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Extreme climate events and adaptation: an exploratory analysis of drought in Mexico

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ABSTRACT. Climate change is increasing the intensity of extreme weather events. Mexico is particularly prone to suffer at least two different types of these events: droughts and hurricanes. This paper focuses on the effects of an extended drought on the Mexican economy. Through a computable general equilibrium model, we simulate the impact of a drought that affects primarily agriculture, livestock, forestry, and hydropower generation. We look at the effects on the overall economy. We then simulate the effects of several adaptation strategies in (chiefly) the agricultural, forestry, and power sectors, and we arrive at some tentative yet significant conclusions. We find that the effects of such an event vary substantially by sector with moderate to severe overall impacts. Furthermore, we find that adaptation policies can only effect modest changes to the economic losses to be suffered.

1. Introduction

Mexico, like many developing countries, is potentially quite vulnerable to the economic damages caused by global climate change. It is located in a region that is fairly susceptible to significant variation in climate patterns and temperature, and its lack of wealth could act as a barrier to funding effective climate change adaptation policies (IPCC, 2001). Additionally, the most significant economic activities in developing countries like Mexico occur in the agriculture and natural resource sectors, which tend to be highly sensitive to changes in weather patterns. An understanding of the connection between climate on the one hand and economic welfare on the other is of great importance then if economic growth is to be sustained in developing countries such as Mexico.

The US Country Studies Program (USCSP), together with the United Nations Environment Program (UNEP) and the Canadian Government, has financed a host of studies in developing countries. These studies have aimed at making an inventory of greenhouse gases, learning the impact of different emission scenarios on climate change, assessing the vulnerability that arises from such change, and evaluating the effectiveness of alternative adaptation and mitigation options. As a part of those efforts, a group of researchers from UNAM (Universidad Nacional Autonoma de Mexico), at the Center of Atmospheric Studies (CCA) thoroughly analyzed a number of climate change scenarios and studied their impact on a variety of sectors of the Mexican economy. Although these climate change scenarios were quite in depth, the linkages between these results and the various sectors of the economy were not quantitative enough to elicit detailed policy prescriptions.

We focus our analysis on the impact of drought on the Mexican economy and for that purpose we pose three research questions:

(i) What is the cost of such a drought to the economy?
(ii) What sectors are chiefly affected and to what extent?
(iii) What are the benefits from adaptation and who receives them?

In this paper then we use the meteorological results from Gay (2003) as the cornerstone for our analysis, and translate their scientific findings on the physical impacts of climate change into economic terms by calculating the overall cost of adapting to altered climatic conditions and extreme weather events. To conduct our analysis we employ a dynamic Computable General Equilibrium (CGE) model of the Mexican economy. The model is quite extensive in scope and is specially modified to account for imperfect competition (in the energy sectors) which presently exists in the Mexican economy. The chief advantage of such a model is that it allows us to take into account the interrelations between the economy and climate change as well as the feedbacks among sectors. This is crucial when one is dealing with a problem such as extreme drought which affects some sectors directly and others indirectly. Furthermore, it is important to have a dynamic model since drought affects the economy over an extended period of time. Finally, such a model as ours allows us to explicitly estimate the costs to the economy of a climate change-related drought as well as the costs and benefits derived from adaptation over time.

Initially, we run the model under the assumption of no climate change. We then rerun it under the alternative assumption of a severe drought throughout Mexico. To do this, we build a scenario that simulates drought. Rather than looking at variations in weather patterns and running them as alternative scenarios, we focus on the effects of repeated drought conditions on the economy. We then run a scenario where adaptation to drought takes place. Finally, we perform our sensitivity analysis by focusing on the differential capabilities of the economy to substitute inputs during its production process as a proxy for technological change.

It is important to mention at the outset of this paper that we do not test for different weather patterns (i.e. different intensities of drought), but this could be dealt with in future research. On the other hand, our scenarios are in no way related to the IPCC SRES scenarios since we are not modeling several story boards as they do, but just looking at the costs from climate change and benefits from adaptation under one single story board (i.e. same level of economic growth, same population growth, etc).

Our results show the importance of modeling extreme weather events through a multi-market framework since such occurrences impact a number of different economic sectors simultaneously. Additionally, a general equilibrium framework such as that used here is critical in capturing the linkages among the different sectors of the economy making it far more appropriate for our purposes than a static partial equilibrium model. In particular, a static analysis does not allow for a gradual weather change, step-by-step policy implementation, or technological change; and a partial equilibrium model would not capture all the feedbacks across the economy.

The analysis proceeds as follows. In section 2, we describe Mexico's current climatic conditions and the expected overall changes under a severe climate change. In section 3 we review the most significant extreme weather events that Mexico has faced in recent decades, characterize the drought that we will be modeling, and describe the expected economic impacts of such events. Then, in section 4, we present the general equilibrium model, discuss its structure, and explain the advantages of using such a tool. Additionally, we describe how the extreme weather events are integrated into our model framework. In section 5, we describe the various scenarios run and discuss the results of our analysis. Finally, in section 6 we draw the most important conclusions from the study.

2. Background

Mexico has an area of almost 2 million km^2 with a wide diversity of climate zones. The northern two-thirds of central Mexico, from the US border to just north of Mexico City, remain dry to very dry throughout the year. It is also extremely arid in the Baja Peninsula south of California. The central western part of the country experiences a temperate sub humid climate while the southern coasts and the Yucatan Peninsula are warm and sub humid. Warm humid conditions prevail in the area west of the Yucatan to the south central interior. Most of the population, however, is located in the center, north, and northwest part of the country where water is scarce.[1]

Climate change is expected to have a host of environmental and economic effects. As of now, Mexico could already be facing some of these. Its overall location and the presence of several distinct climate zones make some parts of the country more prone to both direct and indirect impacts, depending, of course, on economic activity, population density, water availability, and temperature.

To assess these impacts, vulnerability studies have examined the consequences of a doubling of atmospheric CO_2 concentrations. Two general circulation models have been developed to make environmental forecasts for Mexico: the Canadian Climate Change model (CCC) and the Geophysical Fluid Dynamics Laboratory (GFDL-R30) model.[2] In both of these models, it was assumed that atmospheric CO_2 concentration would double from its present levels and the resulting impacts are reported in Gay (2003).

Results from both models indicate that there will be a substantial modification of overall rainfall patterns and hydrological catchments.

[1] For a map showing these regions, see Ibarraran and Boyd (2006).

[2] The General Circulation Models as well as the CCC and GFDL-R30 are described in Gay (2003).

Aquifer recharging will decline and droughts as well as desertification will increase. Regional ecosystems will be significantly altered and this could result in drastic reductions in both tropical and temperate forests. The industrial and energy sectors face potential damage throughout the country but they will be most vulnerable in the central and northern parts as well as the in the Gulf coast states (Gay, 2003).

