%
50% Limit, With International	-0.17%	-0.25%	-0.26%	-0.27%
50% Limit, Domestic Only	-0.37%	-0.48%	-0.51%	-0.58%
Leisure Demand	**2010**	**2020**	**2025**	**2040**
15% Limit, With International	0.07%	0.14%	0.17%	0.26%
15% Limit, Domestic Only	0.13%	0.16%	0.17%	0.27%
50% Limit, With International	0.06%	0.08%	0.08%	0.09%
50% Limit, Domestic Only	0.13%	0.16%	0.17%	0.19%

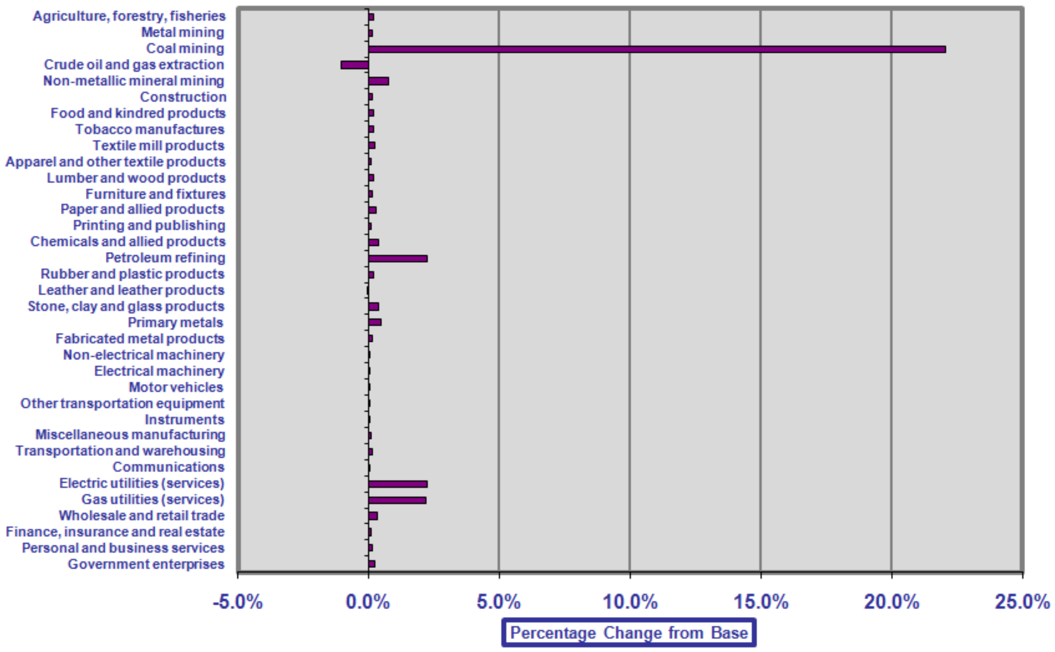
5.5 The mechanisms of economic adjustment

The consequences for the economy are more closely examined by considering the detailed adjustments in a particular year, 2020. These adjustments are representative of what happens in other years and in other simulations; the observed changes are matters of degree and not mechanisms. As shown in Table 5.7, the emissions constraint and resulting permit prices adversely affect each aspect of aggregate demand (real GDP) – consumption, investment, government purchases, exports and imports. Why does this occur? Simply put, everything becomes more expensive and everyone then must adjust to these higher prices. However, the mechanisms that give rise to these reactions are more numerous and complex.

Table 5.7: Detailed Macroeconomic Impacts, 2020	
15% Limits on Alternative Compliance Options with International Permit Trading	
Percent Change from Base	
Real GDP	-0.50%
Consumption	-0.12%
Investment	-1.35%
Government	-0.11%
Exports	-1.06%
Imports	-0.10%
Nominal GDP	-0.19%
Consumption	0.14%
Investment	-1.31%
Government	0.00%
Exports	-0.80%
Imports	-0.85%
Household Full Consumption of	
Goods, Services and Leisure	
Nominal	0.14%
Real	0.05%
Nominal Income	-0.22%
Labor Income	-0.13%
Capital Income	-0.40%
Private Saving	-1.27%
Leisure Demand	0.14%
Labor Demand (Labor Supply)	-0.41%
Capital Demand	-0.55%
Exchange Rate ($/Foreign Currency)	-0.78%
Market Interest Rate	0.65%

The impacts on prices are presented in Figure 5.3. Clearly, energy prices – coal, oil, gas and electricity – are most affected, with coal more so than any other commodity. This is not surprising in that 90% of the year 2000 covered emissions are related to the use of coal (35%), oil (39%) and gas (16%). In addition, coal has high carbon content in relation to the other fossil fuels and is used extensively along with oil and gas in the manufacture of electricity. Domestic crude oil and gas extraction prices decline under the condition in IGEM that approximates an upward sloping oil and gas supply curve. Here, the lower domestic production that follows from reduced demand is obtained at lower cost. This is the only price reduction that occurs. All non-energy prices increase. Some – chemicals, stone, clay and glass, primary metals, electrical machinery (semiconductors) and services (waste management) – are affected both directly and indirectly as their emissions are "covered" by the scenario examined. Others like agriculture, food, paper, plastics, motor vehicles, trade and finance are affected only indirectly.

Figure 5.3: Impacts on Domestic Prices, 2020
15% Limits on Domestic & International Offsets



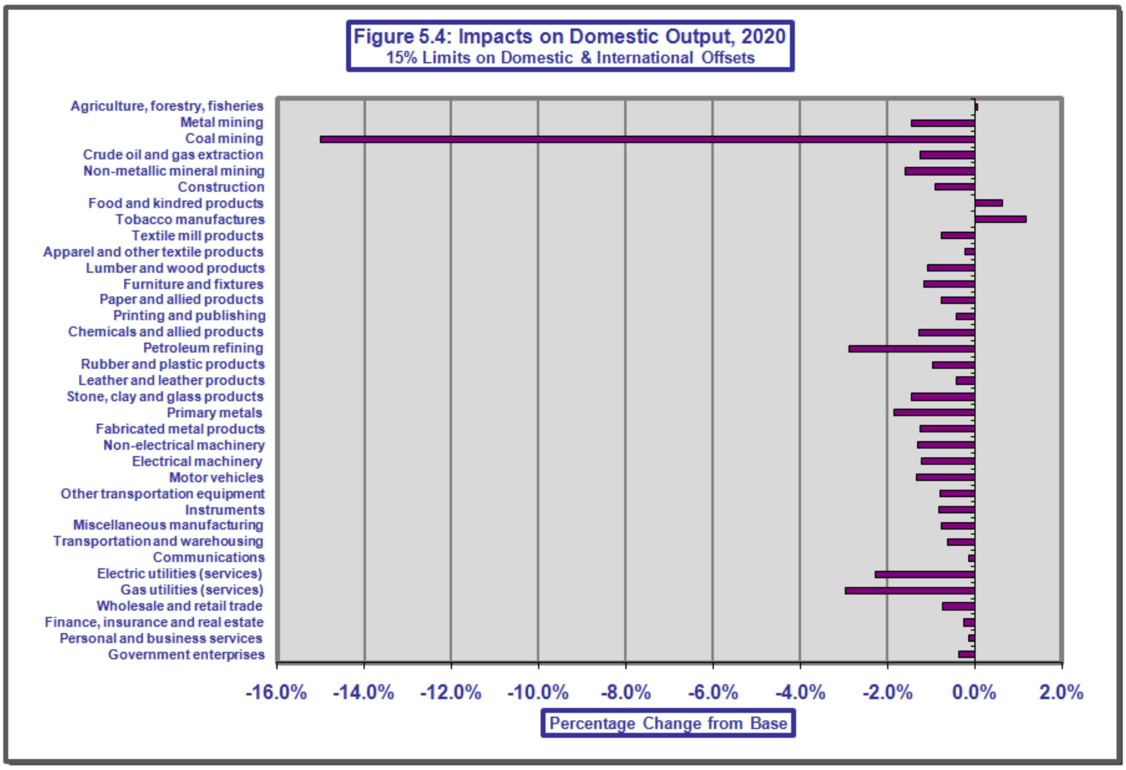
The overall impacts on the economy are dominated by the decisions of households. Their first decision concerns the inter-temporal allocation of expenditure on good, services **<u>and</u>** leisure, or so-called full consumption. Households know that the price increases from mitigation policy will be larger "tomorrow" than they are "today" as the emissions from a growing economy make stabilization at year 2000 emission levels more difficult over time. Households view this as a progressive erosion of real incomes and purchasing power. Accordingly, there occurs a redistribution of expenditure on full consumption toward the present and away from the future. Put another way, households substitute present-day full consumption for the future consumption of goods, services and leisure; they spend "now" rather than "tomorrow."

