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How Can Renewable Portfolio Standards Lower Electricity Prices?

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RESOURCES
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Abstract

Some studies of renewable portfolio standards find that regulations increase generation costs; others find that reduced demand for nonrenewable energy sources lowers natural gas prices and that electricity prices follow. This paper presents reasoning for why these predictions can vary in the direction as well as in the magnitude of their effects. The driving factors are the relative elasticities of electricity supply from both fossil and renewable energy sources. The availability of other baseload generation is another factor, whereas demand elasticity influences only the magnitude of the price effects, not the direction of those effects.

Key Words: portfolio standards, natural gas, renewable energy, climate change

JEL Classification Numbers: Q4, Q5, H2

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Introduction

Concerns about air quality, global climate change, and energy security have increased interest in the potential of renewable energy to displace fossil fuel sources. In 2003, renewable energy sources provided 9.4% of the total electricity generation in the United States, although excluding hydropower, that share amounted to only 2.3% (EIA 2004). Globally in 2003, hydropower contributed 16% of electricity supply, waste and biomass contributed 1%, and other renewable sources supplied another 1% (IEA 2006). Meanwhile, the targets for expanding nonhydro renewable electricity generation are ambitious. The United States aims to nearly double energy production from renewable sources by 2025 (excluding hydro) compared with 2000 levels (U.S. DOE 2003), and the European Union has a target to produce 22.1% of electricity and achieve 12% of gross national energy consumption from renewable energy by 2010 (IEA 2003).

One of the most frequently advanced policies for supporting renewable energy sources in electricity generation is the renewable portfolio standard (RPS). Also known as renewable obligations, green certificates, and the like, these market share requirements require either producers or users to derive a certain percentage of their electricity from renewable sources. Currently, nearly half of the U.S. states and the District of Columbia have established an RPS or a state-mandated target for renewables.¹ Several other countries—including Australia, Austria, Belgium, Brazil, Czech Republic, Denmark, Finland, Italy, Japan, the Netherlands, South Korea, Sweden, and the United Kingdom—have planned or established their own programs.²

As these policies gain in popularity and stringency, understanding their costs and impacts becomes more important. However, little consensus seems to have emerged among analyses of policies for renewable energy, particularly with respect to consumer impacts. Many economic models for climate and energy policy analysis find that policies to reduce greenhouse gas

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¹ Database of State Incentive for Renewable Energy (DSIRE) website: <http://www.dsireusa.org>.

² Source: IEA (<http://www.iea.org/textbase/pamsdb/grresult.aspx?mode=gr>).

emissions from the electricity sector, including RPSs, raise economic costs and raise electricity prices. Examples include studies by the U.S. Energy Information Agency (EIA 1998, 2000, 2001, 2002, 2003, 2004), Palmer and Burraw (2005), and Fischer and Newell (2004). On the other hand, some inquiries find little or no price impacts, including Bernow et al. (1997) and others by the Tellus Institute. Yet other studies find that policies for can actually result in lower consumer prices. Prominent examples include the studies by the Union of Concerned Scientists (UCS), including Clemmer et al. (1999), and the American Council for an Energy Efficient Economy (ACEEE).³ The driving factor behind this result is that additional renewable energy displaces gas-turbine generation; the decrease in demand lowers the price of natural gas and thus gas-fired generation costs and electricity prices. A recent analysis by Wiser and Bolinger (forthcoming) finds that studies of RPS policies using different variations of the National Energy Modeling System (NEMS)—which include the EIA, UCS, Tellus and ACEEE efforts—have produced a wide range of results themselves.

Because the effects on electricity prices are of keen interest to policymakers considering a mandate for a share of renewable energy, it is important to reconcile what causes these contradictory results. This paper presents reasoning for why these predictions can vary not only in magnitude but also in the direction of their effects. It reveals that the driving factor is not the elasticity of electricity supply from natural gas and other fossil sources but this elasticity relative to that of renewable energy. Furthermore, the availability of other baseload generation is important because it affects the relative elasticity of nonrenewable energy supplies overall. In contrast, demand elasticity influences the magnitude of the price effects but not their direction.