Overall, Mexico will see an increase in both temperature and radiation received. The models, however, are not as conclusive regarding changes in overall precipitation. The CCC model predicts a reduction in aggregate precipitation, while the GFDL-R30 model predicts a modest increase. Notwithstanding, these changes are expected to have a profound effect on the overall climatic patterns and to significantly affect the economy. Comparing the functioning of the Mexican economy with and without drought and heat waves will thus help quantify their overall economic impact.

3. Extreme weather events

Worldwide, extreme weather events are now on the rise and more likely to happen in the future (Easterling *et al.*, 2000). This is particularly true of extreme droughts and wet periods. Extreme precipitation events have become more common over the twentieth century, where a disproportionate amount of water fell during short spells, even though the total amount of rain did not change. Indeed, the areas hit by drought and excessive wetness have increased markedly throughout the world. Tropical storms cause more devastation due to the underlying decadal cycle, to the fact that more densely populated areas have developed across the coastlines, and because of their higher strength and intensity.[3]

Extreme weather events may turn into natural disasters if they occur where there are vulnerable populations, fragile infrastructure and ecosystems, and high levels of economic activity. Such disasters can then lead to high-economic and human-related costs (Ibarrarán *et al.*, 2006). Disasters could potentially impose high costs on Mexico, since one out of every ten person there lives in an area where the risk of mortality from environmental factors is already high (CRED, 2004). Furthermore, since most productive capacity in Mexico takes place in fairly confined areas, which are often vulnerable to drought and heavy rains, the potential losses due to such disasters can be quite significant.

The World Bank, through its Hazard Management Unit, studies earthquakes, volcano eruptions, floods, droughts, and cyclones. Mexico is ranked 32 among the 60 countries affected by two or more potential hazards. In Mexico, at least four out of the five hazards listed above happen, and the highest risk disasters are tied to hydro and geophysical sources. Generally speaking, hydro-meteorological hazards occur most frequently on the eastern coast of Mexico, while droughts occur in the semiarid regions of the north. Certain areas of southeastern Mexico experience both

[3] There is an ongoing debate on whether many of these events, and particularly hurricanes, are intensified by decadal fluctuations or if this is due to climate change (Trenberth, 2005; Webster *et al.*, 2005; Emanuel, 2005).

geophysical and hydro-meteorological disasters. The lower central region of the country is somewhat vulnerable to hydro-related hazards, whereas the southwestern states are most susceptible to geophysical occurrences. Because of the nature of such events and the concentration of population and economic activity within these areas, Mexico is likely to face repeated disaster-related losses and costs, leading to recurrent granting of financial relief to regions hit by such events.

Mexico is particularly vulnerable to natural disasters for several reasons. First, its very location is associated with a relatively high probability of being hit by hurricanes and tropical storms. Additionally, it has a dry climate in the northern regions and very wet areas to the south. Climate change is likely to increase the frequency and intensity of hurricanes and extreme precipitation events as well as to lead to higher temperatures and this increases Mexico's vulnerability to natural disasters. Secondly, due to its development level, Mexico has not yet made the investments required to protect itself from such weather events. The presence of large-scale poverty and a highly skewed income distribution exacerbate the situation and increase the vulnerability of certain areas to weather related disasters.

Other than the physical impact of natural events, disasters can also affect people by disrupting the economy and thereby altering their source of revenue. Table 1 presents the most significant natural disasters that Mexico has faced since 1930 based on their economic impact. As can be seen, windstorms (hurricanes) are by far the most damaging disaster, followed by drought and flood. Interestingly, however, the most damaging disasters on a per event average basis are drought related.

When possible, it is important to identify the geographic distribution of disasters and give them a specific value in terms of their human and economic losses, their costs of relief, rehabilitation, and reconstruction. When the impact of such disasters is relatively small and confined to a sparsely populated region, an enumeration of its direct local effects is often sufficient for policy analysis. However, when losses are large, their cumulative effect across sectors and through time can have a range of macroeconomic impacts that eventually affect growth, investment, sectoral outcomes, migration, and income distribution at a national level (Ibarrarán *et al.*, 2006; Khan, 2000). This is what we aim at analyzing in this study.

3.1. Drought: worldview

Extreme weather events such as drought and floods are among the most damaging events a nation can face, since typically such occurrences affect its food producing capacity as well as its infrastructure. Additionally, these effects often have a disproportionately adverse impact on the poor. Extreme events, of course, are nothing new. They have, however, received more attention lately because of their increasing frequency in many parts of the world, likely related to climate change (Watson *et al.*, 1997).

In the last ten years, a host of countries in Africa, Europe, and the Americas have faced severe drought and prolonged heat waves. In 2003, drought and heat waves in Europe led to significant damage in terms of productivity and mortality, and ultimately led to new hypotheses on the impact of climate change in temperate latitudes. Ciais *et al.* (2005) contend

Table 1. *Summary of Natural Disasters in Mexico, 1929–2005*

	# of Events	*Killed*	*Injured*	*Homeless*	*Affected*	*Total affected*	*Damage US dollars (000 s)*
Drought	8	0	0	0	65,000	65,000	1625,000
average per event		0	0	0	8,125	8,125	203,125
Earthquake	27	10,677	33,287	112,275	2411,015	2556,577	76,500
average per event		395	1,233	4,158	89,297	94,688	2,833
Epidemic	2	68	0	0	11,525	11,525	0
average per event		34	0	0	5,763	5,763	0
Extreme temperature	16	1,207	0	16,000	1,400	17,400	4,000
average per event		75	0	1,000	88	1,088	250
Flood	44	4,080	659	165,990	1333,695	1500,344	138,400
average per event		93	15	3,773	30,311	34,099	3,146
Slides	6	202	0	120	200	320	0
average per event		34	0	20	33	53	0
Volcano	10	1,120	500	15,000	146,408	161,908	3,300
average per event		112	50	1,500	14,641	16,191	330
Wild fires	3	83	0	0	0	0	0
average per event		28	0	0	0	0	0
Wind storm	58	4,948	1,803	316,250	2257,815	2575,868	3969,000
average per event		85	31	5,453	38,928	44,412	68,431

Source: EM-DAT: OFDA/CRED International Disaster Database, www.em-dat.net – Université Catholique de Louvain. Belgium. Events recorded in the CRED EM-DAT. First event May 1929, Last entry August 2005. Epidemics included: diarrhea/enteric (cholera), arbovirus (dengue fever).

that total ecosystem productivity as well as total carbon sequestration in Europe decreased due to the recent drought conditions. Forests were affected, tree damage increased markedly, and net carbon sequestration dropped. The net primary productivity of agriculture (estimated from harvest data) in areas affected by heat waves and drought also fell significantly (up to 36 per cent, depending on the crop). In summary then, extreme events of this nature may have harmful long-term effects on continental carbon balances and affect ecosystems in the long run.

