A Very Brief Microeconomics Overview

1.0 The electric market debate is not over…

A story recently appeared in the business section of the Dallas-Fort Worth Star-Telegram Newspaper [1].

"IN MY OPINION * Texas is getting a lot more energy efficient, a push that was included in the deregulation bill. Believe it or not, electric deregulation is working in Texas -- just not exactly how many envisioned. Yes, monthly electric bills are now higher here than in most parts of the country. But look beyond kilowatt price -- and the short-term pain -- and consider how far Texas has come on energy efficiency and wind power. They were side issues a decade ago, when oil and..."

This motivated one reader, a small-business owner, to send in a letter, which said [2]

"If electricity deregulation is so good for me, why don't I feel any better? I'm tired of hearing our elected officials tell us that deregulation is working. It kills me to see that the Star-Telegram's Mitch Schnurman is buying into it. (See: "Give deregulation a nod for some things," Aug. 24) (See: "Texas making strides on energy efficiency," Aug. 24) The rates I am paying rank me right up there with New York and New Jersey. Something is wrong. It is not working for me. How about you?

The most recent Fortune Small Business magazine reports that the national average for electricity is 8.9 cents per kilowatt hour. I'm currently paying 14.4 cents in Arlington. Last time I checked, neither New York nor New Jersey had a nuclear power plant and neither was sitting over any coal or natural gas. Something isn't right…..

…deregulation destroyed a thoughtful and deliberative state planning process that chose energy efficiency policies that offered the biggest bang for the buck. Now special interests just get their specific technology mandated into the law. …

I bet that most have never even heard that our skyrocketing electricity prices are based on marginal fuel costs for gas-fired plants. This is the real culprit, and it is hardly ever discussed when the "why are my rates so high?" question is asked. Here's what I know:

Prior to deregulation, our rates were based on the cost of generating and delivering electricity. State regulators were empowered to review the utility's books to make sure that the rates you and I paid were reasonable and that the company was receiving enough revenue to continue operations. Under deregulation, state regulators have no power to review and approve generation rates.

Electricity generating companies can sell their power to retail electric providers one of two ways. They can enter into a one-on-one contract with a retail provider or they can sell their power on the "spot" market.

The state’s electricity grid operator — the Electric Reliability Council of Texas (ERCOT) — operates a daily wholesale spot market for electricity.

Here’s the catch: This wholesale spot market pays all electricity generators the marginal — or highest — price for electricity regardless of how much it cost to generate. Three-cent electricity from coal and nuclear power plants gets sold for natural gas prices — 9 cents. This is the billion-dollar secret to the broken, deregulated electric market in Texas.

This system has big winners and big losers. Electricity generators are big winners as they make top dollar by either selling in the spot market or extracting a near-spot-market price in a one-on-one contract with a retail provider. What does this mean in dollars and cents? It means that Luminant, the generating arm of Energy Future Holdings (formerly TXU Corp.) and other large electricity generators can sell electricity at three or even four times what it costs to produce.

Consumers are the big losers because instead of driving prices down, this system drives prices up. And consumers can’t choose their way out of high prices because all retail electric providers go to the same high-priced wholesale market for power.

I call this stealing. Our "guardians" have made it legal for the generating companies to do it. Next time you want to complain about Exxon Mobil’s reported 8 percent profit margin, do some figuring on what these guys are tucking away.

Do you see why the venture capitalist group that bought TXU was so willing to participate in the largest leveraged buyout ever? Why they were so anxious to "gamble" on the Texas market being lucrative and assume so much debt? A big piece of the pie, no oversight, high demand, very little competition. There was no "gamble."

Deregulation is working. It is working for the electricity generating company whose product ends up running into my home, and it is working against thoughtful consideration of cost-effective energy efficiency policies.

For me? It’s just working me over. Some of you might feel the same.

Question: Do you agree with him? Let's see if we can shed some light on this issue with classical supply-demand economics.

2.0 Consumer's surplus

Much of the below material was adapted from standard economics textbooks [3, 4, 5].

A demand curve characterizes the manner in which the demand of a good will change as its price changes, holding constant all other factors that influence consumers' willingness or ability to pay for the good.

What might a demand curve for electric energy look like for a large industrial consumer that participates in the market? Figure 1 illustrates a consumer where,

- The consumer will pay anything to get 3 MWhrs – this part is price insensitive or inelastic.
- The consumer may or may not purchase more than 3 MWhr, depending on the price….
- If the price is 40 $/MWhr or below, they will purchase an additional 4 MWhrs for total of 7.
- If the price goes to 20 $/MWhr or below, they will purchase an additional 1 MWhr for total of 8.