Background

Wiser and Bolinger (forthcoming) focus on the role of gas markets in explaining disparate results among several studies that, with one exception, all used the NEMS as a foundation.⁴ “While the shape of the short-term natural gas supply curve is a transparent, exogenous input to NEMS, the model (as well as other energy models reviewed for this study) does not exogenously define a transparent long-term supply curve; instead, a variety of modeling

³ Elliot et al. (2003) do not model electricity price effects explicitly but conjecture this result due to their strong gas price impacts.

⁴ The U.S. Department of Energy’s (DOE’s) Energy Information Administration (EIA) developed, operates, and revises NEMS annually to provide long-term (e.g., to 2020 or 2025) energy forecasts.

assumptions are made which, when combined, implicitly define the supply curve” (Wiser and Bolinger). Many of the studies exclusively evaluated an RPS, whereas others have also looked at energy-efficiency measures and environmental policies. The review from Wiser and Bolinger reveals a range of predicted impacts among these studies, reported in Table 1.⁵ For the most common scenario of 10% RPS by 2020, retail electricity price changes ranged from +1.4% to –2.9%; for 20% RPS by 2020, they ranged from +4.3% to –0.4%.

From the information embedded in these studies on renewable energy, Wiser and Bolinger (forthcoming) derived implicit long-term inverse price elasticities of natural gas supply (as opposed to generation from gas sources) from these model runs. They also compared the long-term elasticities implicit in NEMS with those of other national energy models by using data from a recent study by Stanford’s Energy Modeling Forum (EMF 2003). Table 2 reports these results in terms of the more familiar direct price elasticities. It shows a range of elasticities in the 2010 scenarios of 0.1 to 1.0—in other words, all but one of the scenarios assume relatively inelastic natural gas supply in the short-to-medium run. In the long run, the elasticities ranged from 0.2 to 9.1 (the most elastic being NEMS). The central tendency among these studies is for a 1% reduction in natural gas demand to cause an expected wellhead price reduction of 0.75–2.5% in the long term. Despite a dearth of empirical estimates in their review of the literature, this range does center around Krichene’s (2002) estimate of the long-term supply elasticity for natural gas for the period 1973–1999 of 0.8, which corresponds to an inverse elasticity of 1.25.

However, Wiser and Bolinger (forthcoming) did not evaluate the role of different assumptions for renewable energy technologies. Because the renewables supply influences the equilibrium change in natural gas-fired generation, the renewables supply also helps determine the corresponding reduction in natural gas demand and wellhead prices. This more complex relationship is evident in Figure 1, which compares the implied (inverse) price elasticities for natural gas with the retail electric price increase in the RPS studies compiled by Wiser and

⁵ The studies included “(1) five studies by the EIA focusing on national RPS policies, two of which model multiple RPS scenarios; (2) five studies of national RPS policies by the Union of Concerned Scientists (UCS), two of which model multiple RPS scenarios, and one of which also includes aggressive energy efficiency investments; (3) one study by the Tellus Institute that evaluates three different standards of a state-level RPS in Rhode Island (combined with the RPS policies in Massachusetts and Connecticut); and (4) an ACEEE study that explores the impact of national and regional RE and EE deployment on natural gas prices. The EIA, UCS, and Tellus studies were all conducted in NEMS (note that NEMS is revised annually, and that these studies were therefore conducted with different versions of NEMS), while the ACEEE study used a gas market model from Energy and Environmental Analysis (EEA)” (Wiser and Bolinger, forthcoming, pp. 3–4.)

Bolinger (forthcoming).⁶ Were natural gas the main story, one would expect bigger gas price changes to be associated with a smaller electricity price increase; however, this relationship does not hold with any apparent consistency. Thus, I turn to the following model to explain more fully the relationship among renewable energy, gas-fired generation, and electricity markets.

Model

A simple yet general model of energy supplies and demand demonstrates how the relative slopes of these curves determine the price incidence of portfolio standards.

Consider three types of generation: baseload technologies x , fossil fuel g , and renewable energy r . Baseload generation is characterized as fixed and fully utilized generation capacity, such as nuclear energy, although in some circumstances coal might also be considered baseload, if little output variation is anticipated. The fossil fuel sources are natural gas, oil, and coal, although much of the focus of the debate is on natural gas. Renewable energy sources include wind, solar, biomass, geothermal, and so on; hydropower is sometimes excluded from the renewable sources eligible for preferential treatment because it also functions as a baseload technology.

