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The upside hedge value of California's global warming policy given uncertain future oil prices

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ABSTRACT

The economic modeling that policymakers typically rely on—and all the economic modeling of AB 32 (California's Global Warming Solutions Act)—assumes smooth future price paths, ignoring the reality of significant price volatility of fuels derived from crude oil. To add some insight into the value of reduced exposure to gasoline and diesel price spikes as a result of climate policies like AB 32, we define the benefit of upside hedge value: the extra avoided expenditures on gasoline and diesel fuel that accrue when their prices spike. We develop two historically-grounded price spike scenarios: a moderate spike of 25% and a large spike of 50%. After accounting for short-term price elasticity of demand effects, we estimate the upside hedge value to be between \$2.4 billion and \$5.2 billion (all 2007 dollars) for the moderate and large hypothetical shock scenarios, respectively.

1. Introduction

Americans have become accustomed to oil price shocks. Debates about when oil would reach its maximum production rates began in the 1950s (Hubbert, 1949, 1956), and truly entered the minds of American consumers in the early 1970s. Since then, we have experienced an international oil market that is regularly shaken by sudden price increases. As shown in Fig. 1, in the past 40 years Americans have experienced six significant gas price shocks following spikes in the world oil market.

These oil price shocks impact the California economy given its sizable and growing demand for crude oil and refined products, primarily gasoline and diesel. California oil demand far exceeds in-state production, leaving California dependent on oil imports, which we define as originating outside the state, primarily from Alaska and foreign countries. In 2006, California used the energy equivalent of 593 million barrels of oil to power its cars, trucks, planes, buildings, and industry[1] (CARB, 2010). California's offshore oil rigs and onshore wells produced about 265 million barrels—less than half of what was consumed. In 2006, California therefore imported the equivalent of 328 million barrels of oil for its own use.

These figures take into account California's role as an importer and exporter of refined products, since California "demand" is calculated solely from oil-based products consumed in the state of California's, rather than the amount of oil it physically imports to refine. This is important, since California is the sole supplier of refined oil products for Nevada, a major supplier to Arizona via dedicated pipelines, as well as an importer and exporter of refined products for Oregon. (CEC, 2009). These exchanges with neighboring states, however, are excluded from our calculation of California's "net imports", highlighting the fact that California uses far more crude oil than it extracts from its own land and coastal waters.

California's dependence on imported oil is growing. Oil production in California has been on a steady decline since its peak around 450 million barrels in the mid-1980s. While Alaskan oil initially made up the difference for California-based refiners, Alaskan production has also declined rapidly and is expected to continue to decline. Under all realistic scenarios of California oil production, the imbalance between production and demand is expected to increase the state's oil imports (CEC, 2006).

The balance of payments implications of California oil imports are therefore sizable and growing, as is the economy's resultant exposure to price changes. At the current price of \$100 per barrel, California is spending \$33 billion annually, nearly \$90 million each day to make up for the difference between in-state production and

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[1] The CA demand data is derived from CARB, 2010. For consistency with AB 32 Scoping Plan projections, this chapter uses the 2006 energy data from the AB 32 Scoping Plan to represent current conditions. As described in Section 3.6, total CA oil consumption is derived from primary energy use for oil products converted to oil barrels on a BTU equivalency-basis.

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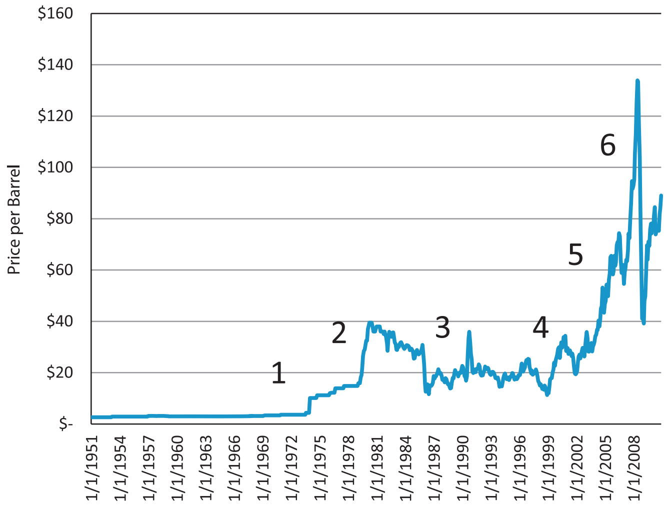

