Welfare Analysis of Offshore Wind

By Julian Silk*

Introduction

International trade analysis has been used to evaluate government interventions in markets, and to evaluate the welfare losses of these interventions relative to free trade. A good example is the work of Professor Ian Sheldon, (see http://aede.osu.edu/sites/drupal-aede.web/files/AEDIS540TradePolicyI.pdf.

What is not generally recognized is that these methods can be used to evaluate government interventions to support renewable energy as well. A particular electricity market plays the role of the domestic economy in the international trade analyses. The pre-existing fossil fuel producers that supply this electricity market play the role of the domestic producers, and renewable energy plays the role of the imports. Quotas are a more general example of renewable portfolio standards (RPS), which have been adopted around the world and by many American states as mechanisms to speed the adoption of renewable energy. There are some differences, but the same general principles apply.

Off the Cumbria coast of Irish Sea of the United Kingdom, a consortium of DONG Energy, Scottish and Southern Energy (SSE) and OPW, itself a consortium of the Dutch pension fund service provider PGGM and Ampere Equity Fund, have just opened the Walney wind farm. Walney comprises the Walney 1 and 2 projects. It is the largest offshore wind site ever constructed, at 367.2 Megawatts (MW) capacity. For more details, see the news release at http://www.pggm.nl/Over_PGGM/Pers/Persberichten/Nieuws_en_persberichten/120209_Worlds_largest_offshore_wind_farm.asp.

Governor Martin O'Malley of the American state of Maryland plans to outdo this, however. He advocates the construction of a 450 MW wind farm off the coast of Maryland in the Maryland Offshore Wind Energy Act of 2012. The specific legalities of the bill are in http://mlis.state.md.us/2012rs/billfile/sb0237.htm, with a statement of claims about the bill in http://www.energy.state.md.us/documents/MDOSWEnergyActof2012.pdf. These claims are not modest. A good evaluation of the specifics of the plan is by Todd Griset, in "Analysis: Maryland's New Offshore Wind Plan", 26 January 2012, at http://offshorewindwire.com/2012/01/26/analysis-md-new-plan/, which also discusses how the plan differs from a similar act proposed in 2011 which failed in the Maryland legislature.

The plan will be evaluated theoretically using the international trade tools herein. Maryland's RPS requires that 20% of the state's energy be supplied by renewable sources by 2022. The 2012 bill only requires that 2.5% of the 20% be directly supplied by offshore wind. But given the size of the project, it is very reasonable to assume that it will by its very nature fulfill more than this: it is being taken to fulfill the entire 20% in this analysis.

The other major feature of the bill is that if Maryland's Public Service Commission projects that the wind farm will add more than $2 per month to the average of residential customer electricity bills, the program will be suspended. This represents a price ceiling in the early going, but a price floor later, and it can be analyzed by these same standard welfare analyses.

Starting Conditions

To analyze the problem, suppose that an electricity market is originally powered by fossil fuel suppliers, who supply 100% of the energy required with no scheduled or unscheduled outages. The electricity market is perfectly competitive, and both upward-sloping supply and downward-sloping demand are linear. The market settles into equilibrium, with an equilibrium price p and an equilibrium quantity q. All quantities to be discussed for all graphs are quantities of electricity, and all prices are prices per kilowatt-hour (kWh) for electricity, unless specifically noted otherwise. No outside supply or demand affects this market. There are also no other renewable energy sources besides offshore wind.

A requirement that a fraction z of offshore wind be taken as supply is now imposed upon the market. Offshore wind is assumed to be available in unlimited quantities, at a constant supply price, without fail, all the time. The only distinction is that the price of the electricity generated by the offshore wind, $p_{ow} > p$.

The requirement represents a quota restriction on the fossil fuel suppliers who are currently in the market. Suppliers must collectively import a quota such that the resulting fossil supply of electricity is (1-z)*q' and the resulting offshore wind supply is z*q', where q' is the new equilibrium quantity established in the market at the new equilibrium price p'. The demand schedule is unchanged. For Maryland, the proposed z is 0.2, or 20%. This is an unusual quota, as the usual quota is a restriction on low-cost unlimited foreign supply, while this is a mandate of purchasing

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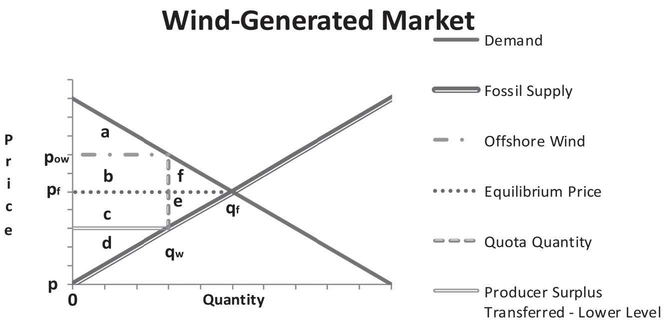
some of unlimited high-cost supply.