3.2. Droughts in Mexico

Due to Mexico's location in a sub-tropical area, extreme droughts associated with climate change are likely to be more frequent, more profound, and last longer than the worldwide average. The expected sectoral effects on Mexico of doubling the level of CO_2 worldwide have been estimated using the two general circulation models discussed above. We briefly summarize the relevant results for our study, taken from Gay (2003).

Overall, Hernandez *et al.* (2003) report that, according to their findings, a doubling of CO_2 levels would cause 36–39 per cent of the area within Mexico to face severe prolonged drought conditions. Hydrological resources will decline since runoff to recharge underground water sources will be reduced (Maderey and Jimenez, 2003). This, in turn, will have a negative effect on the usable water volume and reduce existing water reserves, hurting agriculture, livestock, forestry and ecosystems, and urban life through both water scarcity and the proliferation of water-borne disease. Sustained drought will have its greatest impact, however, on agriculture and forestry. While agriculture's share of total GDP is less than 4 per cent, it still employs over 15 per cent of the total population (INEGI, 2005), most of them subsistence farmers. Presently, only 16 per cent of the land is suitable for agriculture. Of the 20 to 25 million hectares suitable for agriculture, 17 million are rain-fed and 4.8 million are irrigated (Plan Nacional Hidráulico 2001–2006). On the other hand, the poorest Mexicans survive off non-wood products from the forestry sectors.

Agricultural production is constantly threatened due to the high likelihood of drought. In 1994, the entire country was affected by drought, damaging more than 185 thousand hectares. Flooding and hailstorms followed, and states in all regions were affected. In 1996 and 1998, two major droughts took place, once again affecting food production significantly. A further decline in its productivity, due to climate change, will have at least two effects. First, imports of food will rise creating a balance of payments problem, and, second, it will disproportionately impact the poor since they are widely employed in this sector and they spend a larger portion of their budget on food and food services.

Flores *et al.* (2003) analyze Mexico's suitability for rain-fed corn production under several climate change scenarios to determine its vulnerability to losses in suitable cropland. Currently (given their parameters of required temperature and precipitation), 60 per cent of the land in Mexico is not suitable for rain-fed agriculture. Under sensible scenarios of climate change 75 per cent of all cropland becomes unsuitable for corn production, leading to ever-more dependence on imports of corn

– and that is for corn, a relatively drought-resistant crop. Other crops would fair much worse. Conde *et al.* (2003) also find that climate change results in shorter growing seasons and a decrease in corn production. The only adaptation measure able to alleviate these negative effects is the use of fertilizers, and the expense of such fertilizers put them largely out of reach for subsistence farmers. Subsidies are needed even now to support this sector. In the future, however, resources may not be available if massive funds are needed to alleviate other costs associated with climate change.

Even though industry is vulnerable to climate change, it is most likely not significantly affected by a severe drought, since water and weather are not such critical inputs into their production processes.

However, the two most relevant energy sectors, fossil fuels and power, may be affected. Production of fossil fuels may suffer from drought because some refineries located in dry areas would face water availability problems (due to less water and competing agriculture, urban, and industrial uses (Sanchez and Martinez, 2003)).The power sector, on the other hand, could be substantially impacted by the effects of a severe drought. Sensitivity of electric power production to drought is very high in the north and northwestern parts of the country, and both hydro and thermal electric plants could suffer production losses as water sources dry up and become less reliable. The vulnerability of power plants to severe drought is also high in the center, central west, and central east areas of the country, again because of a reduction in precipitation levels and competing water uses.

Indeed, low precipitation levels have played havoc with electricity production throughout Latin America in the past. In 2001, for example, Brazil faced a critical electricity shortage due to insufficient rainfall and years of limited investment in the country's power sector. By 2000, electricity consumption there had increased 58 per cent over its 1990 level, while installed generation capacity only grew by 32 per cent during that same period of time. In June 2001, the government implemented an energy-rationing program, which prevented rolling blackouts. The rationing program ended on 1 March 2002 (EIA, 2005) as new capacity came online. Colombia faced a similar crisis in the nineties.

Finally, drought may also cause macroeconomic impacts. A sustained lack of water may contract economic output, worsen the trade balance, and increase government debt, increase poverty, and slow down economic development (Rasmussen, 2004). Natural disasters such as drought generally have a harsher effect on the poor, and, consequently, a regressive impact on the distribution of income. Developing countries are more prone to feel these setbacks than developed countries due to structural factors, and the effects on the economy may be long lasting (Ibarrarán *et al.*, 2006). The magnitude of these effects is closely linked to the share of land, population, and economic activity affected by the natural disaster.

4. Modeling structure

We turn to the problem of modeling the general equilibrium effects of a severe drought, an extreme weather event intensified by climate change.

Table 2. *Household categories based on income*

Category	*Income*
Agent 1	Bottom 2 deciles: 1–2
Agent 2	Deciles 3–5
Agent 3	Deciles 6–8
Agent 4	Top 2 deciles: 9–10

Economy-wide types of problems are not conducive to analysis within a simplified framework. Often, the number of economic sectors affected is large and changes in one sector can have important repercussions throughout the economy. Such problems are appropriately dealt with using general equilibrium analysis. In this type of framework, all the sectors in the economy are seen as one linked system where a change in any part affects prices and output economy-wide. Mathematically, an interlinked economy can be described by a large system of simultaneous equations. More precisely in an economy with N markets, we require $N-1$ equations to solve for all of the prices and outputs in the system.

In this paper, we look at a national[4] model that has 13 producing sectors and 14 production goods (given that oil and natural gas are produced jointly in one sector). In addition to the eight non-agricultural sectors,[5] agriculture is disaggregated into the livestock, grains, fisheries, forestry, and 'other' agriculture sectors. This was done so that we can now explicitly deal with the Mexican primary sector in detail and quantify its interactions with other sectors when it is affected by a drought as a result of climate change. It is particularly important we do this, given the topic of our paper and the simulations we run. The model also has four household (income) categories (listed in table 2) and seven consumption sectors, namely food, energy, autos, gasoline, consumer transport, consumer services, and housing and household goods. There is also a foreign sector and a government sector in this model.

The economic variables determined by the model are investment, capital accumulation, production by each sector, household consumption by sector, imports and exports, relative prices, wages and interest rates, government budget expenditures and revenues, and total wage income. The level of depreciation and the initial return to capital are taken as exogenous, as is the rate of labor force growth.