Fig. 1. Nominal crude oil prices, 1950–2010 (spot oil price West Texas Intermediate, Dow Jones, Wall Street Journal).

in-state consumption. By 2020, depending on the rate of production decline and demand growth at business-as-usual rates, in the absence of AB 32 measures, net imports to meet California demand are expected to rise to between 430 million and 452 million barrels per year. If oil prices were at the 2009 AEO forecast reference price ($114.50 per barrel) that was used in the California Air Resources Board (CARB) modeling studies that we build upon, California would be spending up to $49.2 billion, per year, on oil imports in 2020.[2]

Demand for oil will be reduced as an indirect benefit of California's strategic response to climate change. The California Global Warming Solutions Act of 2006, referred to herein by its legislative label AB (Assembly Bill) 32, requires California to cap its global warming pollution emissions at 1990 levels by 2020 (CARB, 2009) through programs developed under the leadership of the CARB. The AB 32 "Scoping Plan" developed by CARB lays out measures that go beyond existing state and federal policies and will translate into avoided expenditures on transportation fuels, as well as avoided costs for natural gas, propane, and other fuels derived from petroleum (CARB, 2009).

The Scoping Plan measures that will directly impact gasoline and diesel demand pertain to passenger vehicles, freight, and off-road equipment used in the agriculture, forestry, and construction sectors. Light-duty passenger vehicle measures include fuel efficiency standards, the Low Carbon Fuel Standard (a measure to reduce the carbon intensity of automotive fuels), and regional transportation and land use planning to reduce vehicular travel. There are also heavy-duty vehicle efficiency improvements, cargo ship electrification, and energy demand adjustments resulting from pricing mechanisms, notably an emissions allowance cap and trade program.

Because California is reducing its dependence on conventional energy supplies as a consequence of AB 32, it will also decrease its vulnerability to economic damage from sharp, rapid increases in global prices for conventional sources of energy. We refer to this benefit of reducing the California economy's exposure to price increases as the "upside hedge value." We note that the historical record does show energy prices dipping after peaks. We do not attempt to calculate a downside hedge value, or net hedge value.

In this study, we present findings from a quantitative model developed to study how California's exposure to energy price shocks can be reduced by AB 32.[3] The analysis considers retail price effects under two price shock scenarios (moderate and large). We examine how policies that help California respond to global warming will also help to soften the effects of future energy price spikes on California. Specifically, we quantify the added value of avoided expenditures on gasoline and diesel fuel under these two hypothetical future price shock scenarios.

2. Related research

This work is part of a large body of literature that seeks to assess the economic impacts of climate policy, and it builds directly on CARB's assessment of the economic impacts of AB 32 (CARB, 2010).[4] In addition to several rounds of macroeconomic modeling over the past decade (e.g., CAT, 2007; EPRI, 2007; Fowlie, 2008; CARB, 2007; CAT, 2007; Roland-Holst, 2006a, 2006b) and parallel to its own most recent efforts, CARB initiated a collaborative modeling experiment that included two other modeling teams, one led by economists at Charles River Associates CRA (2010), and the other by David Roland-Holst (2010). The intent of the collaboration was to harmonize assumptions; each used the same business-as-usual scenario to serve as the departure point for comparison of policy impacts, and each used the same cap-and-trade policy assumptions. Crucially, in relation to our study, all three modeling efforts also assumed future crude oil prices based on the reference forecast from the 2009 Annual Energy Outlook (AEO 2009), from the U.S. Department of Energy's Energy Information Administration (EIA).

The EIA's forecasts do not reflect business cycles or external shocks. As a result, price variability is not considered in any of the macroeconomic assessments of AB 32. Fig. 2 demonstrates this. It shows AEO 2009 reference forecast for 2010 through 2020 plus four years of historical prices.

The lack of analytical treatment of price shocks in the literature assessing the economic impacts of AB 32—despite the historical record of frequent and significant occurrence of such shocks—is the departure point for this study. Because California is a major importer of oil, such shocks extract capital from the state's economy and cash from its consumers who must consequently forego other purchases, savings, or investments.

3. Methods

Our estimation of the upside hedge value involves four steps. We will summarize these and then discuss each in greater detail:

1. **Identify AB 32-induced changes in energy use:** Obtain CARB's estimated changes in energy use induced by the measures in the AB 32 Scoping Plan.
2. **Develop retail gasoline and diesel price spike scenarios:** Review the magnitude of historical crude oil and retail transportation fuel price spikes to create moderate and high price

[2] We do not present data for 2020 projection under AEO high price scenarios as there would be no corresponding results for Chapter 2 and this could induce confusion. However, note that with prices at the AEO-forecast high price ($181.18 per barrel) and California production declining at the higher rate (3.23%) seen over the 1998–2008 period, the import bill would be $82.0 billion in 2020.