Whereas the baseload supply curves are fixed and perfectly inelastic (i.e., $dx = 0$), the nonbaseload types of generation are assumed to have inverse supply curves $S_g(g)$ and $S_r(r)$ (where $S_g' \geq 0$ and $S_r' \geq 0$) that are weakly upward sloping. One can think of these supply curves as marginal cost curves and assume that these technologies receive competitively determined prices, so that their marginal costs are equal to the price received. Alternatively, one can allow them more generally to represent the price demanded for an additional unit of generation at the amount supplied. This latter characterization may be more appealing, given that the electricity market is only partially deregulated.

The renewables policy causes the prices received by suppliers to diverge according to the energy source. Although the price received by baseload generation (P_g) is the same as that of generation from fossil fuels, the price received by generation from renewable sources (P_r) may be higher. Let P be the consumer price of electricity. Let consumer (indirect) demand be represented by $D(g + r + x)$, a downward-sloping function of total consumption, where $D' < 0$.

⁶ Studies that include energy efficiency policies are excluded for easier comparison.

The market-clearing conditions are simply that the quantities supplied equal the quantities demanded at the prevailing market prices:

$$\begin{aligned} P_g &= S_g(g) \\ P_r &= S_r(r) \\ P &= D(g + r + x) \end{aligned} \tag{1}$$

Next, one can evaluate the effects of different renewable energy policies on consumer prices. Totally differentiating the market-clearing equations yields

$$dg = dP_g / S_g' ; \quad dr = dP_r / S_r' ; \quad dP = (dg + dr)D' \tag{2}$$

Notice that this framework abstracts from transmission costs or other markups that would place a wedge between the supply and demand prices for the marginal technology. Because the results are driven by price changes, the analysis is not affected as long as those markup costs are fixed and unaffected by the renewable energy policy.

Renewable Production Subsidy

One means of supporting renewable energy is by a direct subsidy to production. For example, the United States has the Renewable Energy Production Incentive of 1.9 cents per kilowatt-hour (kWh), and 24 individual U.S. states have their own subsidies. Germany has been especially generous in supporting wind energy, and some other European countries, Canada, and Korea offer some form of production subsidies. The United States also has a 10% investment tax credit for new geothermal and solar electric power plants. In the long run, subsidies like this—which lower the costs of building and expanding capacity—can also have the effect of subsidizing production.

Let s be a simple subsidy for renewables in the model. In the new market equilibrium, $P_g = P$ and $P_r = P + s$. Using Eq. 2, as well as $dP_g = dP$ and $dP_r = dP + ds$, one can solve for dP , dg , dr resulting from a change in the subsidy. In this case, we find that an increase in the subsidy causes consumer prices to fall:

$$\frac{dP}{ds} = \frac{-S_g'}{S_g' + S_r' - S_g' S_r' / D'} < 0 \tag{3}$$

In other words, as long as natural gas supply is strictly upward sloping, part of the incidence of the renewable generation subsidy will be passed on to consumers as lower electricity prices. The

subsidy shifts the renewable generation supply curve downward, resulting in an equilibrium with more renewables, less generation from fossil fuel sources, and lower prices.

Nonrenewable Production Tax

Another common way of favoring renewable energy is by taxing fossil fuel sources or by exempting renewable sources from an energy tax. This policy measure is used in the United Kingdom, Germany, Sweden, and the Netherlands. Similarly, an emissions tax or permit-trading program also effectively taxes nonrenewable sources disproportionately by imposing a price on their embodied emissions.

Let t be a tax on nonrenewable supply. In the new supply-and-demand equilibrium, $P_g = P - t$ and $P_r = P$. Again, totally differentiating and solving for dP, dg, dr gives

$$\frac{dP}{dt} = \frac{S'_r}{S'_g + S'_r - S'_g S'_r / D'} > 0 \quad (4)$$

Therefore, a fossil fuel tax (or emissions price) will necessarily increase consumer prices, as long as the renewable supply curve is upward sloping. The nonrenewable production tax shifts the supply curve for generation from fossil fuel sources upward, resulting in substitution toward more expensive renewable sources and raising the electricity price.