Households next decide on the allocation of full consumption between goods and services on the one hand and leisure on the other. Because mitigation policy makes all consumer goods and services more expensive, the overall price of consumption is now also higher. The increased price of consumption relative to the price of leisure prompts households to substitute the latter for the former. Within the overall increase in full consumption arising from the inter-temporal effect, comparatively more is spent on leisure than is spent on consumer goods and services. The decline in real consumption occurs because the increase in consumer spending is proportionally smaller than the increase in consumer prices.

In addition to the consumption-related impact on aggregate demand, this second decision by households has important implications for the supply side of the economy. The rising price of goods and services relative to wages results in a reduction in household labor supply that is equal to and opposite from the increase in household leisure demand. Households respond to the decrease in real wages by supplying less labor and demanding more leisure. While increasing leisure is welfare improving for households, their reductions in labor supply, at prevailing wages, reduce labor and, hence, national income (GDP).

The third decision by households concerns the allocation of purchases among the variety of consumer goods and services but within the overall level of reduced total real spending. Like the adjustments above, there occurs here a redirection of expenditure away from those goods and services incurring the larger price increases and toward those goods and services experiencing the smaller price increases. Because household spending is such a large fraction of overall spending, the actions taken here strongly influence the structure of real GDP and the domestic production that supports it.

The production side of the economy also is affected adversely. With the exception of agriculture, food and related activities, all industries, especially those related to energy, experience declines in output volumes (see Figure 5.4). This results from not only higher prices and declining demands throughout the economy but also from the limitations on supply that arise from changes in labor and capital availability and from productivity. Producers do their best to insulate their output prices from the impacts of more expensive energy and non-energy inputs to production. Substitutions away from more costly inputs and toward relatively cheaper materials, labor and capital help minimize the adverse effects. Beyond these factor substitutions, there is also price-induced technical change (discussed in detail in Chapter 6) at work in each industry. This also affects output prices. The observed patterns of induced technical change unique to this policy are seen to help some industries but harm others. For some industries, induced technical change enhances the price-insulating benefits of factor substitution while, for other industries, it diminishes them. Overall, there is a small economic benefit from this mechanism as it reduces the economic costs of adjusting to the emissions of constraint. Ultimately though, there is only so much producers can do in the face of reduced demands and limited factor supplies. In the end, firm and industry profits and cash flows (i.e., the returns on invested capital) are unavoidably less.



The reduction in labor income arising from the household sector's reduced labor supply and increasing demand for leisure combines with lower capital income from businesses to yield a reduction in national income and nominal GDP. However, as indicated above, personal consumption increases. In part, this is due to the inter-temporal effect of shifting spending from the future to the present. It is also due to the fact that overall consumption is price inelastic. This means that the proportionate reduction in real consumer purchases is smaller than the proportionate increase in the overall price of consumer goods and services. With falling income and rising consumption, private saving falls unambiguously. The reduction in saving leads to a corresponding reduction in private investment. With higher prices for investment goods, the available investment funding buys even fewer capital goods. Lower saving leads to lower investment, a lower capital stock, lower returns on that capital stock and less capital availability. This and the reduced availability of labor are primarily what limit the economy's domestic supply possibilities following the introduction of this policy.

IGEM's saving-investment balance summarizes the net flow of funds available for investment. These funds arise from three sources. The first source, discussed above, is the domestic saving of households and businesses. All things being equal, increases in saving lead to more investment while decreases in saving lead to less. The second source reflects the behavior of the collection of governments that comprise the national economy and the magnitude of their combined annual deficit or surplus. The third source focuses on the nation's interactions with the rest of the world and whether the annual current account balance is deficit or surplus.

To eliminate governments' direct effects on real investment spending through the saving-investment balance, the simulations conducted for this analysis assume not only deficit but also revenue neutrality. Given these conditions of neutrality, as the prices facing governments rise, there occurs a proportionally equal reduction in the real goods and services that governments are able to purchase. While there are numerous reactions concerning the fiscal policies of governments, each with their own implications for spending, deficits and, hence, investment, the above assumptions give rise to transparent outcomes that are uncomplicated by speculations on what governments might do to soften any adverse policy impacts.

The prices of U.S. exports rise relative to goods and services from the rest of the world. As exports are estimated to be price-elastic, export volumes fall by proportionally more than export prices rise. In addition, there are no assumed policy-induced income effects associated with exports and, so, with only the aforementioned price effects, U.S. export earnings decline.

Real and nominal imports also decline. First, import reductions occur from the overall reductions in spending associated with a smaller economy. Second, import reductions occur in those commodities directly affected by mitigation policy. The cap on emissions and the corresponding emissions permits fall on all of the commodities that contribute to U.S. greenhouse gases, irrespective of whether they were produced domestically or imported. Thus, within total imports, there are disproportionate reductions in oil, gas and other policy-sensitive commodities as their prices rise along with those of their domestic counterparts. Finally, there is the matter of import substitution which partially offsets the above two forces. There is a greater incentive to import as domestic prices now are relatively higher for the commodities not directly affected by policy. For unaffected imports, there occurs a restructuring toward those commodities that obtain the greater price advantages in relation to those produced domestically and to those imports that are relatively cheaper within overall imports.

With only prices affecting exports and both prices and incomes affecting imports, the reduction in nominal imports exceeds the decline in export earnings. To neutralize this impact so that the effects on investment arise solely and transparently from those on domestic saving, the dollar strengthens to the point where it restores the current account balance to its pre-policy level. The condition in policy experiments that the value of the dollar adjusts to preserve existing (i.e., base case) current account balances (i.e., desired foreign saving) and U.S. indebtedness (i.e., willingness to hold dollar-denominated assets) is intentional in that IGEM is specified to represent only the domestic U.S. economy.

In the simulations in which there are no international permit purchases, current account balances and U.S. indebtedness to the rest of the world remain at their pre-policy levels. The adjustments in exports and imports, real and nominal, and in the value of the dollar are as just described. However, in the situations in which the U.S. purchases emissions permits from other Annex I countries, there occurs a presumed additional capital outflow as foreign investors are assumed to be less willing to maintain pre-policy U.S. asset levels. This capital outflow combines with the aforementioned domestic saving effect to further restrict domestic investment. In the case with 15% offset limits, this amounts to only a few percentage points of the total investment effect. In the case with 50% limits, the outflow effect is proportionally higher. The U.S. is purchasing even more foreign permits and the additional offsets explain much more of the overall investment effect. The purpose in making an assumption that is admittedly less favorable to domestic capital formation is to aid in establishing a plausible upper-bound estimate of the policy costs to the economy.

By way of sensitivity, changing export quantities and import prices to also reflect a plausible range of impacts from overseas emissions-reducing initiatives alters the magnitude of these export and import quantity changes. However, the changes in real net exports and GDP are not materially different from those reported above. They appear somewhat insensitive to the range of general equilibrium outcomes that were estimated for the policies of other nations and subsequently applied to IGEM's exogenous trade variables. Obviously, this experiment would benefit greatly from the use of detailed results, were such available, from world model policy simulations to better inform its conclusion.

5.6 Model comparisons

While a comparison of model differences, features, strengths and weaknesses lies well beyond the scope and purposes of this exercise, it is useful to put the aforementioned results in a perspective with other modeling efforts. To this end, key assumptions and outcomes from four additional assessments are compared, in Table 5.8, to those from DJA's IGEM. The other models are:

1. The Multi-region National and Multi-sector, Multi-region Trade (MRN & MS-MRT) Models of Charles River Associates (CRA).
2. The National Energy Modeling System (NEMS) of the U.S. Energy Information Administration (EIA).
3. The Emissions Projection and Policy Analysis (EPPA) Model of the Massachusetts Institute of Technology's (MIT's) Joint Program on the Science and Policy of Global Change.
4. The Applied Dynamic Analysis of the Global Economy (ADAGE) Model of the Research Triangle Institute International (RTI).

