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The role of energy conservation and natural gas prices in the costs of achieving California's renewable energy goals

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ABSTRACT

This paper develops an econometric forecasting system of energy demand coupled with engineering–economic models of energy supply. The framework is used to quantify the energy and environmental impacts of renewable and natural gas based electricity power generation in California, considering the role of on-going energy conservation efforts and incorporating different natural gas price scenarios over the forecast horizon (2011–2035). The results indicate that, relative to a business-as-usual scenario of continuing to rely on imported electricity to meet future demand, California's renewable portfolio standard (RPS) of 33% renewables by 2020 will increase electricity rates by over 10%. However, the RPS will also provide substantial annual savings in carbon dioxide emissions, equal to 40 million metric tons in 2020. Continuing non-price induced energy conservation at the historical rate will only result in a marginal reduction in electricity rates, although lower electricity use means that substantial savings are nonetheless achieved in electricity expenditures. In addition, continuing trend energy conservation leads to substantial savings in carbon dioxide emissions. Like the RPS, developing domestic natural gas generation also leads to rate increases and reductions in carbon dioxide emissions (relative to the baseline). However, these impacts are minor compared to the RPS scenario.

1. Introduction

In April 2011, California passed into law the California Renewable Energy Resources Act (Senate Bill X 1–2). This law requires all California electricity providers to supply one third of their retail electricity sales from renewable energy by the year 2020, which constitutes one of the most ambitious renewable portfolio standards (RPSs) in the United States.[1] If these renewable energy goals are not pursued, the most likely alternative to be adopted is natural gas based electricity generation. Natural gas plants are currently the most frequent choice for new power in California, and for the U.S. overall.[2]

Implementing California's RPS will require the construction of a large number of renewable energy facilities that will help to reduce reliance on electricity imports, promote sustainable energy, and control greenhouse gas emissions. On the other-hand, this energy development path could also significantly raise electricity rates and expenditures. Wind, solar and some other renewable forms of energy have substantial construction costs which will be passed through to consumers when the new electricity production capacity goes into operation. These impacts, however, could be lessened if on-going gains in energy efficiency from energy conservation, driven either by energy prices or non-price induced technological change, continue in the future.

Since the early 1970s, California has achieved considerable improvements in energy efficiency, allowing its economy to grow with proportionately less energy use over time. This progress has in part been driven by non-price induced energy conservation. In fact, California is often considered a poster-child for energy efficiency regulations (which may be offered by government or utilities) that other states should follow.[3] California has also committed to continuing its energy conservation efforts in the future.[4] By reducing energy consumption, such energy conservation efforts will reduce energy expenditures, and

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[1] The standard applies to all electricity retailers in the state, including publicly owned utilities (POUs), investor-owned utilities (IOUs), electricity service providers and community choice aggregators.

[2] Since 1995, 80% of new electricity generation capacity in the U.S. has been gas-fired units.

[3] The so-called Rosenfeld Curve, showing that in the past 40 years residential electricity consumption per capita has remained nearly constant in California despite growing by 75% in the rest of the United States, is often used to demonstrate the success of energy efficiency programs in California. However, Levinson (2013) finds evidence that undermines this argument.

[4] California's Energy Efficient Resource Standards include separate electricity savings and demand reduction requirements for each of the three investor-owned electrical utilities and energy savings requirements for the state's three gas utilities, through to 2020.

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will reduce the build out of renewable resources and the associated capital expenditures necessary to achieve California's RPS objective.

The supply of natural gas will also affect the costs of meeting California's renewable energy goals. Higher (lower) natural gas production leads to lower (higher) natural gas prices, which in turn tends to increase (decrease) the relative cost of renewable power options. Natural gas prices are historically quite volatile; just six years ago in 2008 gas prices were near parity with oil prices on a heat equivalent basis and now, with the surging supplies from shale gas production, they are less than a fifth of those levels. Although many analysts anticipate abundant future natural gas supplies, higher demand in transportation, industry, electric power generation, and exports could put upward pressure on natural gas prices. Hence, there is considerable uncertainty surrounding the future trajectory of natural gas prices.

The objective of this study is to estimate the energy and environmental impacts of renewable and natural gas based electricity power generation in California, considering the role of on-going energy conservation efforts and incorporating different natural gas price scenarios. To consider these two options for electricity generation, this study develops an econometric forecasting system of California energy demand coupled with engineering–economic models of energy supply.[5] The model estimates the separate effects of income, prices, and non-price induced technological change on energy demand by sector. Total forecast electric power demand is balanced with electricity supply in the model, which is determined by existing and planned capacity and capacity utilization rates. The cost of this power generation determines electricity rates. Accordingly, this modeling framework estimates the impacts on electricity rates from different electric capacity plans, allowing for the endogenous response of electricity consumers to the associated rate impacts. With the estimation of the effects of energy prices and non-price induced technological change, the model also provides a means to estimate the impacts of energy conservation on the costs of adjusting to higher levels of renewable energy production.