Portfolio Standard

The portfolio standard combines elements of the two preceding policies. Generators of energy from renewable sources receive a subsidy in the value of their certificates, s , whereas generators of energy from nonrenewable sources must pay a tax proportional to the certificates they need to fulfill the standard, α . Let $A = \alpha/(1 - \alpha)$ be the ratio of generation from renewable sources to generation from nonrenewable sources, which represents the number of certificates required to accompany an additional unit of nonrenewable generation. Under this policy, the prices received are

$$\begin{aligned} P_r &= P + s \\ P_g &= P - As \end{aligned} \quad (5)$$

In addition to the previous market-clearing conditions, the portfolio standard adds the following condition:

$$r = (x + g)A \quad (6)$$

Totally differentiating yields

$$\begin{aligned} dg &= (dP - Ads - sda) / S_g' \\ dr &= (dP + ds) / S_r'(r) \\ dP &= (dg + dr)D' \\ dr &= (x + g)dA + Adg \end{aligned} \tag{7}$$

which gives a set of four equations and four variables (dg , dr , dP , and ds) responding to dA .

Substituting and solving for the price change induced by a change in the standard, one sees the impact on consumer prices of an increase in the renewable requirement:

$$\frac{dP}{dA} = \frac{(1+A)s - (S_g' - AS_r')(g+x)}{(1+A)^2 - (S_g' + A^2 S_r')/D'} \tag{8}$$

The denominator of this expression is necessarily positive because of the assumptions of upward-sloping supply curves and downward-sloping demand curves. With the numerator then determining the sign, the price of electricity will fall if the supply curve for natural gas generation is sufficiently steep relative to that of renewables:

$$dP/dA < 0 \quad \text{if} \quad S_g' > AS_r' + (1+A)s/(g+x) \tag{9}$$

Of course, the relative slopes of the supply curves for fossil fuels and renewables are not the only factors. Eq. 9 clearly shows that the electricity price is more likely to fall at low levels of the portfolio requirement. Suppose the constraint is just nonbinding, implying that $s = 0$ and $A = A_0$. Then $S_g' > A_0 S_r'$ suffices to cause consumer prices to drop initially as the standard is raised. Thus, the supply curve for fossil fuel need not be steeper than that for renewable energy—only steeper than the renewables slope in proportion to the renewable share of total production. However, as the stringency of the standard increases, consumer prices also are likely to increase, unless the gas supply curve is very steep. Note that the second term on the right side of Eq. 9 increases by three factors (the RPS share, the implicit subsidy, and the reduction in output from fossil fuel sources), all of which increase with program stringency. Indeed, Palmer and Burraw (2005) find a distinct nonlinearity in the electricity price response to more stringent portfolio standards.

One can also see how the rest of the system responds to an increase in the portfolio requirement:

$$\frac{dg}{dA} = \frac{s/D' - (1+A - AS'_r/D')(g+x)}{\chi} < 0 \quad (10)$$

$$\frac{dr}{dA} = \frac{As/D' + (1+A - S'_g/D')(g+x)}{\chi} > 0 \quad (11)$$

$$\frac{ds}{dA} = \frac{\left(S'_r + S'_g\right)(g+x) + \left(As - S'_g\right)S'_r/D' - (1+A)s}{\chi} \quad (12)$$

where $\chi = (1+A)^2 - (S'_g + A^2 S'_r)/D'$, as in the denominator of Eq. 8. Because $\chi > 0$, it follows with no surprise that $dg/dA < 0$ and $dr/dA > 0$. However, the sign of ds is ambiguous.