Table 5.8: Comparison of Policy Assumptions and Outcomes: 2020

Model	MRN & MS-MRT (CRA)		IGEM (DJA)				NEMS (EIA)	EPPA (MIT)			ADAGE (RTI)	
Policy Assumptions												
Constraint, CO_2 or GHG	CO_2	CO_2	GHG	GHG	GHG	GHG	GHG	CO_2	CO_2	CO_2	GHG	GHG
Non-CO_2 Abatement Possibilities Unlimited at Economic Cost	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes
External Abatement Opportunities	15% of Cap at Zero Cost	Not Competitive	15% of Cap at Economic Cost	15% of Cap at Economic Cost	15% of Cap at Economic Cost	Not Modeled	15% of Cap at Economic Cost	Not Modeled	Not Modeled	Not Modeled	15% of Cap at Zero Cost	15% of Cap at Economic Cost
Non-covered GHG Household, Small Business,	-	-	Yes	Yes	Yes	-	Yes	-	-	-	-	Yes
Domestic Sequestration	-	-	Yes	Yes	Yes	-	Yes	-	-	-	-	No
International Permit Trading	-	-	Yes	No	Yes	-	Yes	-	-	-	-	No
Banking	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	No	Yes	Yes
Policy Outcomes												
Permit Price - $(2000)/MTCO$_2$E	$16.8	$31.5	$5.8	$9.9	$10.5	$25.6	$33.2	$13.6	$35.7	$42.8	$7.1	$13.6
- $(2000)/MTCE	$61.6	$115.5	$21.4	$36.4	$38.5	$94.0	$121.6	$50.0	$131.0	$157.0	$26.0	$50.0
Real GDP, % Change	-0.48%	-0.84%	-0.50%	-0.66%	-0.69%	-1.46%	-0.22%	NR	NR	NR	-0.12%	-0.24%
Real Consumption, % Change	-0.82%	-1.37%	-0.12%	-0.24%	-0.26%	-0.48%	-0.19%	-0.02%	-0.13%	-0.18%	-0.05%[1]	-0.12%[1]
Real Investment, % Change	-1.05%	-1.85%	-1.35%	-1.30%	-1.34%	-3.14%	-0.45%	NR	NR	NR	NR	NR
Coal Price, % Change	120.7%	229.6%	22.1%	37.4%	39.5%	95.6%	284.1%	NR	NR	NR	44.4%	100.0%
Coal Quantity, % Change	-52.2%	-64.4%	-15.0%	-22.3%	-23.2%	-40.4%	-37.2%	-20.6%	-38.2%	NR	-34.4%	-49.6%
Electricity Price, % Change	13.6%	22.8%	2.2%	3.7%	3.9%	8.5%	20.1%	NR	NR	NR	6.6%	11.3%
Electricity Quantity, % Change	-7.8%	-12.4%	-2.3%	-3.6%	-3.8%	-8.3%	-5.4%	NR	NR	NR	-3.8%	-6.6%

NR = Not Reported
Changes in energy quantities are averages of reported consumption and production changes
[1] Developed from reported results assuming 130 million households and a base level consumption of $(2000) 11,830 billion

The first three models have been used to analyze the Climate Stewardship Act of 2003 proposed by Senators McCain and Lieberman. For comparison purposes, the IGEM-like ADAGE model utilized the same modest emission cap level as that proposed in the Climate Stewardship Act. Even with the same cap level, however, the results of all of these models vary widely because these models vary widely. IGEM is a general equilibrium model linked to the U.S. National Income and Product Accounts (NIPA). Its nested construction uses so-called flexible functional forms (i.e., functions with non-constant elasticities) that are econometrically estimated from the observed market behavior evidenced in the U.S. Accounts. The MRN & MS-MRT, EPPA and ADAGE models also are general equilibrium and linked to the social accounting matrices (SAMs) of their underlying nations and regions. These models are constructed with nested constant-elasticity-of-substitution (CES) functions populated with parameters from the extensive empirical literature and, in turn, calibrated to SAM benchmarks. Indeed, the EPPA and ADAGE models share a largely common parameter set. NEMS is an integrated, hierarchical system of partial equilibrium models linked to NIPA and to EIA's official U.S. Energy Accounts. The system combines econometrically-based, reduced-form (i.e., partial equilibrium) models of macroeconomic and energy-demand behavior with detailed process models related to energy production and supply. Dynamically, IGEM, the MRN & MS-MRT and ADAGE models feature inter-temporal optimization wherein economic agents are endowed with perfect foresight and make "current" consumption, leisure (labor) and saving (investment) decisions accordingly. The EPPA and NEMS models are dynamically recursive featuring current, within-period optimization based on knowledge only of the past and present.

The representations of various climate policy provisions within each model are also as varied as the models themselves. The IGEM, NEMS and ADAGE simulations involve caps on total greenhouse gas (GHG) emissions arising from "covered" activities whereas the MRN & MS-MRT and EPPA runs impose constraints on only carbon (CO_2) emissions. The IGEM, NEMS, EPPA and ADAGE analyses allow non-CO_2 abatement opportunities to compete at their economic cost; the MRN & MS-MRT simulations do not incorporate these. Only IGEM and NEMS consider the cost and availability of the full range of external offset opportunities. For the other models, the offsets from households, small businesses, domestic sequestration and international permit trading are not modeled, not competitive or compete at zero cost, the lone exception being the economic costs of household and small business offsets in the ADAGE model. Finally, only the IGEM and the EPPA runs permit a comparison of model outcomes with and without banking. Simulations from the other models all involve "optimal" banking in which permit prices rise at the prevailing interest rate throughout their reported time horizons.

In spite of the "apples-to-oranges" differences among these models and their policy assumptions, there are valuable insights to be gained from comparing their outcomes. First, when lower cost abatement options compete in the mix of market responses, the economic costs of mitigation, as measured by consumption or income (GDP), are reduced substantially. That the magnitude of cost reduction is so large, from 40 to 85% depending on the model and variable, testifies to the steepness of the marginal abatement cost schedules implicit in each of these methodologies. More or less the same abatement to reach 2000 emissions levels is very expensive. Thus, the combination of unlimited internal (non-CO_2) and-or limited external offsets, each at their lower cost, releases significant resources back to productive use that otherwise were diverted to compliance. Second, the economic costs of mitigation associated with a modest policy scenario are small; all models suggest that the economy easily absorbs initiatives of this magnitude. In terms of foregone consumption, the MRN & MS-MRT models yield the largest impacts while the EPPA and ADAGE models yield the smallest; the IGEM and NEMS outcomes lie in between. The similarity in the EPPA and ADAGE results is not surprising given the commonality of their structures and parameters. Moreover, as discussed in Chapter 7 below, a change in but a single IGEM parameter – that which governs the consumption-leisure tradeoff – reduces its losses to those levels among the lowest. Third, there is ample explicit (MRN & MS-MRT, IGEM and NEMS) and implicit (EPPA and ADAGE) evidence that the impacts of cap and trade policies on investment and capital formation significantly exceed those on consumption and household spending.

There are technical differences among these outcomes that, while of analytical interest, are somewhat less relevant to policy evaluation.[7] Broadly similar abatement requirements yield radically different patterns in permit prices and their associated impacts on energy and the economy. Indeed, all possibilities are represented. There are high permit prices showing relatively little economic effect (NEMS and EPPA), high permit prices showing the larger economic effects (MRN & MS-MRT), low permit prices showing the larger economic effects (IGEM as estimated) and low permit prices showing the smaller economic effects (ADAGE and the IGEM runs of Chapter 7). These patterns arise from the differing degrees of flexibility (i.e., elasticities) within the structures of these models. If emissions-generating goods and services are demanded inelastically, then permit prices need to be high to achieve their desired impact. Models with high permit prices imply models that are less elastic in energy prices (MRN & MS-MRT, NEMS and EPPA). The converse also is true (IGEM and ADAGE). In turn, if these changes interact less elastically with important segments of the larger economy, then responses at the "micro" level have less of an impact at the "macro" level. This explains, for example, why the higher permit prices in NEMS appear to have a disproportionately smaller impact on consumption than do the lower permit prices in IGEM.

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[7] It is assumed that what really matters is achieving the desired emissions target with only minimal damage to the economy; all of the reported model runs generally satisfy this requirement.

A minor difference that surfaces in this comparison concerns the government and trade components of GDP. In the IGEM and NEMS simulations, adjustments in these complement the changes in consumption and investment, further reducing GDP. In the MRN & MS-MRT analysis, the reductions in GDP are proportionally smaller than both those of consumption and investment. This can occur only if the changes in real government spending and-or real net exports (i.e., exports less imports) partially offset the combined changes in household and business spending. While interesting, and presumably related more to trade than to changes in government behaviors, this difference merits explanation only in discussions of the impacts on overall spending (GDP) and income. As the principal evaluative metric for these assessments is consumption (household spending), this difference loses some of its relevance.

In the end, there is but one dominant conclusion from this cursory comparison – namely, that legitimate, verifiable and competitive market-based abatement opportunities can reduce significantly the already small economic costs of mitigation policy.

5.7 Longer-term considerations: banking and beyond 2020

There are two remaining issues that relate to economic costs over the intermediate and long run. The first of these is banking which typically is not considered a long-run issue but has the potential for being so. The second concerns the cap and trade policy beyond 2020. To simplify analysis and to better focus on matters most relevant, the simulations examined in this section allow all competing offsets – those from households and small businesses, domestic sequestration and from international markets; there are no runs involving only domestic offsets. However, there continues the distinction between 15% and 50% limits on the use of these.