[4] Data restrictions prevent us from constructing a regional model. Furthermore, a regional model is largely impractical given that the capital in any given region is owned by individuals and corporations throughout the country. Lack of regionalization is not a major drawback however. To a great extent the effects of a major drought will be economy-wide since agriculture is the economic sector most affected, and (largely poor) consumers will be more or less equally impacted.

[5] These are oil and gas, chemicals, refining, manufacturing, coal mining, electricity, transportation, and services.

4.1. Production[6]

In each time period, producers maximize profits in a competitive environment. Profit maximization, based on the described production technology, yields output supply and factor demands for each production sector and factor market in the model. Output and input prices are treated as variables. Taxes are also included, with producers facing tax exclusive prices and consumers (and input consuming firms) facing the tax inclusive prices. As a word of caution, the goods produced in the model's production sectors are not the same final goods consumed by consumers. Agricultural products, for example, must be combined with transportation services, manufacturing, and chemicals before they can be consumed by individuals as food. Hence, in our model, we use a matrix to map from the vector of production goods to the vector of consumption goods. We do this through the use of nested functions to the production side of the economy as well as to the production of final consumption goods and services. This allows for different degrees of substitution for the inputs considered. In the particular case of production, it allows for substitution between labor, capital, energy, as well as non-energy inputs. Technologies are represented by production functions which exhibit constant elasticities of substitution. Technical progress is taken as exogenous to the model.

4.2. Consumption and income distribution

On the demand side, the model reflects the behavior of domestic consumers and foreigners (who can also invest through their savings), as well as that of the government. Domestic consumers are assigned to four groups (agents) according to income and a demand equation is specified for each group, which has a different consumption bundle depending on its income. All four groups are endowed with labor. Since only the wealthy actually have (formal) savings in Mexico, we assume here (in accordance with the latest data from INEGI) that only the top two groups (agents 3 and 4) own capital.[7] The gross income of each group rises by the rate of population growth plus the rate of technological change which is taken as capital augmenting. These resources are rented out to firms in order to finance the purchase of domestic or foreign goods and services, save, or pay taxes to the government. The membership of each group is fixed and, although group income increases (or decreases) with GDP, individuals do not 'migrate' as such from group to group.[8]

[6] For a formal mathematical description of the model, see Ibarraran and Boyd (2006: 114–126).

[7] Household savings here have a certain degree of endogeneity. The levels of savings for each income group (i.e. agents 3 and 4) are set at the levels which actually occurred in the base year (i.e. 2005). After that time, however, they are allowed to vary in response to changes in the relative prices of consumption and savings.

[8] Such migration, though a concept to explore, is computationally beyond the scope of this model. Furthermore, our chief concern with income distribution is how different income groups with varying consumption bundles and income streams are differentially impacted by the effects of a sustained drought.

4.3. Government

The government agent is modeled with an expenditure function similar to the household expenditure functions (i.e. based on a CES utility function). Revenues derived from all taxes and tariffs are spent according to an expenditure function. Within this expenditure function, the government spends its revenues on goods and services from the various private production sectors discussed above. Consistent with the treatment of Ballard *et al.* (1985) and others, we posit an elasticity of substitution between inputs to the government's utility function. This allows for price responsiveness in the provision of government purchased goods. The government also spends its revenues on labor. Together these arguments represent the government purchases and payment of government employees necessary for it to carry on its work. The government also separately redistributes income through exogenously set subsidies and transfer payments, and all revenues are spent.

Taxes in the model are expressed *ad valorem* and include personal income taxes, labor taxes, capital taxes, property taxes, revenue taxes (such as payments from oil and gas activities), value added taxes, sales taxes, import tariffs, and export taxes. The taxes on final goods such as gasoline differ from other consumer goods because of special taxes levied on them by the government. By the same token, final goods such as electricity differ in treatment due to existing government subsidies. When applicable, taxation is based on marginal tax rates. Subsidies, on the other hand, are essentially treated as negative taxes and in these cases the government transfers funds back to a sector in proportion to that sector's output. Thus, if these subsidies are abolished, the government has more revenue.

In most CGE applications, it is appropriate to represent all government income as equivalent, regardless of the source, and to send it directly to the government sector for spending without differentiating between sources. In this analysis, however, it is important to distinguish those funds that come from PEMEX (oil state-owned company), those that come from CFE (power state-owned company), and those that come from all other sources throughout the economy. To do this we construct two 'dummy' sectors in the economy. The purpose of these sectors is to collect the funds from PEMEX (the oil-producing state-owned company) and CFE (the power producing state-owned company) and then transfer them on to the government general fund. By so doing, we are then able to obtain an accurate measure of all government revenues derived from CFE and PEMEX.

4.4. Trade

International trade within the model is handled by means of a foreign agent. Output in each of the producing sectors is exported to the foreign agent in exchange for foreign-produced imports. Under this setup, the aggregate level of imports is set and grows at the steady-state level, but the level of individual imports may change in response to changes in relative prices. Exports are exogenous as well and are assumed to follow a constant growth path. They are, however, responsive to changing prices, and can change as individual sectors are shocked. Transfer payments, on the other hand, are endogenous and act so as to clear the model. The exchange rate is determined then by the interaction of capital made available for external uses, goods supplied for export, and the exogenous level of imports.[9] Price-dependent import supply schedules are derived from elasticity estimates found in the literature.[10] In specifying the level of substitutability between goods, we replace the classic Heckscher–Ohlin assumptions and rely instead on the Armington (1969) assumptions which allow for imperfect substitutability between foreign and domestically produced goods. One feature of this setup, which is particularly important to our present analysis, is that it incorporates flexible trade prices and thereby allows for the adaptation to severe droughts via adjustments in the balance of trade.

In this model, we assume that Mexico has no market power in the world petroleum market. Hence, we treat the international price of oil as given and Mexican oil producers as price takers in the market. Consequently, when the Mexican government institutes investment policies to increase aggregate oil output, the domestic price drops as output increases and more is exported as the international price increases relative to the domestic price.[11] On the other hand, oil depletion and lack of investment (due to drought) have the effect of raising the domestic price and curbing exports.

4.5. Labor growth and capital formation

Growth within our dynamic CGE model is brought about by the changes over time in both the labor force and the capital stock. In keeping with the theoretical underpinning of the Ramsey model (1928), we model the changes in the population as exogenous and constant over the time period considered. In the absence of any perturbation, Ramsey predicts that the economy will grow at the labor supply growth rate in the steady state.