The analysis proceeds as follows. The next section presents the modeling framework in detail. Section three then develops the energy supply scenarios, and section four presents and discusses the results. Finally, section five concludes.

2. Modeling California's electricity future

California's energy sector might be considered as an example of how America should achieve a more sustainable energy future. California leads the nation in non-hydroelectric renewable energy production. The Golden State has also achieved considerable improvements in energy efficiency and in 2011 ranked 47th in the nation for per capita energy consumption. Nonetheless, California is the second largest energy consuming state in the nation behind Texas and in the future will continue to require more energy with economic and population growth. California is also becoming more dependent on energy sources outside its borders, especially fossil fuels. In 1970 California imported just 37% of its total energy needs, and yet by 2011 the state imported 67% of its energy (56% imported oil and natural gas and 11% imported electricity).

This paper uses an energy-forecasting framework built from two different perspectives. First, the end-use demand for fuels in the residential, commercial, and industrial sectors is modeled from an economic perspective in which energy demand is specified as a function of relative prices, population, and level of economic activity. The demand models are estimated and then used to project future energy consumption by sector in the California economy from 2011 to 2035. Second, on the supply-side for electricity, an engineering–economic perspective is adopted in which capacity expansion plans, operating rates and heat rates are specified exogenously and determine the composition of fuel consumption by utilities. Imports of electricity are determined endogenously as the difference between demand and electricity generation within California. Hence, imports of electricity are modeled as the swing fuel, which is consistent with the recent past in California.

Capital expenditures to build generation capacity are estimated. Electricity costs and rates are then determined by assumptions for fuel prices and the capital costs associated with each electricity technology scenario. As new electricity production capacity goes into operation, the costs are passed through to consumers in the form of higher electricity rates that then affect the demand for electric power. In the analysis, building out renewable or natural gas capacity increases electricity rates as these sources of energy replace cheaper imported electricity. The end-use electricity prices in turn have a feedback effect on electricity demand. A schematic of the line of causality between the assumptions and the endogenous variables is presented below in Fig. 1.

As Fig. 1 illustrates, carbon emissions are tracked for each sector of the economy, providing a nearly complete account of carbon dioxide emissions in California. As a result, carbon emissions are endogenous and depend upon energy prices and economic activity driving energy demand and the choice of electricity generation capacity. The feedback of final electricity demand on the demand for fuels and end-use electricity prices allows an integrated evaluation of electricity demand and fuel choice in power generation.

Overall, there are five main components of the energy model. The first three include systems of energy demand equations for the residential, commercial, and industrial sectors. The fourth involves the demand for transportation fuels, including gasoline and diesel fuel. The fifth and final component involves the electricity generation sector. The following two sub-sections describe the formulation of the models within each of these components in more detail.

2.1. End-use stationary energy demand

The energy demand equations in the residential, commercial, and industrial sectors are specified as expenditure systems. This approach incorporates two key features of demand systems consistent with consumer utility maximization or producer cost minimization. The first feature is that relative prices matter in determining the mix of fuels. The importance of relative price changes follows from the homogeneity condition of demand equations, which implies that if all prices increase by the same proportionate amount then total energy expenditures also increase by the same percentage. The other important property involves symmetry. If the demand for fuel oil increases when relative propane prices increase, then propane and oil are substitutes. In this case, the demand for propane should increase with relatively higher oil prices. An energy demand forecasting system with inter-fuel substitution should have these symmetric price effects.

Economists have developed a variety of methodologies for ensuring consistency between demand equations. One group of methods uses flexible functional forms to approximate systems of demand equations derived from neoclassical cost or expenditure functions, such as the translog (TL) and generalized Leontief (GL). Considine (1989) shows that the nonlinear price elasticities associated with these forms often result in counter-intuitive results, such as positive own price elasticities. In addition, incorporating dynamic quantity adjustments is impossible using the TL and is highly restrictive for the GL.

The linear logit (LL) model of cost shares developed by Considine and Mount (1984) provides an attractive alternative to conventional demand systems. Many researchers associate logit functions with discrete choice models. Logistic functions ensure that probabilities are non-negative and sum to one. These properties also must hold for cost shares. Considine and Mount (1984) derive the symmetry and homogeneity conditions for the linear logit cost share system. They also show that this specification is particularly well suited for modeling dynamic adjustments. A dynamic specification is essential because it is unlikely that energy consumers would respond fully to shocks within one

[5] The model originates from the Considine and McLaren (2008) report on Arizona's energy future.