Segregation – the Best Case

The best possible case for wind is one in which the wind supply can be completely segregated from the existing market, and the wind supply can be devoted to a segregated wind energy market. If this occurs, deadweight losses, and price rises are minimized. The wind market is shown below. Call the additional quantity that would be purchased in the wind-generated market if it were to be powered by fossil fuel q_f, with corresponding price p_f, and call the quantity that is purchased when powered by wind q_w.



It is reasonable to assume that fossil fuel could supply the additional market less expensively than offshore wind. If wind is mandated, then there is producer surplus transferred to the wind suppliers equal to area c, and consumer surplus transferred equal to area b. Consumer surplus would be the sum of areas a + b + f without the mandate; it is now only area a with the mandate, for a deadweight loss (hereafter DWL) of area f. . Likewise, producer surplus would be the sum of areas c + d + e without the mandate; it is now only area d with the mandate, for a deadweight loss of area f. As usual, deadweight loss is the loss of a potential transaction that could benefit all parties involved in the transaction that does not occur – the trades you do not make that you could have and wanted to (see http://market.subwiki.org/wiki/Deadweight_loss).

If it is not unprofitable or impossible to transfer electricity between the original and additional markets via transmission lines, there will be arbitrage and some response to it unless a response is prevented or impossible.

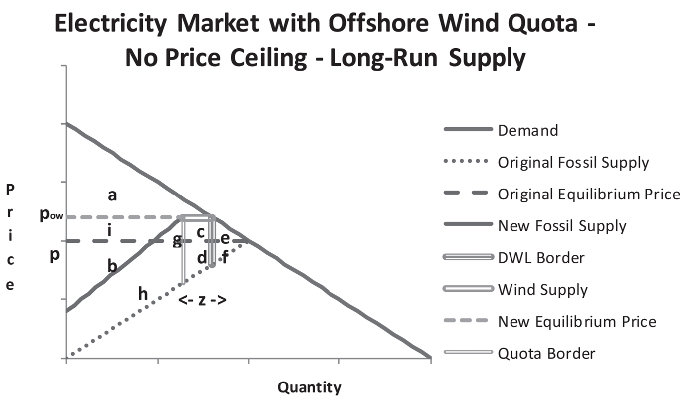
A Quota With No Subsidies

A quota with no subsidies is where standard international trade analysis can be directly applied.

First, in the absence of production subsidies, the price going to the wind suppliers will be p_{ow}. If the price is higher, more wind supply will come into the market to drive it down. If it is lower, wind suppliers will exit the market. Since the quota restriction is assumed to be binding, below z*q' will not be allowed, and so the suppliers who make up the quota get just enough to cover their constant reservation price and no more.

Second, it will be the case that the higher-cost fossil-fuel suppliers will be the ones who are driven out of the market by the quota requirement. This is just a matter of the producers acting to minimize losses they must suffer because of the imposition of the requirement to make room for the new higher-cost supply.

Third, the last, marginal, fossil supplier has a supply price equal to p_{ow}. If this fossil supply price is higher, more wind will be purchased, and the price will be driven back down. If it is lower, the electricity market will attempt to purchase more fossil energy, and come upon the binding quota restriction, which will drive the price back up.



Fourth, the resulting leftward shift in fossil-fuel supply will be a parallel shift, since there is no *a priori* reason to assume that the quota will affect different fossil fuel suppliers differently.

The resulting situation is displayed in the adjacent graph.

The original price p is displayed by the dashed line. The original supply is displayed by the dotted upward sloping line. Demand, which is not changed, is displayed by the solid downward-sloping line. Original consumer surplus is all of the areas a + i + g + c + e. Original producer surplus is all of the areas b + h + d + f. The fraction z is denoted by the horizontal length between the quota border and the DWL border divided by the entire horizontal length that denotes market output.