In the model, we assume that there is only one type of raw capital good, which goes into the various sectors. In addition, to add realism we assume that the capital, which does go into a sector, works like putty and clay. More specifically, we assume that capital which is new can be readily combined with other inputs to produce outputs. Over time, this capital becomes locked into an older technology (i.e. clay) and has a harder time combining with other inputs. In the growth literature, this is also known as 'vintage capital'. This is plausible as illustrated by sectors such as electricity production, which has been subject to a great deal of technological change over the years. The capital growth rate is modeled in accordance with neo-classical capital theory assumptions. More specifically, the growth of capital is modeled as investment net of economic depreciation. Such depreciation could, of

[9] As a side note to this, closure in our model is determined by the equality of domestic and foreign leakages and domestic and foreign injections. More formally we have $(S + M) = (I + X)$ where S is domestic savings, M is imports (current account), X is exports (current account), and I is the total amount of investment made available from foreign and domestic agents. The government budget is assumed to be balanced.

[10] See, for example, Serra-Puche (1984), Romero (1994), Fernandez (1997), and Wylie (1995).

[11] Domestic and international price of oil may differ due to quality and transportation costs.

course, vary as both capital and its productivity are affected by climate change.

4.6. Terminal conditions

One potential drawback of a computable model, such as the one employed here, is that it can only be solved for a finite number of periods. Consequently, a few adjustments are necessary to design a model that, when solved over a finite horizon, approximates infinite horizon choices. First of all, to keep consumers from consuming all of the remaining capital in the final period we, in essence, 'trick' them in the model. We endow them with capital in the initial period. Then in the terminal period we take away all capital from the capital-owning agents, preventing them from consuming it all in the final period of the analysis. We model this following Lau *et al.* (2002).

We then need to specify an equation or specific value for capital in the final period. At first glance, it might seem best to impose the long-run steady-state level, but then the model horizon would have to be sufficiently long to eliminate terminal effects. As an alternative, we include the level of post-terminal capital as a variable and add a constraint on investment growth in the final period. Thus we have $INV_T/INV_{T-1} = Y_T/Y_{T-1,}$ where Y_T gives GDP at time T. This constraint imposes a balanced growth in the final period, but does not require that the model achieve steady-state growth. The advantage of this approach is that it alleviates the need to determine a specific target capital stock or a specific terminal period growth rate. In the particular model that we employ in our simulations in the next three sections we set the terminal time at 2026 and hence $T = N = 22$.

4.7. Depletion and imperfect markets

All of the meaningful runs of the model assume that oil resources in Mexico are finite and that they are subject to depletion after some point in time. Thus, in most of the model's runs we restrict output to some exogenous pre-determined level in line with existing depletion estimates. Another modification designed to yield empirical realism to the model is the inclusion of markup prices in the state-run energy sectors. Since both the petroleum (PEMEX) and power generation (CFE) sectors are run by state monopolies, we allow for markup pricing in these two sectors.[12]

4.8. Calibration and data

The model is calibrated for 2005 using different sources. Data on consumer expenditures on final goods by income category are from the *Encuesta Nacional de Ingresos y Gastos de los Hogares*, 2000, published by the Instituto Nacional de Estadística, Geografía e Informática (INEGI). Data on imports and exports are from *International Financial Statistics*, various editions, published by the International Monetary Fund (IMF), *The Mexican Economy*, 2000, published by the Banco de México, and the *Anuario Estadístico de*

[12] For a full discussion of these issues within the context of the model, see Ibarraran and Boyd (2006).

los Estados Unidos Mexicanos, 2000, published by INEGI. Data on inputs, outputs, and use of labor and capital by production sector comes from data compiled by INEGI and supplied by the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). This same source along with the *Anuario Estadístico de los Estados Unidos Mexicanos* were used to calculate the transformation matrix as well as to find investment levels by sector. All results on fossil fuel consumption (both aggregate and sectoral), fuel prices, fuel imports and exports, and government consumption of various fuels were provided by the Secretaría de Energía (SE), PEMEX, and INEGI. These data were then scaled using 2005 GDP numbers. Some of the most critical parameters for a model such as this are the elasticities of substitution between the various inputs. For these we relied on existing estimates gleaned from the literature.[13] Most values were close to one (except in petroleum extraction, refining, and mining where they were substantially lower). There remains, however, some uncertainty on this point. Hence, we ran a sensitivity analysis to check how robust our results were with respect to changes in these parameters.[14]

5. Simulations and results

The dynamic CGE model described above can now be used to examine the economy-wide effects of a sustained drought in Mexico. The model is first run in what is termed a Benchmark using an updated 2005 Mexican social accounting matrix (SAM). In this situation imports, exports, consumption, government expenditures, and production as well as carbon emissions in all sectors rise steadily by the initial rate of growth, and all prices expressed in 2005 decline each period by the rate of discount. Put more precisely, the values of all future outputs measured in today's terms decline by the discount rate, and in our model this is accomplished by letting the current prices decline in each period after the initial period. In addition, income, household welfare, and the capital stock, grow by this same initial rate. In the literature, the original Benchmark equilibrium is often referred to as 'steady-state' equilibrium since in this particular case no forces act to move the economy off from this growth rate in all sectors. Such equilibrium has a number of desirable characteristics because in this situation all markets clear in all periods; there are no excess profits being made by any firm or sector, and consumer welfare is maximized given the constraints of labor, capital, and natural resources in the model.

After having the benchmark we include other features such as oil depletion, based on plausible changes in oil stocks, as well as the degree of substitutability between capital, labor, energy, and material inputs into

[13] Substitution elasticities between capital, labor, and energy for the manufacturing and agriculture industries were derived from recent case studies (Hueter, 1997 and Skuta, 1997, respectively; Wylie, 1995; Salgado Banda and Bernal Verdurgo, 2007). The elasticities of substitution for petroleum and electricity were based on US estimates from Tarr (1989) and Mexican estimates by Sterner (1989).

[14] A summary of these results is contained in the relevant footnotes in the results sections below. A complete listing of these results can be obtained from the authors upon request.

the production process in each of the model's sectors. We also include imperfect markets since these are relevant in the case of the petroleum sector, the power sector, and for the labor market in Mexico. This scenario, which we refer to as scenario 1, is, in turn, the relevant scenario to simulate a no-drought case.

To see the effects of a sustained drought, we develop parameters based on expectations from the literature (see section 5.1) regarding the impacts of long-term drought conditions on the various agriculture and energy sectors in our model, giving rise to scenario 2. By running the model with these changes and comparing the results with those in scenario 1, we are then able to look at the economy-wide costs of this extreme event on consumption, consumer welfare, and economic growth. Additionally, we are able to quantify the impacts of the various economic sectors as well as the effects on the balance of payments, and the distribution of income in Mexico for the period between 2005 and 2026.