5.7.1 Banking

Most of the climate change legislation being discussed allows unlimited banking. When banking occurs, covered sources more than meet their compliance targets in earlier years. They then bank permits for future use when marginal abatement costs are much higher and required emissions reductions are more difficult. Banking, therefore, is equivalent to imposing a tighter emissions constraint initially and a looser one later.

Effective permit prices with banking are initially higher than those without banking. Eventually, they give way to prices lower than those without banking. With banking, there are more economic resources reallocated to abatement activities in the earlier years but fewer in the later years. An efficiency gain is realized as the present value of the greater nearer-term costs is more than compensated by the present value of longer-term savings.

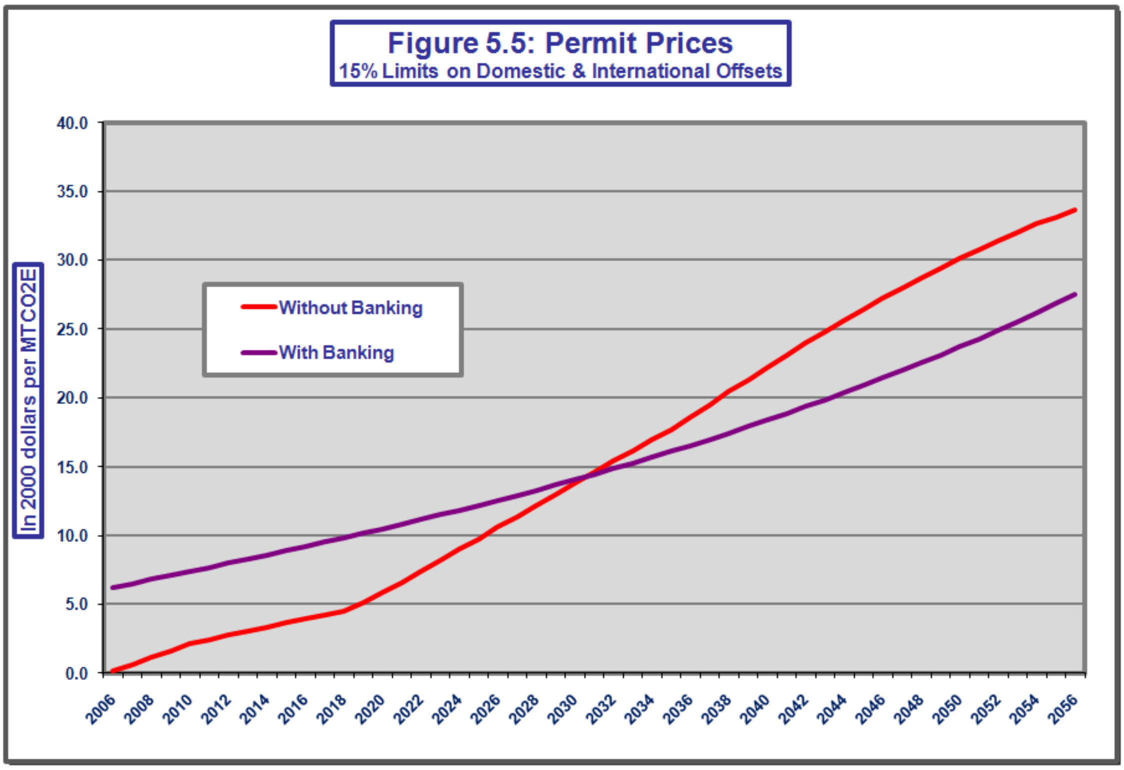
Assuming the right to bank is permitted throughout a policy's time horizon, the driving force in modeling the banking decision is the market rate of interest, reflecting, as it does, opportunity cost and the time value of money. If the annual rate of change in permit prices is lower than the rate of interest, there is no incentive to bank permits for future use. However, if the annual rate of change in permit prices exceeds the market interest rate, there is an arbitrage opportunity that can be seized by banking permits.

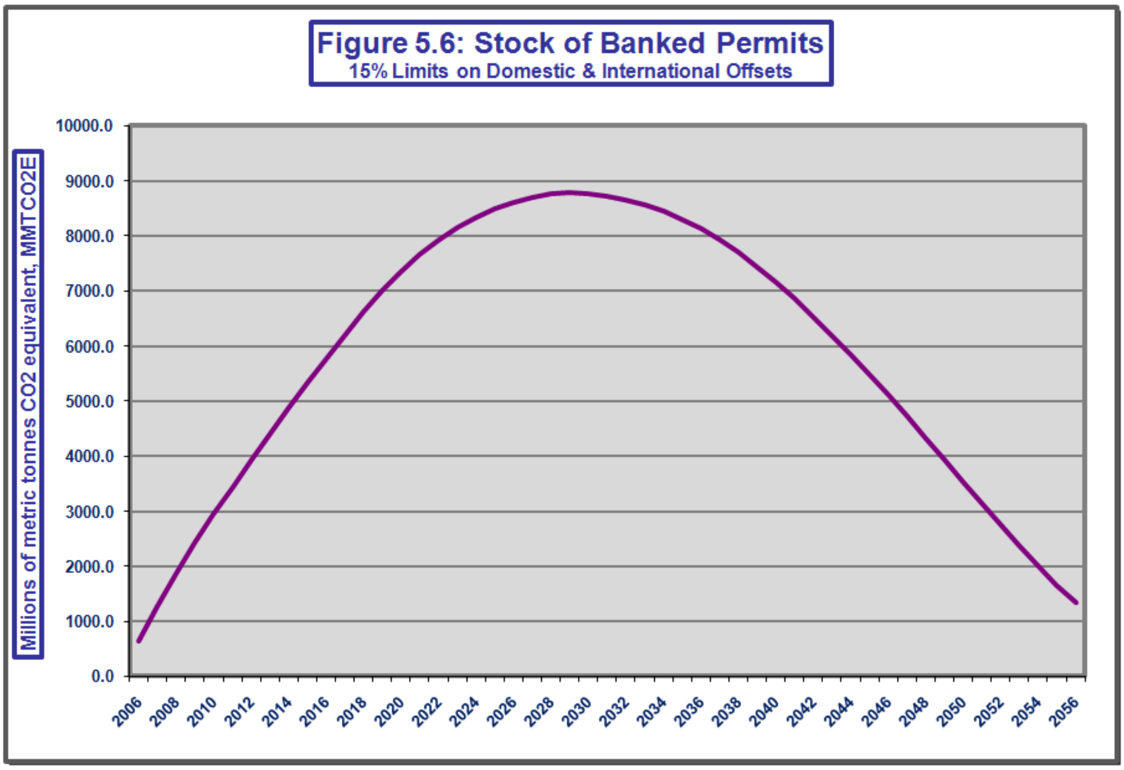
For a given interest rate and assuming inter-period trading on a one-for-one basis, optimal banking is an analytical problem with two jointly determined unknowns. The first is the initial permit price which then rises annually with prevailing interest rates. The second is the year in which the permit price is high enough to equate annual permit demand with new permit issues while simultaneously exhausting the supply of banked permits. Lower interest rates encourage more banking over a longer time horizon. Compared with no banking, permit prices and economic costs are higher earlier but lower later. Higher market rates reduce the incentives for banking and shorten its window of opportunity. Higher interest rates tilt the rewards and penalties of banking toward those of not banking. In the limit, any incentive for banking is eliminated.

As IGEM tracks to a zero-growth, steady-state solution, there is convergence among the market rate of interest, the marginal physical product of capital and the household rate of time preference. This is a predicted outcome of neoclassical growth theory. In IGEM, the market interest rate is a model output (i.e., endogenous), not a model input (i.e., exogenous). At the onset of policy, the simulated rate stands in the neighborhood of 3.2% and then gradually declines toward 2.6%, the econometrically estimated rate of time preference.