[3] An earlier version of this study provides details about the SHOCK model, and includes other fuels, such as aviation, propane and natural gas. See Busch (2010), Shockproofing Society: How California's Global Warming Solutions Act (AB 32) Reduces the Economic Pain of Energy Price Shocks, September 2010 at http://www.resource-solutions.org/pub_pdfs/Shockproofing%20Society.pdf. As well, a copy of the SHOCK model is freely available upon request from the authors.

[4] The authors critically evaluate these other studies, and describe the SHOCK model in detail in a prior report. See Shockproofing Society, op cit. 6.

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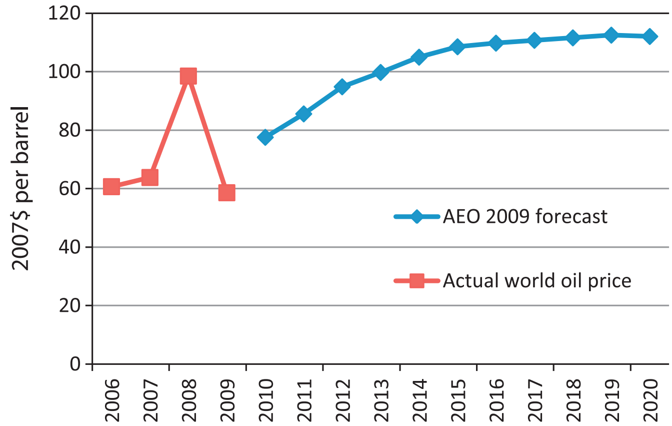

Fig. 2. AEO energy price forecast and recent history.

shock scenarios that are hypothetical but similar to past experiences.

3. **Develop range for price elasticity of demand:** Review literature to develop high, medium, and low values for short-term price elasticity of demand for gasoline and diesel.
4. **Calculate the upside hedge value**, the avoided extra energy expenditures, as a function of price spikes, AB 32 energy savings, and price elasticity ranges.

3.1. *Identifying AB 32-induced changes in energy use*

The analysis uses as an input the changes in energy use forecast to result from implementation of the AB 32 Scoping Plan measures (Case 1).[5] These estimates are published in an analysis by CARB (2010).[6] CARB coupled a macroeconomic model with a detailed model of energy supply and demand to produce these results. The economic model is a computable general equilibrium type known as the Environmental Dynamic Revenue Assessment Model (E-DRAM). The energy model, Energy 2020, represents energy supply (including technology and location-specific details for electricity generation) and the specific end uses that drive demand for energy.

Using this modeling framework, CARB first developed a reference case forecast of what the economy would look like in the year 2020, in the absence of AB 32 implementation. CARB's forecast used as inputs energy prices forecast through 2020 by the U.S. Department of Energy's EIA, which publishes an AEO. In particular, CARB assumed the prices in the AEO 2009 reference case.

3.2. *Developing price spike scenarios*

The next step involves developing hypothetical price spike scenarios. Given that our purpose is not to explain the determinants of the prices of oil, gasoline, and diesel fuel, and that forecasting prices for what has proven to be a very volatile commodity is inherently imprecise, we have adopted a relatively simple method that directly builds on historical data.

[5] We focus on CARB's "Case 1," which reflects the policy instruments included in CARB's proposed blueprint for achieving the AB 32 emission reductions and CARB's best estimates of the costs and energy savings associated with each of these policies.

[6] Information about CARB modeling tools, including EDRAM, can be found at http://arb.ca.gov/cc/scopingplan/economics-sp/models/models.htm. The application of EDRAM to evaluate AB 32 was a multi-year, multi-step process; presentations can be found at http://arb.ca.gov/cc/scopingplan/economics-sp/economics-sp.htm.