Scenario 3 presents further simulations conducted to observe the economy-wide effect of using adaptation strategies to ameliorate negative climate impacts on agriculture, forestry, and electricity. All told, we report the results of three simulations below. To then gain a full understanding of the consequences of long-run drought and adaptation policies, we go over the results of the main simulations in detail below.[15]

5.1. Assumptions for drought

To simulate a prolonged and repeated drought, we follow Liverman and O'Brien (1991) who finds that global warming will most likely bring warmer, drier conditions to Mexico. They predict that soil moisture and water availability will significantly fall nationwide with the most severe effects occurring in rain-fed and irrigated agriculture, forestry, urban and industrial water supplies, hydropower, and delicate ecosystems. Using this information and combining it with Rosenberg (1993) to follow his modeling framework, we design the drought scenario that we use to address our research questions posed in the introduction to this paper. Drought impacts the following sectors most severely: forestry, grains, other agriculture, livestock, and hydropower. It takes place at two points in time with the same level of severity. The first drought occurs between years 2010 and 2015 and the second between 2019 and 2024. After the second drought the model is given a period to re-equilibrate before the terminal period. In our model, drought is reflected in reduced productivity of those sectors most affected.

Scenario 1: Depletion in the oil and gas industry

In scenario 1, the level of oil produced is allowed to rise according to the overall rate of economic growth until the year 2009, but from that time onward the amount of oil production is held constant at 5.2 million

[15] For purposes of completeness and to measure the robustness of our model to parametric changes, we also do a sensitivity analysis by varying the substitution and demand elasticities that we use. These are reported in the footnotes. The complete results may be obtained from the authors upon request.

Table 3. *Summary of CGE Results Data for Mexico for 2026*

	Scenario 1	*Scenario 2* %	*Scenario 3* %
GDP	12.188	−3.05	0.33
Oil output	0.251	1.63	0.22
Power output	0.170	−2.13	0.24
Consumption	8.657	−0.25	−0.01
Imports	3.808	0.00	0.00
Exports	3.920	−0.60	0.04
Exports oil	0.236	−0.96	0.09
BoP surplus	0.112	−26.14	1.88
Cumulated welfare agent 1	4.193	−1.12	0.06
Cumulated welfare agent 2	12.529	−1.13	0.05
Cumulated welfare agent 3	19.460	−0.85	0.03
Cumulated welfare agent 4	32.465	−0.54	0.00
Terminal capital stock	29.767	−4.05	0.43
Cumulated Govt. revenue from PEMEX	0.407	0.05	0.00
Cumulated Govt. revenue from CFE	0.057	−0.35	0.00
Cum. Govt revenue from other sources	6.416	−0.90	0.06

Note: The numbers for scenario 1 are given in hundreds of billions of 2000 US dollars. The numbers for scenario 2 are the percent change from Scenario 1 and the numbers for scenario 3 are the percent change from scenario 2.

barrels per day. This is done because the depletion of existing stocks of petroleum will make it impossible for extraction to rise with the rest of the economy without massive investment of PEMEX (i.e. the national oil company of Mexico) in drilling and oil exploration activities. Furthermore, by capping oil production at 5.2 million barrels per day our model simulations correspond exactly to PEMEX's current long-run planning goals (see Secretaría de Energía, 2000). Holding extraction at 2009 levels, then, is much more realistic than assuming that oil extraction expands as fast as general economic growth. This assumption, in turn, gives us a much more reliable benchmark with which to measure the impacts of climate change and policies to adapt to permanent drought conditions. Additionally, we assume that PEMEX (oil extraction) and CFE (electrical power) in their capacity as state-run monopolies exercise their power to mark up prices.

The aggregate results from scenario 1 are given in table 3 while the sectoral results are listed in table A1 (appendix). In both cases, the results are listed for 2026 (i.e. the terminal year) as absolute numbers (in hundreds of millions of 2000 dollars). The most important factor taken into consideration in this scenario is that there is depletion of Mexico's oil reserves. Had the benchmark been run without this assumption, crude oil production in 2026 would have been some 37 per cent higher than the numbers we listed here. Likewise, since oil is the chief contributor to the generation of CO_2, the emissions of that gas are 33 per cent lower than if we had not taken depletion into account. Thus, the natural process of depletion can limit to some extent the emissions of greenhouse gases and failure to include depletion could possibly result in an overestimate of emissions.

Since crude oil serves as a direct or indirect input into other economic sectors, the decline in petroleum production due to depletion leads to significant declines in the production of refinery, coal, manufacturing, and chemical products as well.[16] There is also a decline in the production in all of our model's agricultural sectors. Energy is essential to agricultural production and as the price of energy goes up so do agricultural costs. Agricultural producers are forced to cut back on production and high cost producers are forced to leave the industry altogether. Even without climate change, then, there are cost factors that are going to bring about pressure on Mexico's agricultural sectors and this has to be taken into account by policy makers attempting to ameliorate future crop and forest damage. Since oil plays such a vital role in the Mexican economy, depletion leads to a drop in GDP, the final (i.e. 2026)[17] level of investment, the economic welfare of all four agents, and the final value of the capital stock.[18] Because of the high proportion of energy consumed by Mexico's poor and middle-income groups, the decline in oil growth has a generally regressive impact on income distribution as the poorer agents experience proportionally greater losses than the richer agents. Depletion also has a significant impact on Mexico's foreign trade. As mentioned in section 4.4 above, much of Mexico's foreign exchange is earned through its oil exports, and the loss in oil production results in a significant curtailment of total exports and, consequently, deterioration in Mexico's terms of trade.

Scenario 2: The effects of a climate event (moderate elasticity case)

In scenario 2, we adjust the model so as to simulate a period of sustained drought in Mexico and quantify the impacts of such a change in climate on the various sectors of the Mexican economy. More precisely, in this exercise we simulate a drought during years 2010–2015 and 2019–2024 of the same intensity as the Mexican drought during the years 1993–1996. According to Rosenberg (1993), the primary impacts of a sustained drought are on crops which are sensitive to heat and lack of water, livestock that feed on rain-fed grass, forestry, and electricity (in as far as it is produced by hydro sources). Hence, we would expect that the damage by such a weather occurrence will be strongest in these sectors and that the adverse effects suffered by other sectors will depend on the strength of their linkage to agriculture and electricity. As with scenario 1, we run the model from 2005 to 2026. We adjust the productivity in the agricultural and electricity sectors during the drought years so as to replicate the impact of the drought on those particular sectors. We then see how this affects these and other sectors in the model (as well as the model aggregates such as GDP and the level of

[16] Due to space constraints the exact magnitude of the declines due to depletion are not given here. They can, however, be obtained from the authors upon request.

[17] This stems from the fact that the maximum number of times a model of this size could be run is 22 and since it was run on an annual basis we solved it for 22 years. This should provide sufficient time for practically all of the adjustments to drought (both market and technological) to take place.

[18] This value along with the welfare and government expenditure numbers is discounted back to 2000 dollars for purposes of consistency.

the capital stock) by comparing our results here to that of scenario 1 above. This then will give us an initial idea as to the sector-by-sector consequence of a climatic event as well as giving us an initial estimate of its overall impact.