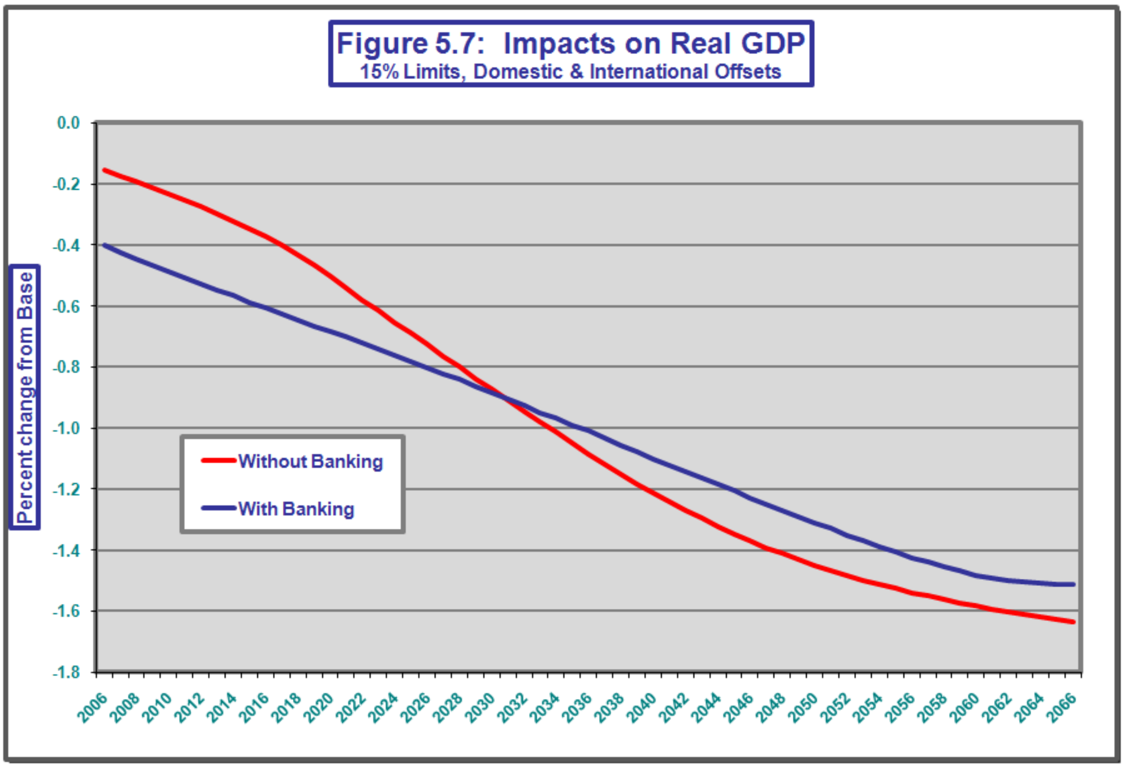
Assuming no banking and a 15% limit on offsets, the market-clearing permit price increases at a slowly decreasing rate as the economy evolves toward its post-2060 steady state. Under these conditions, the annual rate of increase exceeds the market interest rate until mid-century. Thus, there is a strong incentive for banking over an extended time horizon.

Figure 5.5 shows the trajectory of permit prices with and without banking while Figure 5.6 depicts the accumulation and drawdown of banked permits. The crossover year for permit prices is 2032. The stock of unused permits peaks in 2029. For the economy, the crossover year also is 2032. As productive inputs are redirected to abatement activities prior to 2032 and are released from same after 2032, the economic costs in terms of income and consumption foregone are greater in the earlier years and smaller in the later years.





For GDP, the incremental cost associated with banking averages 0.2 percentage points, 2010-2025 (see Figure 5.7). There is virtually no cost differential, 2025-2040. From 2040-2060, the gain or benefit from banking averages 0.1 percentage points and is half again as much in steady state. For consumers, banking costs a extra $94 per household in 2010 and an extra $198 by 2020. Thereafter, these additional costs diminish rapidly becoming gains of $18 in 2040, $62 in 2060 and $110 in steady state.



Real-world uncertainties aside, the amount of banking and its economic impact in model simulations depend on the time paths of evolving permit prices and prevailing interest rates. If real interest rates are in the range of these in IGEM, optimal banking is a long-run proposition. Here, economic efficiency warrants incurring higher costs for multiple decades, not just multiple years. In these circumstances, achieving a net benefit requires endurance and patience.[8] Conversely, higher rates, like the 5% rate employed by CRA and MIT and the 8.5% rate used by EIA, bring about lesser amounts of banking and shorten the period over which it is desirable. In turn, these will lower banking's nearer-term losses and raise its longer term gains, increasing the immediacy of an overall net benefit. Understanding how quickly a net benefit from banking materializes under various schemes of permit prices and interest rates is an important consideration in the analysis of mitigation policy.

[8] That the later gains from banking do not appear to compensate the earlier economic losses is an artificial result. Were the proximity of steady state more distant from the crossover point, the discounted benefits from banking would continue to expand and, ultimately, outweigh the earlier discounted costs.

5.7.2 Emissions policy after 2020

The scenarios evaluated in this report can be thought of as modest first steps toward discouraging future emissions growth. Accordingly, all of the simulations to this point maintain the cap at 2000 levels indefinitely. This section provides estimates of the economic costs of more restrictive emissions ceilings beginning in 2020.[9] Specifically, two additional constraints, shown graphically in Figure 5.8, are analyzed.[10] In the first, the cap is reduced annually by 0.5% and, in the second, allowable emissions in the covered sectors decline by 1.0% per year. In the former, emissions reach 1990 levels of 5121 $MMTCO_2E$ by 2050 while, in the latter, this level is achieved by 2035. Relative to the base case level in 2040, the simulations to this point involved an emissions reduction of 31.8% or 2768 $MMTCO_2E$. Here, the corresponding figures are 38.3% (3334 $MMTCO_2E$) and 44.2% (3849 $MMTCO_2E$) for the 0.5% and 1.0% constraints, respectively.

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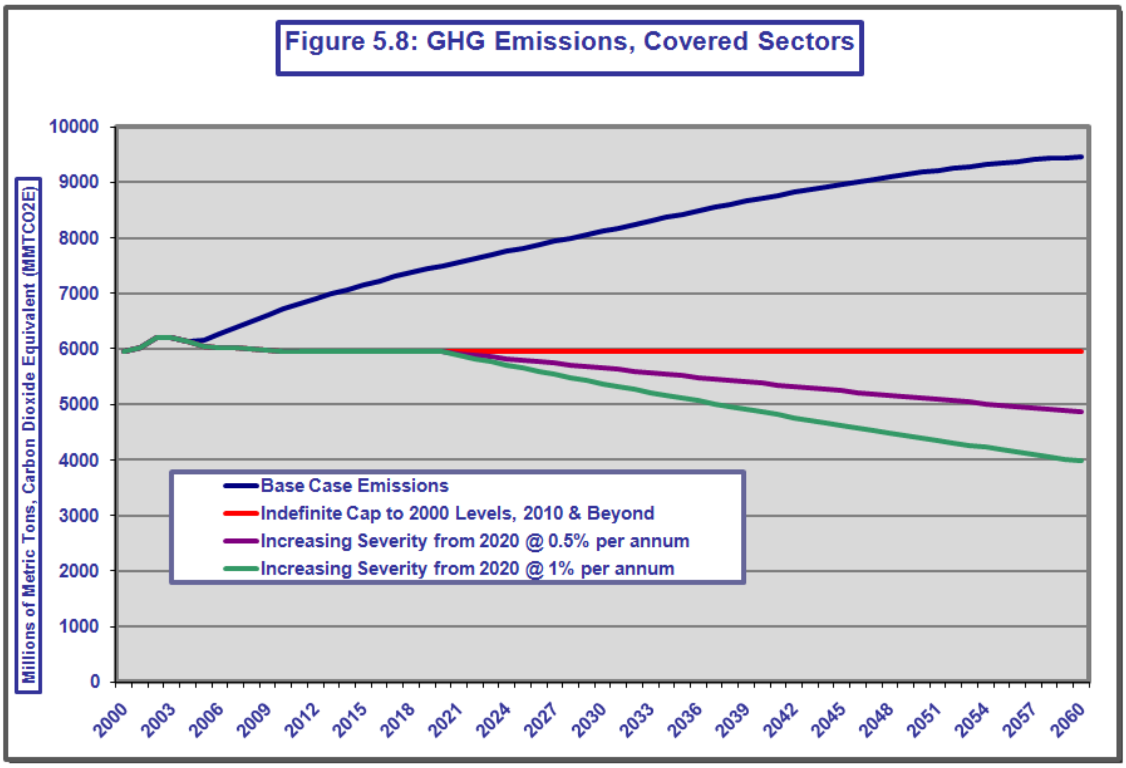
[9] A variety of climate change bills have been introduced in the 110th Congress that require more restrictive emissions reductions over time.

[10] The more restrictive emissions ceilings are arbitrary and intended purely to measure the impacts of further reductions beyond 2020; neither scenario has been considered in any formal policy proposal or deemed optimal in any formal modeling exercise.



The 15% and 50% limitations on offsets remain and it is assumed that all domestic and international offsets are available at their economic cost. However, there is one difference. In these simulations, the limits on offsets follow the cap. As allowable emissions become further restricted so, too, does the ability to use external offsets. After 2020, the 892 and 2974 MMTCO_2E limits in the 15 and 50% cases, respectively, also decline at the annual rates of 0.5 and 1% depending on the scenario.