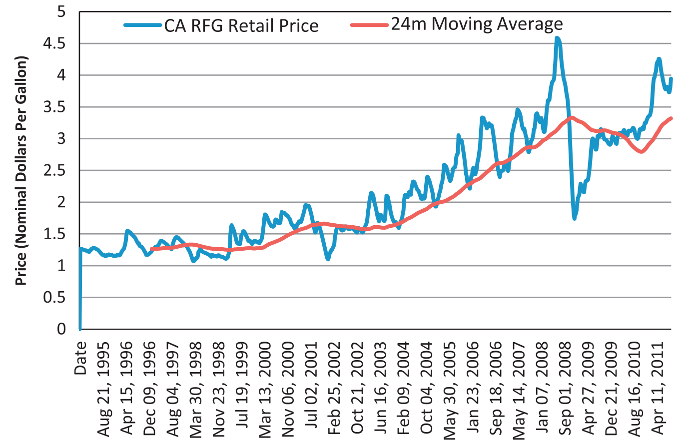

Fig. 3. California reformulated fuel gasoline price and 24-month moving average, 1995–2011.
Sources: EIA, authors' calculations.

Our hypothetical shock scenarios are informed by real-world price shocks of the past, but for reasons of tractability differ somewhat in magnitude and duration from the historical record; our shock scenarios are an instantaneous rise of retail gasoline and diesel prices on January 1, 2020 that remains at that level for a full year. We define two scenarios:

- **A moderate shock** in which prices increase 25% above the AEO reference price forecasted for 2020.
- **A large shock** in which prices increase by 50% above the AEO reference price forecasted for 2020.

We arrived at these scenarios as follows: we calculated the 24-month rolling average retail price for gasoline, then defined a spike as occurring when the weekly price rises above the 24-month average for at least 20 weeks. Since 1995, Americans have experienced 10 such spikes as shown in Fig. 3. The maximum and average weekly price above the 24-month average at the start of each shock is shown in Table 1, which is sorted by duration of the price shock.

Using this approach and building on the CARB forecast, which is itself built on the AEO 2009 Reference Case, we developed the retail prices under moderate and large shock conditions, summarized in Table 2.

As stated above, our intent in defining the above scenarios is not precise forecasting, but rather to illustrate the hedge value under hypothetical shock scenarios that are historically grounded. We attach no particular probability to either scenario. We note that the historical record does show energy prices dipping after peaks. That said, we do not attempt to calculate a net hedge value in light of the long term upward trend in prices illustrated in the 24-month moving average (see Fig. 3).

3.3. *Incorporating price elasticity of demand response*

The next step involves recognizing that some energy users will change their behavior in response to a sudden price increase. The price elasticity of demand is determined by consumers' ability and willingness to change behavior once they become aware of price changes. Our analysis involves a one-year price shock, so short-term responses are most relevant. An example of a short-term response to fuel prices spiking would be to avoid driving by cycling or walking, or to make more use of existing public transit. Long-run responses might include moving one's residence to be nearer to work or nearer to public transit or purchasing a more energy efficient vehicle.

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Table 1
Ten gasoline price shocks since 1995.
Source: EIA, authors' calculations.

Spike start date	Max weekly price above 24-month avg at spike start date	Average weekly price above 24-month avg at spike start	Weeks until price back to 24-month moving avg
3/28/1999	157%	130%	123
3/22/2010	139%	114%	86
9/17/2007	160%	128%	58
1/19/2004	143%	127%	51
1/6/2003	136%	117%	49
1/31/2005	154%	127%	46
1/9/2006	145%	127%	39
2/19/2007	126%	115%	26
1/27/1997	110%	105%	24
8/11/1997	113%	109%	19
4 Largest Avg	**150%**	**125%**	
4 Smallest Avg	**124%**	**114%**	

Table 2
Fuel prices: inputs and shock scenario assumptions.
Source: Authors' calculations.

California retail energy prices	CARB forecast (price)	Moderate shock (change)	Moderate shock (price)	Large shock (change)	Large shock (price)	Units
Gasoline	$3.42	+$0.85	$4.27	+$1.71	$5.13	$2007/gal
Diesel	$3.78	+$0.94	$4.72	+$1.89	$5.67	$2007/gal

*Numbers may not sum due to rounding errors.

Table 3
Range of Elasticity Values and their Sources.
Sources: Victoria Transport Policy Inst., 1999; Haigler Bailly, 1999; Espey 1998; Goodwin et al., 2004, and Dale et al., 2009.

Short term price elasticity of demand	Low	Mid	High
Gasoline	−0.03	−0.15	−0.34
Diesel	−0.05	−0.1	−0.15

We searched the literature for elasticity values and have sought to capture low, middle, and high estimates of short-term price elasticity of demand for gasoline and diesel fuel. We generated a bounded range of results using the low and high elasticities to show the sensitivity of findings to this input assumption. The specific values used in the analysis are shown in Table 3.