The results of scenario 2 are given in tables 3 and A1 next to those of scenario 1. We see that, as expected, the most dramatic results are in the model's agricultural sectors. As the drought effects persist, production in all agricultural sectors goes down and fewer agricultural goods and wood products are available for consumers. The effect of this climate event, however, is not limited to production in the primary sectors alone. Electricity too suffers significant losses, as less water is available for conversion to hydroelectric power. The combination of less production in agriculture and electricity, in turn, has ripple effects on the model's other production sectors. As food and electricity prices rise, productivity slows in the manufacturing, chemicals, and refining sectors. The losses in these secondary sectors are not as pronounced as in the primary sectors. They are, however, not trivial in nature. Production in the extractive industries fluctuates and declines a bit in the long run. Production in the transportation and services sectors, however, only decline slightly and actually rise a bit in the early years of the simulation as resources are released from other, less profitable industries.

Turning our attention next to the consumption sectors, we find that in the wake of generally higher prices, consumers cut their aggregate purchases. As expected, the purchases affected the most are those in the food sector. Energy consumption also declines slightly due to higher electricity prices. There are gains in the other sectors as consumers switch their purchases. Consumption as a whole, however, declines as expected. The other aggregate economic numbers are down as well. Investment, government spending, GDP (see the GDP chart), the level of the capital stock, and, consequently, the level of economic growth, decrease slightly, reflecting the general downturn in economic activity. Because food and energy are by and large necessities, they make up a larger portion of the poorer consumers consumption than that of the rich. The upshot of this is that (as can be seen in table 3) the welfare of the poorer agents generally declines more than that of the wealthier agents. In addition to decreasing income then, a severe drought would also be regressive in nature and have its most severe impact on Mexico's lower-income groups.

The foreign trade sector is also impacted by a sustained drought. Given that less in the way of agricultural goods is produced, fewer agricultural goods are available for export to other nations. Furthermore, since agricultural goods are generally necessities, there is more of a demand for imported agricultural goods for domestic consumption. As pointed out above, international markets in agricultural commodities and flexible capital trade flows provide Mexico with a buffer against some of the most severe consequences of a sustained drought. As a consequence of this, however, the terms of trade are negatively impacted and the balance of payments declines precipitously. This all assumes, however, that international prices remain fairly constant during this drought period. To the extent, however, that other countries such as the United States would also be affected by a climate event, these numbers may change, and the decline in the terms of trade may not be as great as indicated here.[19]

Scenario 3: The effects of adaptation to a climate event

In scenario 3, we measure the combined impact of a sustained drought in Mexico and a series of measures, spearheaded by government policy makers, which are designed to dampen the disruptive impact of such a climate event. In these scenarios, the effects of depletion and weather damage to agriculture and energy are modeled exactly as they were above in scenario 2. Now, however, in addition to these earlier changes we assume that actions are taken to increase productivity in the agricultural sector. Following Rosenberg's 1993 study of the central US, we increase productivity in agriculture in line with what can reasonably be expected over the next 25 years. Rosenberg had also explored the possibility of adjusting the time when crops were planted and harvested in order to avoid crop damage. While this is a realistic strategy in the US, it is not that realistic a strategy for Mexico where similar temperatures are encountered all year round. Rosenberg also looked at the impact of increasing drought resistance through breeding to produce crops with higher stomatal resistance (making them more efficient water users) as well as the impact of increased irrigation efficiency. Using Rosenberg's numbers then we increased irrigation efficiency by 10 per cent and drought resistance of grain crops by 15 per cent. The Rosenberg study found that technological change was generally ineffective in alleviating timber damage. It is highly probable, however, that the deforestation associated with timber growth would lead to more pasture land and, consequently, to more land for livestock grazing. Hence, we increased the amount of land available for livestock grazing by 10 per cent. We then adjusted our model so that these adaptation policies were implemented gradually over the period of simulation. Such technological change, however, is not without cost. While increasing land availability due to timber loss and higher yield crops may

[19] We run essentially the same simulation as in the previous scenario. Now, however, we vary the values of the elasticity of substitution in the production sectors. More specifically, in this model simulation we change the parameters governing the ease of substituting labor, capital, materials, and energy within the production process of major production sectors. By so doing we allow Mexican producers to more (or less) easily substitute relatively abundant factors of production for relatively scarce factors of production and thereby lower (or raise) the cost of adapting to a sustained drought. In practice, we raise the substitution elasticities to 1.5 times their original value and lower them to half of their original value.

The results of our sensitivity tests indicate that the results we obtained earlier in scenario 2 are fairly robust and give a good indication of the qualitative nature of the sectoral economic changes that would follow a sustained drought in Mexico. They also reinforce the important notion that input substitutability is an important aspect of dealing with climate change, and that the more substitutable a country's labor, capital, land, and material inputs are, the more resilient an economy will be to the higher costs brought about by a severe climate event.

involve minimal expenses for Mexico, improvements in irrigation systems often involve considerable outlays. Hence, further adjustments were made to our model's results to reflect these costs.[20] No adjustments, however, were made to the electricity sector since various studies have indicated that the generation of hydroelectric power is pretty much proportional to the amount of water actually available for hydroelectric use.

Here we see in tables 3 and A1 that the effect of such adaptation policies is to increase production in all sectors. Of course, the largest increase in production (relative to scenario 2) occurs in the grains and livestock sectors that are directly affected by technological change. Interestingly, however, all sectors (including electricity, forestry and other crops) rise. This is because the direct effect of the technological change makes more items available for export and leads to an influx of international funds. This, increase, in turn, along with an increase in savings makes more funds available for internal investment. Investment, GDP, and the level of the capital stock all rise and, with more investment, productivity goes up in all sectors. The fact that sectors are linked shows an advantage of using a CGE model such as ours to analyze these types of climate change scenarios.

Most of the other results of the simulation are fairly close to what we would expect. Since food is consumed in larger proportions by the lower income agents we would expect any increase in food production to have the most positive impact on these consumers, and indeed our model results indicate this to be the case. Government revenues also go up, as do the exports of all industries except refineries and chemicals.[21]

The magnitude of the changes brought about by the adaptation strategy is moderately significant. Our figures show that by the last year of the simulation, the production of grains recovers almost one-fourth of the loss they suffered from the sustained drought, while the livestock sector recovers a little more than 10 per cent of its original losses. Overall, the economy regains about 10 per cent of its losses, with different sectors recovering greater or lesser amounts according to their linkages to the agricultural sectors. From one standpoint, then, our results here can be seen as encouraging and as pointing to the positive role to be played by technological change and irrigation investment in adaptation policies designed to limit the deleterious impacts of severe climate events. On the other hand, however, it can be seen that even the best adaptation policies can only make modest changes in the level of overall economic losses to be suffered.