Table 5.9 compares the permit prices under the various caps. Prior to 2020, there are virtually no differences among the permit prices for comparable limitations on alternative offsets. This is to be expected since the more restrictive emissions ceilings do not take effect until 2021 which is when prices begin to diverge. By 2040 and with a 15% limit on offsets, permit prices rise by \$14 and \$18 per MTCO_2E as the cap is successively reduced. Under the 50% limit with the significantly lower permit prices from more generous offsets, the successive increases rise to \$16 and \$20 per MTCO_2E. Ratcheting down the target on allowable GHG emissions clearly imposes additional costs on the economy no matter what the offset policy.

Table 5.9: GHG Permit Prices under Alternative Caps Post-2020				
	15% Limit on Alternative Compliance Options			
	2000 Levels Indefinitely	0.5% Annual	1.0% Annual	
2010	$2.1	$2.1	$2.1	
2015	$3.7	$3.6	$3.6	
2020	$5.9	$5.8	$5.7	
2025	$9.8	$11.9	$14.2	
2040	$22.3	$36.7	$54.3	
	50% Limit on Alternative Compliance Options			
	2000 Levels Indefinitely	0.5% Annual Reduction	1.0% Annual Reduction	
2010	$2.1	$2.1	$2.1	
2015	$3.7	$3.6	$3.6	
2020	$5.1	$5.0	$4.9	
2025	$6.1	$9.5	$12.9	
2040	$8.7	$24.6	$44.4	
Dollars per metric ton of carbon dioxide equivalent.				
Dollars in terms of GDP's purchasing power in the year 2000.				
Alternative compliance options at zero cost.				

Figures 5.9 and 5.10 show the effects of more restrictive caps on real GDP and consumption, respectively. The differences among these time paths prior to 2020, more pronounced for GDP than for consumption, are evidence of IGEM's inter-temporal effects and their general equilibrium aftermath. Some of the adjustment in the driving forces of supply and demand in these earlier years is related to knowledge of the future evolution of permit prices beyond 2020. Greater economic costs in the future often trace backward to greater economic costs nearer term.

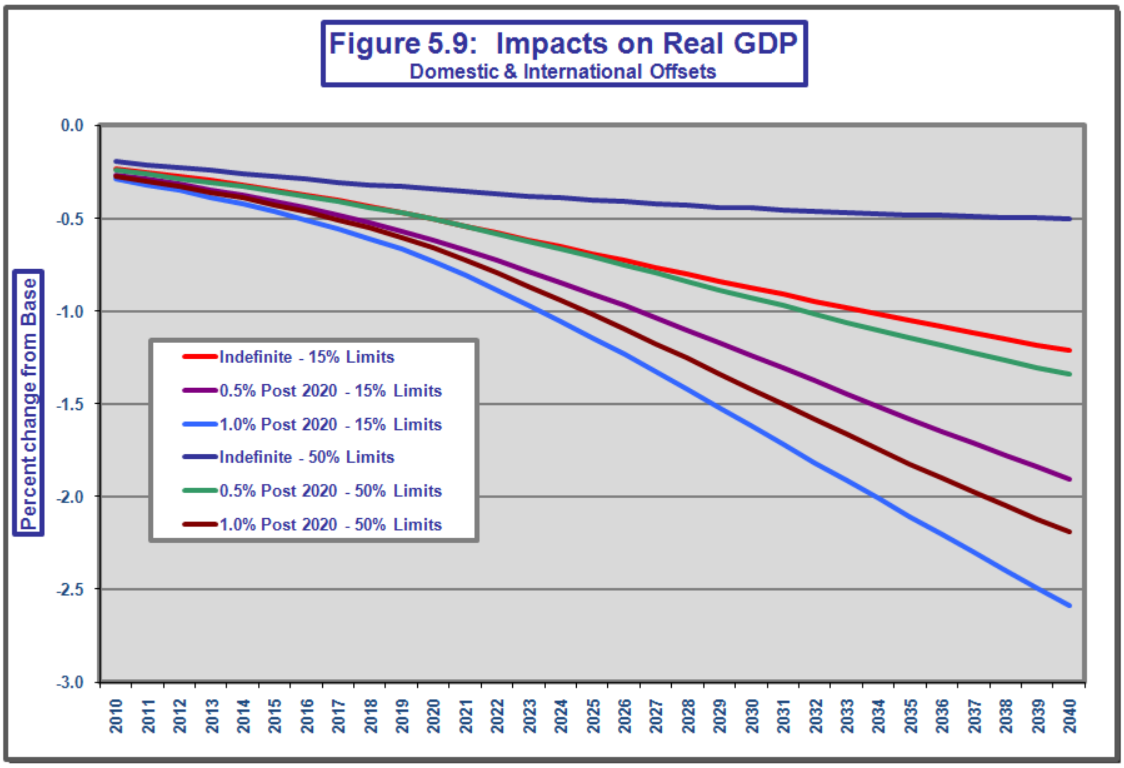


Figure 5.9: Impacts on Real GDP
Domestic & International Offsets
Percent change from Base
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
Indefinite - 15% Limits
0.5% Post 2020 - 15% Limits
1.0% Post 2020 - 15% Limits
Indefinite - 50% Limits
0.5% Post 2020 - 50% Limits
1.0% Post 2020 - 50% Limits
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
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2039
2040

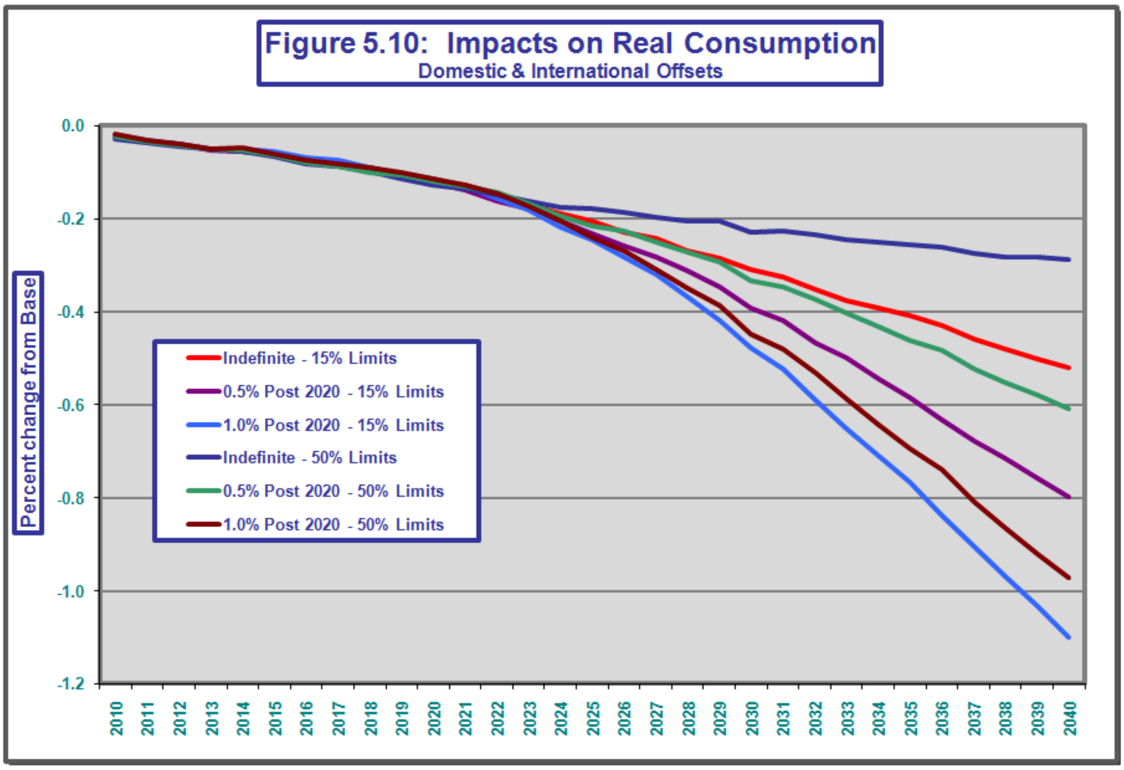
Figure 5.10: Impacts on Real Consumption
Domestic & International Offsets
Percent change from Base
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
Indefinite - 15% Limits
0.5% Post 2020 - 15% Limits
1.0% Post 2020 - 15% Limits
Indefinite - 50% Limits
0.5% Post 2020 - 50% Limits
1.0% Post 2020 - 50% Limits
2010
2011
2012
2013
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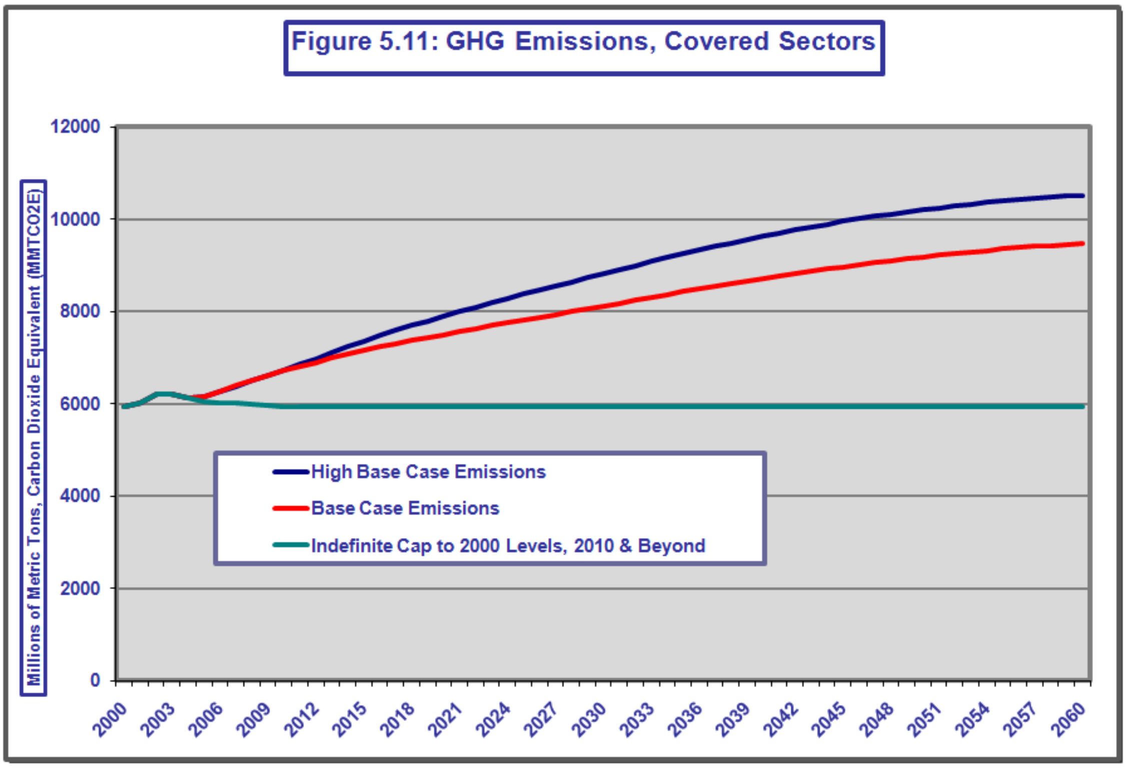
2039
2040