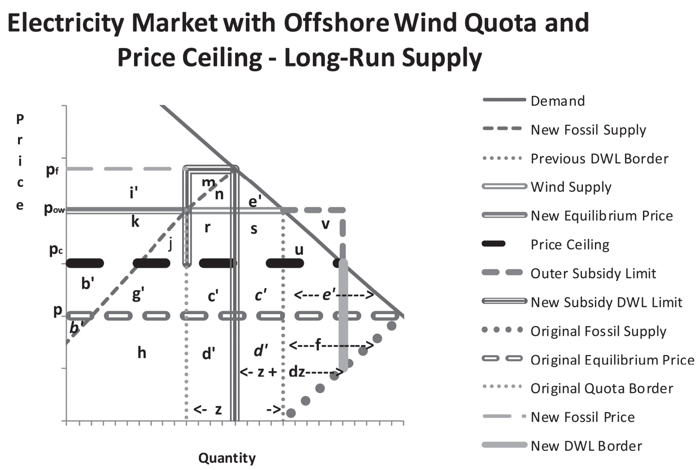
After the quota is installed, fossil fuel producer surplus is now b + i. Consumer surplus is now only a. Areas g + h can be considered to be costs for fossil fuel producers. Areas c + d are transferred to the wind suppliers. Areas e + f are now DWL. For elastic demand, this is a significant loss, but not for inelastic demand. If we accept the sensible definition that areas g + h are simply increased costs that do not lead to increased output, then areas g + h are also DWL, and these areas do not depend on the elasticity of demand.

Price Ceilings

Governor O'Malley's plan makes Renewable Energy Certificates (RECs), the right to dispose of a certain amount of wind-generated electricity, a very important vehicle.

In the absence of outside financing, a REC for 1 megawatt-hour (MWH) of electricity would have an initial price equal to p_{ow}. But it would be reasonable for generators to purchase the REC, and immediately sell 1 MWH of their own generation. The meaningful criterion then becomes the net price, or the profit of p_{ow} minus their own generation cost. A fair-market net price for a REC would then seem to be $p_{ow} – p$, which would recreate the price difference in the generation market in the REC market. Suppose that p_c is the ceiling price, and $p_c < p_{ow}$. Then demand increases over what it would be before. Call the quantity of offshore wind that must now be supplied z + dz, with dz > 0.

The fossil fuel quantity that must be supplied also goes up. But it is supplied according to the same fossil supply function as before, the new fossil supply. The subsidies are applied to the price of output, not the production process itself. Call the price the fossil fuel producers would have to receive to supply the new total quantity of output they must supply p_f, with $p_f > p_{ow}$. The situation is displayed in the, unfortunately busy, graph adjacent.



It is important to recognize that fossil fuel electricity producers *must* also receive some subsidy, since the price they have to receive to produce is not being covered by the ceiling price. The distinction in this case is that they are assumed to receive it immediately.

Consumer surplus has shrunk to the triangle above areas i', m. n and e'. Areas i'+ m+ n represent the subsidy that must be transferred to the fossil fuel producers. Area n + e' is a new addition to DWL, just because of this transfer. The sum of areas k + b' + *b'* is equal to area b before. So the producer surplus of the fossil fuel suppliers must go up from b to b + i' + m. The sum of areas g'+ j is equal area g before; that DWL does not change. Areas h and f do not change. The offshore wind suppliers must receive area equal to the product of $(z + dz)*p_{ow}$. Area s can be considered a legitimate transfer from consumers to the offshore wind suppliers now. (If stretched, it might be possible to claim that area u is as well, but consumers didn't really need to pay it.) The DWL that was area e has shrunk to area *e*' now. But areas r + c' + d' have been added to DWL because of the change, leaving only areas s + *c'* + *d'* out of the original transfer c + d as not being DWL. In sum, DWL has increased by areas n + r + *c'* + *d'* + e' + v, a very considerable amount. (Even if we subtract area u, the result is quite an increase.)

No subsidies have been announced for Maryland offshore wind. If this is the case, how does this miracle of increased output with no explicit means of support occur? Through the RECs and a schedule of rate increases for the offshore wind output itself.

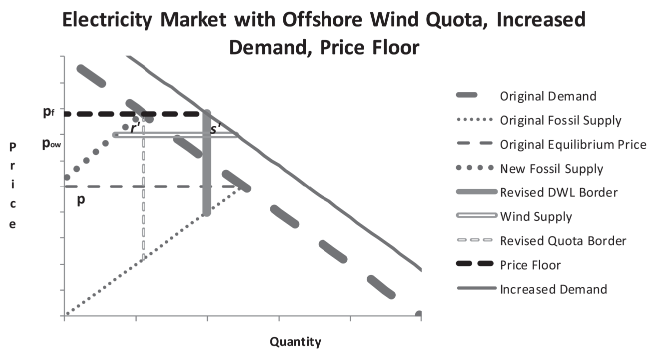
The Cape Wind Farm, which is discussed by Avalon Energy Services, LLC, in its weblog, online at http://avalonenergy.us/blog/?p=176, provides an example of what might be expected for Maryland. The initial price is 18.7 cents (¢) per kilowatt-hour (kWh), and given the compounding rate and the 15-year period of the contract, the wind output reaches a price of 30.3 ¢/kWh at the end of the contract. Avalon states that these prices are significantly above the New England average, or what can reasonably be forecast to be the New England average. (Avalon does not mention a price ceiling per year for the Cape Wind output.)