3.4. Calculating benefit as energy saved, multiplied by price spike increment

The last step in our estimation method involves multiplying the price change and the quantity change to calculate the value of energy savings for moderate and large price shocks.

4. Results: estimates of upside hedge value

We combine the various elements of our analysis to provide low and high bound estimates of the upside hedge value. We find that with AB 32, in moderate and large price spike scenarios, Californians will avoid spending each year $2.4 billion to $5.2 billion more on energy. This is the equivalent of $170 to $362 per household, when averaged across the number California households expected in 2020.[7] Some of the hedge value would accrue to business entities, so this household-level calculation is only to provide illustrative scale.

Our findings for the retail price shock impacts are summarized in Table 4 and Fig. 4.

Table 4
AB 32 savings from reduced expenditures in price shocks.
Source: Authors' calculations.

Scenario	Price elasticity of demand ($2007 billions) Low	Mid	High
Large shock	$5.2	$4.9	$4.5
Moderate shock	$2.6	$2.5	$2.4

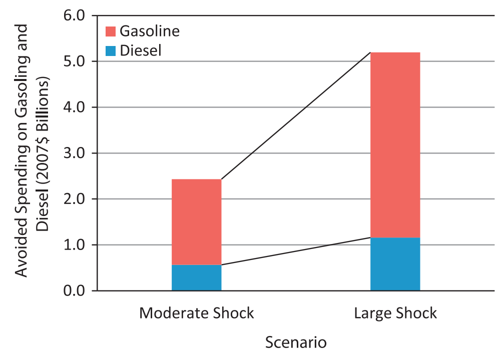

Fig. 4. AB 32 savings by fuel type from reduced expenditures in price shocks ($2007 billions).
Source: SHOCK-CA V2.0.

The lowest result follows from a moderate price increase (25% above the CARB forecasted prices) and smaller energy savings due to the increase in energy prices (an assumption of a larger price elasticity of demand). The highest impact follows from the combination of a larger price shock (50% above the AEO reference price) and a smaller reduction in energy savings due to that price increase (an assumption of a smaller price elasticity of demand).

Viewing the results by fuel type, we observe that the largest hedge value results from avoided expenditures on gasoline. Gasoline savings range from $1.9 billion to $4.0 billion in the moderate and large shocks, while diesel users save $0.6 billion to $1.2 billion.

5. Variables not considered in results

Here we review some of the factors not accounted for in our analysis. Some of these would increase the upside hedge value. However, AB 32-related changes to California's energy systems also introduces new vulnerabilities, an unaccounted for policy-related cost.

First we cover factors that would increase the benefits from AB 32. If our analysis considered a broader set of the crude oil-derived fuels that California depends on, then the upside hedge value would be greater. For example, we do not account for aviation fuel, propane, natural gas or industrial oils. Our analysis also excludes the indirect macroeconomic effects that would follow from future price shocks, which would increase the upside hedge value.

[7] Based on California Department of Finance projection of 44.1 million California residents, 14.4 million households in 2020.

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It is also worth noting the EIA's tendency in recent years to underestimate future prices. Its own reviews have concluded that "the crude oil price projections in the *AEOs* completed after 1997 tended to be underestimated" (EIA, 2010). We do find it hard to accept a starting gasoline price in 2020, before any price shock, of $3.42 per gallon when current California prices are considerably higher and were above that price for all but six weeks of 2011. Higher future prices would increase the expected value of energy savings, but this is a separate issue from price variability and is thus not relevant to the upside hedge value that we calculate.

Our estimated savings are for only a one-year shock. This may underestimate the duration and magnitude of future price shocks, since history suggests that, while prices are not likely to jump instantaneously (as we have assumed out of necessity), there have been longer shocks and larger shocks. The 1999 price shock involved a doubling of crude oil prices within seven months, and prices continued to rise until they peaked at more than 350% of the starting price after 23-month. Similarly, both the 1979 and 2003 price shocks saw prices still rising after 24-month. Of the 10 spikes in weekly prices that we identify since 1995, six have lasted at least 46 weeks, and the four longest averaged 80 weeks before prices returned to the 24-month moving average.