The principal findings from these additional simulations are twofold. First, the benefit from more generous offsets diminishes with ever more restrictive constraints. The largest gain from expanding these limits from 15 to 50% occurs when emissions are capped at 2000 levels and held there indefinitely. The second largest gain is when the emissions target, post-2020, is reduced by 0.5% annually. The smallest gain arises under the most severe constraint of a 1.0% annual reduction following 2020. Explaining this diminishing benefit is the fact that the offset allowances follow the emissions cap, becoming less generous as the cap becomes more restrictive. In addition, for any given emissions path, there is a diminishing benefit from the greater use of offsets. Even though more is better than less, allowing the first 15% from these lower cost external sources reduces the overall policy costs by more than allowing the next 35%.

Second, the increases in the policy costs associated with ever more restrictive emissions targets are larger in moving across the 50% cases than they are in moving across the 15% cases. Increasing the severity of the emissions constraint involves greater incremental costs when offsets are more generous and smaller incremental costs when they are less generous. This arises from the scale of the economy and its associated marginal abatement cost schedule. With the more generous offsets, there is more abatement provided by these lower cost offsets. The economy, therefore, is larger and the more restrictive emissions targets prove more costly. With the less generous allowances, the opposite occurs. Thus, the conclusion for policy design on a cost-benefit basis is not to set limits independently from the use of offsets but rather to take their cost and availability into account when first establishing emissions price-quantity targets.

5.8 Base case sensitivity

More aggressive emissions reductions raise policy costs and signal the importance of underlying base case conditions. If more restrictive constraints prove more harmful then so too does an indefinite cap imposed on an economy characterized by higher emissions. Moreover, that higher baseline emissions entail higher policy costs for a given emissions target only strengthens the case for earlier intervention when emissions are, in fact, lower. To examine this, the simulations of Sections 4 and 5 are recast for a new base case involving faster energy and emissions growth over the period 2010-2025. This is shown graphically in Figure 5.11. Relative to the original base case, GHG emissions from covered sources are 5% higher (7898 $MMTCO_2E$) by 2020, 7% higher (8373 $MMTCO_2E$) by 2025 and 11% higher (9627 $MMTCO_2E$) by 2040. Constraining emissions to 5945 $MMTCO_2E$ indefinitely requires abatement in these same years of 1954, 2427 and 3685 $MMTCO_2E$. Under these conditions, required emissions reductions are between 26 and 33% higher over this period.



For comparability, these model runs repeat the provisions of Section 4. Namely, there are two pairs of scenarios involving 15% and 50% limits on external offsets each with and without international permit trading. The alternative compliance options again are evaluated at their economic cost.

Tables 5.10 and 5.11 show the sources of abatement and their external costs; these are comparable to Tables 5.3 and 5.4 of Section 4. Because required emissions reductions considered in this scenario are larger, there is more abatement occurring from sources within IGEM and a greater use of external offsets. Driven by higher permit prices, the external sources become competitive more quickly, enter the mix earlier and, when constrained, reach their limits faster. When unconstrained, they have a greater presence, though not proportionally so. Obviously, as their use increases, their average cost is higher and their claim on the economy's productive resources increases. But, since they are competitive, the economic costs of this diversion are more than compensated by the release of resources from abatement activities internal to IGEM.

Table 5.10: Sources of Emissions Abatement, Higher Baseline Emissions
In millions of metric tons, carbon dioxide equivalent ($MMTCO_2E$)

	Covered and unlimited		Non-covered and limited				
	Internal to IGEM	External to IGEM					
			Non-covered	International	Stavins-Richards	Total	
	IGEM	Non-CO2 GHG	Res.&Comm.	Trading	Sequestration	Offsets	Total
15% Limit, With International							
2010	196	107	15	459	0	474	777
2020	886	177	31	861	0	892	1954
2025	1312	224	31	861	0	892	2427
2040	2499	294	31	861	0	892	3685
15% Limit, Domestic Only							
2010	481	150	40	0	106	146	778
2020	1012	191	68	0	684	752	1954
2025	1312	224	76	0	816	892	2427
2040	2499	294	76	0	816	892	3685
50% Limit, With International							
2010	194	107	15	461	0	476	777
2020	604	148	39	1084	79	1201	1954
2025	757	158	45	1249	219	1513	2428
2040	1219	181	61	1659	565	2285	3685
50% Limit, Domestic Only							
2010	479	151	40	0	108	148	777
2020	1009	191	68	0	686	754	1954
2025	1252	210	80	0	885	965	2427
2040	1956	272	116	0	1341	1457	3685

Notes:
The 15% limit on alternative compliance options is 892 $MMTCO_2E$ and is always reached in these simulations.
The 50% limit on alternative compliance options is 2974 $MMTCO_2E$ and is never reached in these simulations.

Table 5.11: Abatement Costs External to IGEM, Higher Baseline Emissions
In millions of $(2000)

	Covered and unlimited	Non-covered and limited				
		Non-covered	International	Stavins-Richards	Total	
	Non-CO2 GHG	Res.&Comm.	Trading	Sequestration	Offsets	Total
15% Limit, With International						
2010	-$70	$20	$312	$0	$332	$262
2020	$225	$56	$1,217	$0	$1,273	$1,498
2025	$706	$56	$1,217	$0	$1,273	$1,979
2040	$1,812	$56	$1,217	$0	$1,273	$3,085
15% Limit, Domestic Only						
2010	$56	$97	$0	$519	$616	$672
2020	$344	$299	$0	$4,562	$4,861	$5,205
2025	$702	$371	$0	$5,787	$6,158	$6,859
2040	$1,813	$371	$0	$5,787	$6,158	$7,971
50% Limit, With International						
2010	-$70	$20	$315	$0	$335	$265
2020	$47	$91	$2,193	$385	$2,669	$2,716
2025	$97	$124	$3,054	$1,120	$4,298	$4,395
2040	$251	$236	$5,851	$3,479	$9,566	$9,817
50% Limit, Domestic Only						
2010	$57	$97	$0	$527	$624	$681
2020	$349	$302	$0	$4,613	$4,915	$5,264
2025	$532	$417	$0	$6,537	$6,954	$7,486
2040	$1,356	$1,006	$0	$13,807	$14,814	$16,170

Note:
These costs represent the cumulative abatement costs derived from the external MAC schedules adopted for this analysis.