[20] To get an estimate of this cost we obtained information from the *Instituto National de Ecologia* (INE) on the present expenditures on such projects. We then increased these by 10 per cent (to conform to Rosenberg, 1993) and calculated the cost through the relevant time horizon. We then deducted those expenses from aggregate government welfare in the model to adjust for such costs.

[21] As before in scenario 2 the elasticities are raised and lowered. The results of this exercise indicate that the numbers are again fairly robust with respect to the elasticity parameters of the CGE model, and give us reason for confidence in our results.

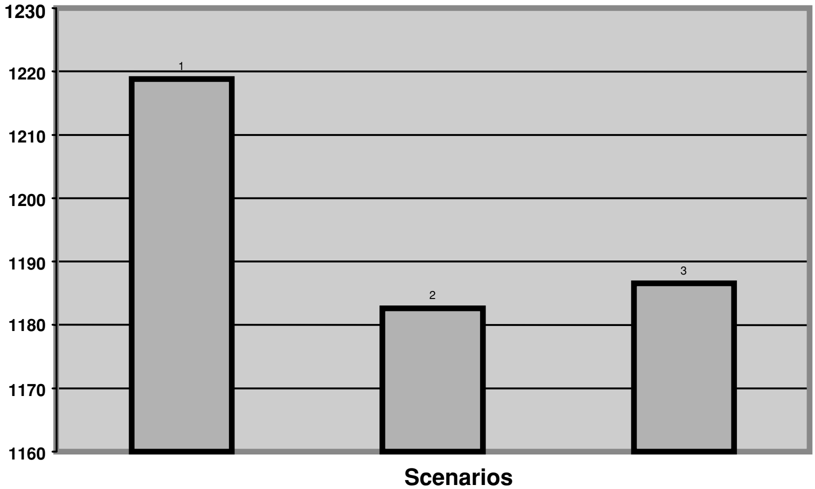

Figure 1. *GDP (billions of 2000 US dollars) in 2026 under each scenario.*

6. Conclusions

Climate change is increasing the intensity of extreme weather events, and with these changes come new challenges for developing countries such as Mexico. In this analysis, we have employed a dynamic CGE model and have looked at the effects of an *extended drought* on the Mexican economy as well as looking at the effectiveness of several adaptation strategies in the agricultural and forestry sectors. In so doing we have sought to quantify the effectiveness of adaptation strategies within Mexico's various agricultural sectors. We have found that, as expected, the largest production losses occur in the rural sectors with output in the grains, livestock, forestry, and other agriculture sectors dropping 11.56 per cent, 13.78 per cent, 18.52 per cent, and 12.23 per cent respectively. Smaller losses occur in urban areas since declines in the manufacturing sectors (i.e. manufacturing, chemicals, refining, and electricity) are, by and large, less severe than in agriculture, while the service sectors (i.e. service and transport) hardly suffer any losses at all.

To say, however, that urban dwellers remain largely unaffected would be a mistake. As shown by our CGE model there are significant linkages between sectors and consumers, and rising food and energy prices combined with an influx of workers from drought affected areas would put a strain on urban facilities and consumers as well. Furthermore, to the extent that investment, GDP, and growth are negatively impacted by drought, the effects will be widespread. With that said, however, it is important to point out that agriculture is relatively more important to the lower-income groups, and our results suggest that a drought would have a damaging regressive impact on consumer welfare.

Although it can be somewhat costly in the short run, our model's results do suggest that technological change has a positive role to play in the alleviation of some of the more serious effects of sustained drought. More specifically, our results indicate that, on net, investment policies geared to enhance technology, adaptation, and irrigation can indeed mitigate losses in agriculture due to climate change. At best, however, these policies can only serve to *limit* those losses and not to prevent them entirely.

Finally, our model simulations serve to reinforce the notion that input substitutability is critical to adapting to climate events such as a sustained drought, and the more substitutable labor, capital, and material inputs are, the more resilient the economy will be to the higher economic costs brought about by a severe climate event. This, in turn, suggests that technological change should be coupled with a focus on increasing input substitution when a country such as Mexico is faced with the negative effects of climate change.

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Appendix

Table A1. *Quantities: CGE results for individual sectors for 2026*

	Scenario 1	*Scenario 2* %	*Scenario 3* %
Production			
Grain	0.3400	−11.56	2.76
Livestock	0.4049	−13.78	1.70
Coal	0.0200	−7.77	1.09
Oil	0.2510	1.65	0.22
Manufacturing	5.4946	−5.25	0.67
Chemicals	0.5727	−5.93	0.71
Refining	0.2210	−10.14	1.36
Transport	1.0016	−0.66	0.06
Electricity	0.1705	−2.08	0.24
Forestry	0.0446	−18.52	0.69
Fish	0.0717	−0.49	0.07
Other Agriculture	0.4027	−12.23	0.38
Services	6.5042	−0.48	0.04
Natural Gas	0.0298	−2.01	0.34
Consumption			
Food	2.2461	−2.27	0.23
Living Costs	3.2235	0.43	−0.08
Gasoline	0.3538	0.69	−0.10
Autos	0.3796	0.04	−0.03
Energy	0.2720	0.17	−0.11
Transport	0.3866	0.58	−0.09
Services	1.7958	0.58	−0.10
Imports			
Grain	0.0191	7.33	−1.71
Livestock	0.0139	9.71	−0.98
Coal	0.0048	−1.05	0.00
Oil	0.0000	0.00	0.00
Manufacturing	3.0512	−0.12	−0.01
Chemicals	0.5284	−0.98	0.11
Refining	0.0783	−1.15	0.13
Forestry	0.0049	13.27	0.00
Fish	0.0023	−2.17	0.00

Table A1. *Continued*

	Scenario 1	*Scenario 2* %	*Scenario 3* %
Other Agriculture	0.0971	6.90	0.00
Services	0.0024	−2.13	0.00
Natural Gas	0.0057	−6.14	0.93
Exports			
Grain	0.0047	−7.53	2.33
Livestock	0.0250	−9.22	1.10
Coal	0.0007	7.69	0.00
Oil	0.2362	−0.95	0.09
Manufacturing	3.1948	−0.36	0.05
Chemicals	0.2703	0.50	−0.07
Refining	0.0322	0.78	−0.15
Forestry	0.0020	−12.50	0.00
Fish	0.0271	0.37	0.00
Other Agriculture	0.1206	−6.89	0.00
Services	0.0063	0.80	−0.79
Natural Gas	0.0006	0.00	0.00

Notes: The numbers for scenario 1 are given in hundreds of billions of 2000 US dollars. The numbers for scenario 2 are the percent change from scenario 1 and the numbers for scenario 3 are the percent change from scenario 2.