Why are these prices what they are, if offshore wind is supposed to be financially competitive with fossil fuel energy? Because the prices, discounted back to the present, have the subsidies for both wind and fossil fuel embedded within them, so that owners of fossil fuel generators who purchase the RECs receive a financial subsidy for the output they have to produce. If they don't, under these conditions, the fossil fuel producers are producing at a loss. Length of contract may also be longer under the wind agreement than what the fossil producers could get on the open market. The fossil fuel producers who survive, and the wind producers, may not see the entirety of the subsidies in the prices they receive in the first year, but eventually they all must be paid.

Demand Increases

Demand increases in later years wash away a host of sins in earlier years. This does not include eliminating the early DWLs, but it does (or can) include paying for losses suffered by the fossil fuel electricity producers in the early years as they subsidize the wind producers, so that the fossil fuel electricity producers are willing to suffer them. The major difference between demand increases and delayed subsidies is that with demand increases, since quantity is neither fixed nor declining, the supply schedules of the fossil fuel electricity producers and the wind suppliers come into play.

The arrangements between the fossil fuel electricity producers and the wind producers are summarized in the following graph. The graph is showing the second year, in which the price ceiling has just increased enough to cover the supply price for the fossil fuel electricity producers, and is greater than the offshore wind price, so it (p_f) has become a price floor. Demand has just increased enough to take the place of the government subsidy paid at the end of the first year to the fossil fuel electricity producers and the wind producers above. Suppose interest rates are zero. The fossil fuel electricity producers *loan* the wind producers the equivalent of the government subsidy for the first year. The second year comes, and demand increases just enough to pay the fossil fuel electricity producers back, as long as they aren't undercut by the wind producers, which is part of the loan agreement.



The DWLs for the second year are, however, much more modest, and are just ***r'*** and ***s'*** in the graph.

RECs can also be the vehicle through which the loans are made. If they are purchased for a year at a time, without any overhangs, then the clientele for the RECs changes from what it was in the case when the price ceiling was below the price of offshore wind. Once the ceiling rises above it, and becomes a price floor, the purchasers are looking to make profits, not just cut losses. So the purchasers become those whose supply costs are in between the price floor and the price of the offshore wind. (The wind producers could still sell to those whose costs are above the price floor, but unless those producers are willing to offer more than the floor price for the RECs, it makes sense not to sell to them but to hold onto the rights and sell into the market and receive the floor price. The reduction in losses which was important no longer is so.) Again, the price of the RECs must make the marginal purchaser just indifferent between holding the REC and producing. For a perfectly competitive market, without lumpiness, the REC price would then be the average of the shore price and the offshore wind price; for a more lumpy market, the REC price would then be the median fossil fuel electricity cost between the two.

Is It Worth It Regardless?

The DWL is essentially a reduction in consumption and ongoing, regular business expenditures. The wind farm would nevertheless be validated as an investment if it spurred either private or public investment in addition. Because of the large minimum scale of public investment, and the relatively small savings the wind farm would generate, since the share of energy costs in total costs for public investment is small, it is doubtful that public investment will be elastic enough to validate the wind farm on its own. School construction, road repair and building, and septic system upgrades are not the ideal consumer base for the wind output.

That leaves private investment. Andy Bollman, E.H. Pechan & Associates, "Characterization and Analysis of Small Business Costs", April 2008, at http://archive.sba.gov/advo/research/rs322tot.pdf, goes into useful detail on how the shares of energy costs vary across businesses. The only remotely reasonable nonagricultural businesses for which energy shares are high (as a percentage of the value of shipments) are hospitals, accommodation, truck transportation, couriers and messengers, chemical and nonmetallic and metallic product manufacturing, textile mills and wood product manufacturing and possibly plastics manufacturing. Each of these face the same problem: because of its distance from metropolitan areas and major transportation routes, increased transportation costs would eat up any saving that might accrue from low-cost wind energy, if it is low cost.

It thus appears that the wind farm, if kept at its current size, imposes significant DWL, at least in the early years, and possibly significant costs and systemic instability in its later years. Because of its location, it requires significant investments in transmission, and its success requires that transmission losses be zero or low.