Table 5.12 compares the impacts under the two levels of base case emissions. There are ratios, baseline to baseline, of average permit prices as well as the average percentage changes in GDP, consumption, the capital stock, labor supply and leisure demand for two intervals, 2010-2025 and 2025-2040. With few exceptions, the economic costs are greater when baseline emissions are higher. For example, over the period 2025-2040, permit prices average about forty percent higher with 15% limits and about twenty percent higher with 50% limits. This 40%-20% pattern also is observed for the impacts on GDP and the capital stock. Labor supply and leisure demand work in equal and opposite directions. The reductions in labor supply are about 50% greater under the 15% limits and 30 to 40% greater under the 50% limits. The increases in leisure demand are proportionally equivalent in magnitude.

Table 5.12: The Effects of Higher Baseline Emissions

Percentage Changes in Average Annual Policy Impacts, Higher versus Lower Baselines

	15% Limit on Alternative Compliance Options		50% Limit on Alternative Compliance Options	
	With International	Domestic Only	With International	Domestic Only
Increases in GHG Permit Prices Due to Higher Baseline Emissions				
2010-2025	47.9%	14.4%	18.2%	13.5%
2025-2040	46.6%	43.1%	23.4%	21.6%
Real GDP				
Original Baseline				
2010-2025	-0.44%	-0.60%	-0.31%	-0.58%
2025-2040	-0.96%	-0.99%	-0.46%	-0.87%
Higher Baseline				
2010-2025	-0.59%	-0.73%	-0.30%	-0.63%
2025-2040	-1.38%	-1.40%	-0.55%	-1.07%
Real Consumption				
Original Baseline				
2010-2025	-0.10%	-0.19%	-0.10%	-0.19%
2025-2040	-0.36%	-0.40%	-0.24%	-0.40%
Higher Baseline				
2010-2025	-0.12%	-0.21%	-0.10%	-0.19%
2025-2040	-0.53%	-0.57%	-0.26%	-0.47%
Capital Stock				
Original Baseline				
2010-2025	-0.47%	-0.67%	-0.34%	-0.65%
2025-2040	-1.10%	-1.15%	-0.56%	-1.03%
Higher Baseline				
2010-2025	-0.62%	-0.80%	-0.32%	-0.69%
2025-2040	-1.58%	-1.61%	-0.64%	-1.24%
Labor Supply (Labor Demand)				
Original Baseline				
2010-2025	-0.36%	-0.46%	-0.23%	-0.45%
2025-2040	-0.67%	-0.67%	-0.26%	-0.55%
Higher Baseline				
2010-2025	-0.51%	-0.58%	-0.25%	-0.52%
2025-2040	-1.00%	-0.98%	-0.36%	-0.73%
Leisure Demand				
Original Baseline				
2010-2025	0.12%	0.15%	0.08%	0.15%
2025-2040	0.22%	0.22%	0.09%	0.18%
Higher Baseline				
2010-2025	0.17%	0.19%	0.08%	0.17%
2025-2040	0.33%	0.32%	0.12%	0.24%

With higher baseline emissions, the losses in consumption are 40 to 50% greater when external offsets are limited to 15% of the cap and 9 to 18% greater under the more generous 50% allowances. In comparisons to the original base case, consumption foregone in 2040 on a per household basis is in the range of $680 with 15% limits, $370 with 50% limits and overseas permit trading, and $630 with 50% offsets from only domestic sources. With higher baseline emissions, these figures are $1050, $460 and $800, respectively.

The patterns observed across scenarios under the lower baseline emissions are repeated here under the higher emissions. With 15% limits, the economic losses are initially larger when only domestic options compete but, ultimately, converge with international participation showing only a slight advantage. With the more generous 50% limits, the economic losses are smaller and, especially so, when foreign permits are available. Under higher baseline emissions, the case with 50% limits and international permit trading incurs the lowest policy costs as it did under the lower baseline.

Most striking is that the gains provided by external offsets increase as baseline emissions increase. The incremental reductions in policy costs secured by raising the limits on these external sources first from 0 to 15% and then from 15 to 50% are greater under the higher baseline emissions than under the lower baseline. This further strengthens the case for allowing these lower cost options to compete in the first place and for allowing still greater use, as economically justified, when policy-enacted emissions reductions become more costly.

5.9 Summary and conclusions

The purpose of this exercise is to offer an economic analysis of some of the key policy provisions currently being debated for dealing with climate change. The analysis employs the Inter-temporal General Equilibrium Model (IGEM) of Dale Jorgenson Associates (DJA) and is structured to highlight those empirical and design issues that most influence policy outcomes.

The overall economic impacts from a modest initiative such as described in this report are estimated to be small. By 2020, the annual losses in real GDP from implementing a similar GHG policy are in the range of 0.5 to 0.7% and reach 1.2% by 2040. The effects on household spending, as measured by foregone consumption, are less than half of these income effects. This translates into losses of $150 to $300 per household by 2020, approaching $700 by 2040. The latter amount is about what households spent in additional energy costs 2006 over 2005 due to the actual increases in energy prices.

While the aggregate costs are small and readily absorbed, there are much larger impacts at the industry level. The energy sectors – coal mining, crude oil and gas extraction, petroleum refining and electric and gas utilities – are hardest hit. By 2020, compliance related reductions in coal use reach 15% with reductions in electricity, oil and gas use in the range from 2 to 3%. As investment and exports are more heavily affected, the capital goods industries experience losses in demand of 3 to 5%. The declines in communications, finance and services are minimal while agricultural and food processing outputs actually increase.

The principal conclusion of this analysis concerns the limits independently placed on emissions offsets from households, small businesses, domestic sequestration and international permit purchases. These alternatives offer abatement at a lower cost than can be secured elsewhere within the activities covered by policy. As such, their presence reduces the already small economic costs of mitigation policy. Moreover, the benefits from allowing the use of these offsets increase as the required abatement increases. While there are shown to be diminishing benefits from ever more generous offsets usage, there are, nevertheless, benefits to be obtained to the point where these sources are no longer competitive. In the spirit of market-based incentives, the limits governing the use of marketable and verifiable abatement offsets should arise solely from their "economics" within an overall, present-value assessment of policy benefits and costs.

In considering interest rates and permit banking, real market interest rates in IGEM are ***simulated*** not assumed. Their role is to equilibrate the balances between saving and investment and between present and future (full) consumption. Behaviorally, they trend toward the economy's long-run marginal physical product of capital and its econometrically estimated social rate of time preference. Near-term rates generally are in the range of 3.0 to 3.5% and systematically decline toward 2.6%. These are far below the rates assumed in other assessments.

Because IGEM's interest rates are comparatively low and annual percentage increases in permit prices are projected to be initially high, the incentive for banking persists well into the future. In comparing outcomes with and without banking, economic costs are comparatively larger over the interval in which permits are accumulated and comparatively smaller as banked permits are withdrawn and used. With lower interest rates, the net, present-value gains from banking take a long time to materialize and favorable policy evaluations will require a longer time horizon to achieve because near-term costs are even more dominant.

Real-world uncertainties aside, the time profile of banking ultimately depends on the evolving patterns of permit prices relative to interest rates. Thus, banking and its consequences are "live" outcomes of the responses to policy enactment. If net gains are realized quickly then banking improves present-value benefit-cost comparisons. However, if net gains take much longer to materialize then banking worsens these comparisons. There is no way to know ahead of time which of these would prevail.

Finally, there is the matter of the ultimate context for this analysis. The goal of any climate policy will be to balance the benefits and costs of climate change and climate change policy. Arguably, there are already private costs associated with government and business mitigation initiatives just as there are already damages associated with climate change (Smith J.B., 2004). Some of these damages are market-based and are numerically comparable to the economic costs of climate change policy (Jorgenson et al., 2004). Policy-driven reductions in emissions will lead to lower greenhouse gas concentrations. In turn, these will have favorable impacts on climate in terms of their effects on temperatures, precipitation, storms, floods and the like. The favorable outcomes for climate produce both market and non-market benefits in the form of delayed or avoided damages. At a minimum, the market benefits help to reduce the net economic costs of environmental policy. At their best, the market benefits more than compensate policy costs and, thus, economically justify timely enactment.