Interestingly, Eq. 12 raises the possibility of a Laffer curve for the portfolio standard: that for large values of A , the subsidy to renewables may fall—that is, if

$$A > \frac{\left(S'_r + S'_g\right)(g+x) - S'_g S'_r / D' - s}{s(1 - S'_r / D')}. \text{ This kind of Laffer curve does not apply to the effective}$$

tax on nonrenewable generation, however; this effective tax must increase with the stringency of the standard:

$$\begin{aligned} \frac{d(As)}{dA} &= s + A \frac{ds}{dA} \\ &= \frac{s(1 - S'_g / D') + A \left(\left(S'_r + S'_g\right)(g+x) + S'_r x + S'_g g - S'_g S'_r / D' + s \right)}{\chi} > 0 \end{aligned} \quad (13)$$

Thus, a falling equilibrium renewable subsidy indicates a point at which it is easier to cut back on generation from nonrenewable sources than to add more renewable sources. Although this point may be attainable, the present analysis is limited to the range in which energy generation from fossil fuel sources is not crowded out completely.

Discussion

A portfolio standard in essence combines a subsidy to producers of energy from renewable sources (in the value of a credit) with a tax to producers of energy from nonrenewable sources (in the cost of credits to accompany its production). When the supply curve of nonrenewable generation is not perfectly flat, a subsidy for renewables tends to depress electricity prices overall, whereas a tax on energy production from fossil fuel sources tends to

raise consumer prices. The price impacts of a portfolio standard can therefore be ambiguous, depending on whether the tax or subsidy effect dominates.

This paper reveals that relative elasticities are more important for electricity price effects than the elasticity of the natural gas price alone. Baseload generation capacity is also important, so for long-run modeling, the relative elasticities of coal and other options will also help drive outcomes. Demand elasticity remains important for estimating the magnitude of the price effects but not their direction.

To understand why different models produce very different results in evaluating portfolio standards, one must evaluate the assumptions in the standards about the relative slopes (elasticities) of the supply curves for generation from natural gas and from renewable sources. One should also assess how other fossil fuel energy sources, baseload generation, and the RPS requirements are presented. Models are more likely to predict that portfolio standards will produce lower consumer prices when they embed rigidities in natural gas supply, assume that large portions of nonrenewable generation are fixed, or parameterize relatively flat marginal costs for renewables.

Given these wide-ranging predictions, better empirical evidence is needed to understand how renewable energy and natural gas markets will respond to these policies—in both the short and long runs. Because all supplies tend to be more elastic in the long run, the relative elasticities could evolve in either direction. Therefore, decreases in electricity prices as a result of portfolio standards may not necessarily be a short-run phenomenon.

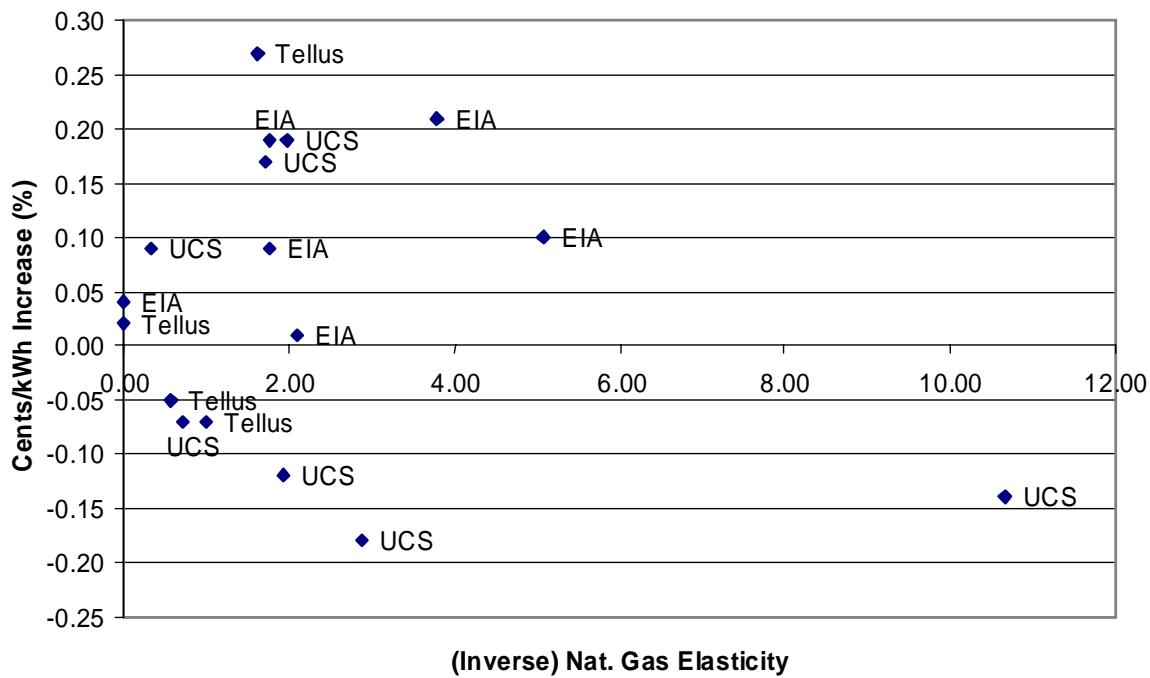
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Figure