There are also factors not considered in our analysis that would result in lower net benefits than we estimate. Prolonged economic recession between now and 2020 would lower energy demand (with or without AB 32 implementation) and thus reduce the magnitude of benefit we calculate. As well, our estimate incorporates neither the potential for discovery of significant fossil fuel reserves nor the potential for technology innovations that might fundamentally alter the economics of extracting hard-to-reach known reserves.

While our analysis focuses on the hedge value for consumers, we also recognize that California oil producers and retailers will stand to benefit from higher gasoline prices. It is also possible that higher prices would spur increased California oil production. While theoretically possible, we find it unlikely that California would see an increase in production. California oil production has been steadily declining and has not been responsive to past price increases. Moreover, the California Energy Commission (CEC, 2006) has analyzed oil production and finds that any significant increase in California's offshore oil production is at least a decade away.[8]

However, even if increased local oil production occurred, it would not impact our current analysis of the effects on consumers effects. California production has a negligible effect on global oil supply, and since oil is priced globally, consumers will pay the high prices regardless of whether it is produced locally or overseas. Higher California production would, however, provide some benefits (i.e., producer surplus) to the oil production sector of California.

The upside hedge value we estimate as a benefit of AB 32 results from the greater use of energy efficient and renewable energy technologies. If implemented, by 2020 the result will be a diversification of California's energy system. While a greater mix of energy sources is a risk minimization strategy, some new vulnerabilities or energy reliability challenges will be introduced. For example, the intermittency of some renewable energy sources like wind and solar (though not biomass or geothermal) present a new challenge to electricity reliability.

Increased reliance on renewable energy also introduces some new risks. For example, wind turbines currently rely on rare earth metals that are currently mined almost exclusively in China, which controlled 95% of the market as of May 2011 (Bradsher, 2011a). Moreover, despite the World Trade Organization's rules against raw material export restrictions, China has been limiting exports to bolster its domestic industries and as an instrument of foreign policy. In September 2010, China imposed a two-month embargo on rare earth shipments to Japan during a territorial dispute (Ibid.). There are efforts underway to increase global supply outside of China, including the development of what will be the largest refinery in the world in Malaysia (Bradsher, 2011b). If the recent experience with polysilicon, a key input for photovoltaic panels, is any indication, the tightness of supply and record prices for rare earth minerals will reverse with the introduction of new sources. From a high price of $450 per kilogram, polysilicon has fallen to approximately $50 per kilogram today.

Finally, although this study does not include indirect effects, we would note that the potential impact of oil price spikes goes beyond the direct effects measured in this study, to include a range of indirect impacts, including a possible contribution to economy-wide recessions. This is a point of debate, however. While some (e.g., Bernanke et al., 1997) have suggested that economic output is influenced less by oil price shocks than by monetary policy (that is, government responses to such shocks), others (e.g., Hamilton & Herrara, 2000; Leduc & Sill, 2004) have found that monetary policies do not offset the recessionary consequences of oil price shocks. Kubarych (2005) observed that the economic consequences of price shocks have been declining: "the latest surge in oil prices has been largely taken in stride within the financial markets, in contrast to past responses."

6. Policy implications and conclusion

The macroeconomic analyses that dominate the discussion of economic impacts of climate change policies ignore the vulnerabilities imposed by California's dependence on imported oil and gasoline. These macroeconomic models are based on a smooth AEO price forecast, while history has shown there is likelihood of future price shocks. Our analysis shows the significant value that AB 32 will provide in the likelihood of such events.

To further explore and quantify the economic effects of climate change policies, we define upside hedge value: the extra avoided expenditures for California consumers of gasoline and diesel fuel should a price shock occur. Using two price shock scenarios and a range of price elasticity estimates testing different possible short-term demand responses, we arrive at low and high bounded estimates of the upside hedge value: from $2.4 billion to $5.2 billion in 2020.

These calculated savings are in addition to the reduced energy expenditures that CARB estimates will result from AB 32 implementation, based on the value of avoided energy use priced according to the AEO reference forecast. Though, we should note that these lower energy expenditures would shrink somewhat under price shock conditions because the price elasticity effect would reduce their value.

This study shows that California's climate change policies reduce California's exposure to price shocks in oil and oil-derived fuel products that history has shown to be common. We hope that quantifying the upside hedge value of AB 32 will lead to future economic analysis of climate change policy that includes consideration of volatile future energy prices. Policymakers should demand that such a perspective is factored into economic analyses.

Acknowledgments

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[8] CEC. 2006. California Crude Oil Production and Imports. California Energy Commission. Sheridan M. CEC-600–2006-006 (April).

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