Figure 1. Combinations of Electricity Price Increases and Natural Gas Price Elasticities in Studies Reviewed by Wiser and Bolinger (forthcoming)



Tables

Table 1. Implied Natural Gas Price Elasticities and Retail Electricity Price Increases

| <i>Source</i> | <i>RPS</i> | <i>Elasticity of</i> | <i>Elasticity of</i> | <i>Retail Electricity</i> <i>Price Increase:</i> <i>cents/kWh (%)</i> |
|-----------------------|------------------|--|--|---|
| | | <i>Implied Natural</i> <i>Gas Price</i> | <i>Implied Natural</i> <i>Gas Price</i> | |
| | | <i>Inverse:</i> $dP/P/(dQ/Q)$ | <i>Direct:</i> $dQ/Q/(dP/P)$ | |
| EIA 1999 | 7.5%—2020 (U.S.) | 5.08 | 0.20 | 0.10 |
| EIA 1998 | 10%—2010 (U.S.) | 3.79 | 0.26 | 0.21 |
| Tellus Institute 2002 | 10%—2020 (RI) | 0.00 | Infinite | 0.02 |
| EIA 2003 | 10%—2020 (U.S.) | 0.00 | Infinite | 0.04 |
| UCS 2002b | 10%—2020 (U.S.) | 0.71 | 1.40 | -0.07 |
| EIA 2002 | 10%—2020 (U.S.) | 1.76 | 0.57 | 0.09 |
| UCS 2004 | 10%—2020 (U.S.) | 1.94 | 0.52 | -0.12 |
| EIA 2001 | 10%—2020 (U.S.) | 2.10 | 0.48 | 0.01 |
| UCS 2002a | 10%—2020 (U.S.) | 2.89 | 0.35 | -0.18 |
| UCS 2003 | 10%—2020 (U.S.) | 10.67 | 0.09 | -0.14 |
| Tellus Institute 2002 | 15%—2020 (RI) | 0.57 | 1.75 | -0.05 |
| UCS 2004 | 20%—2020 (U.S.) | 0.32 | 3.10 | 0.09 |
| Tellus Institute 2002 | 20%—2020 (RI) | 1.00 | 1.00 | -0.07 |
| EIA 2001 | 20%—2020 (U.S.) | 1.61 | 0.62 | 0.27 |
| EIA 2002 | 20%—2020 (U.S.) | 1.76 | 0.57 | 0.19 |
| UCS 2002a | 20%—2020 (U.S.) | 1.71 | 0.50 | 0.19 |

Notes: RI = Rhode Island only.

Source: Adapted from Wiser and Bolinger (forthcoming).

Table 2. Implicit Gas Price Elasticities in a Range of National Energy Models

| <i>Energy Model</i> | <i>Implied Price Elasticity of Natural Gas</i> | |
|---------------------|--|------|
| | 2010 | 2020 |
| NEMS | 0.5 | 9.1 |
| E2020 | 1.0 | 1.4 |
| CRA | 0.4 | 1.1 |
| POEMS | 0.6 | 0.6 |
| MARKAL | 0.5 | 0.5 |
| NARG | 0.1 | 0.4 |
| NANGAS | 0.1 | 0.2 |

Notes: NEMS—National Energy Modeling System; E2020—Energy 2020; CRA—Charles River Associates; POEMS—Policy Office Electricity Modeling System; MARKAL—MARKet ALlocation; NARG—North American Regional Gas model; NANGAS—North American Natural Gas Analysis System.

Source: Adapted from Wiser and Bolinger (forthcoming).