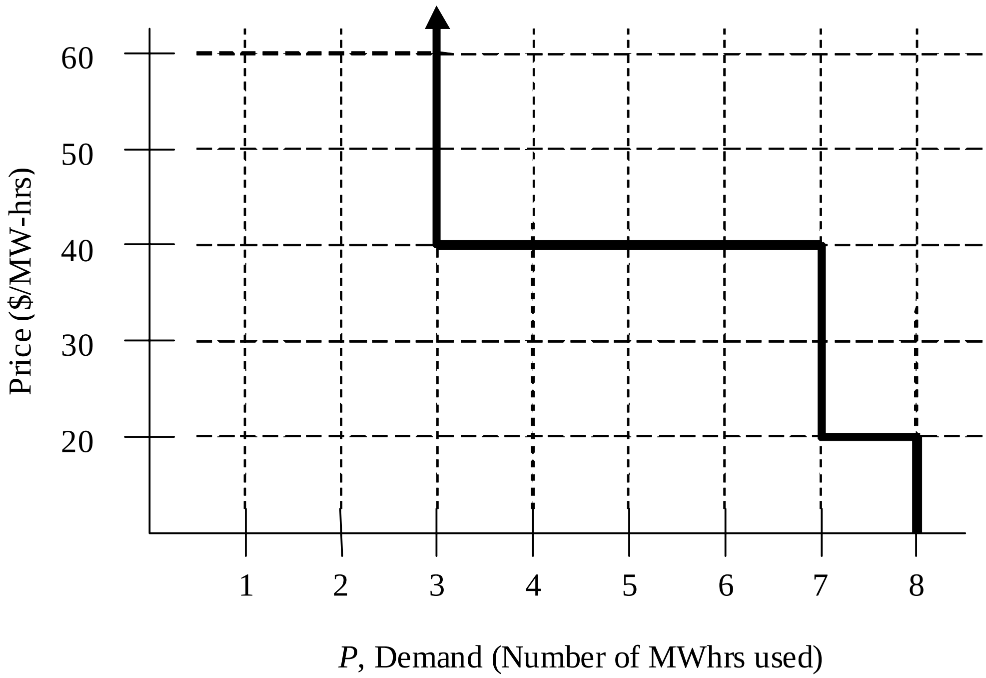


Fig. 1: Demand function

Let's consider now[1] the utility function for the industrial consumer as a function of the amount of energy the plant consumes in an hour *x*, and the money that it has at the end of that hour, *y*.

$$U(P,y)=v(P)+y \tag{1}$$

where *v(P)* quantifies, in dollars, the satisfaction associated with the amount of energy consumed, *P*, and is the utility function for energy. We require *v(P)* to be an increasing and concave function, and *v(0)=0*.

Assume the company has an amount of money *m* to use for the hour, and the energy price is *p*, so that:

[1] The remainder of this section was adapted from notes developed by Oscar Volij of Iowa State University.

$$y + pP = m \tag{2}$$

The company wants to maximize its satisfaction *U(P,y)*, but it must do so subject to the constraint identified in (2):

$$\max_{P,y}\{v(P) + y\}$$
$$\text{s.t.} \quad y + pP = m \tag{3}$$

Form the Lagrangian:

$$F(P, y, \lambda) = v(P) + y - \lambda(y + pP - m)$$

and then apply first order conditions:

$$\frac{\partial F(P,y,\lambda)}{\partial P} = \frac{\partial v(P)}{\partial x} - \lambda p = 0 \Rightarrow \frac{\partial v(P)}{\partial P} = \lambda p$$
$$\frac{\partial F(P,y,\lambda)}{\partial y} = 1 - \lambda = 0 \Rightarrow \lambda = 1$$
$$\frac{\partial F(P,y,\lambda)}{\partial \lambda} = y + pP - m = 0 \tag{4}$$

From the first two equations above, we obtain

$$v'(P) = p \tag{5}$$

where *v'(P)* expresses the change in utility per unit change in *P*, the *marginal utility* for energy. It provides an upper bound to what the company should be willing to pay for one more unit of energy. If they have to pay more, then the value of what they can do with that energy is less than what they have to pay for it.

We call (5) the inverse demand function, i.e., it expresses price as a function of demand. The demand function expresses demand as a function of price.

Question: Consider that the company has a choice of participating in the electric energy market or not. Will it benefit by doing so?

The answer to this question depends on the difference between its total utility when it participates and its total utility when it does not, given the energy price is *p*. We can use (1) to express the total utility under these two conditions, and then, with a little work (see Appendix A), we can find that the difference is given by the *consumer surplus* at price *p*, denoted as *CS(p)*, expressed as:

$$CS(p) = \int_0^{P(p)} v'(P)\,dP - pP(p) \qquad (6)$$

Equation (6) has a nice graphical interpretation illustrated by Fig. 2, where we assume a price p^* results in a demand P^*. Observe:

- The first term of (6) corresponds to the area under the $p=v'(P)$ curve from 0 to P^*, which is the entire area shaded by vertical lines.
- The second term of (6) corresponds to the lower "box," not shaded by horizontal lines, lower side $0{:}P^*$ and left-hand-side $0{:}p^*$.

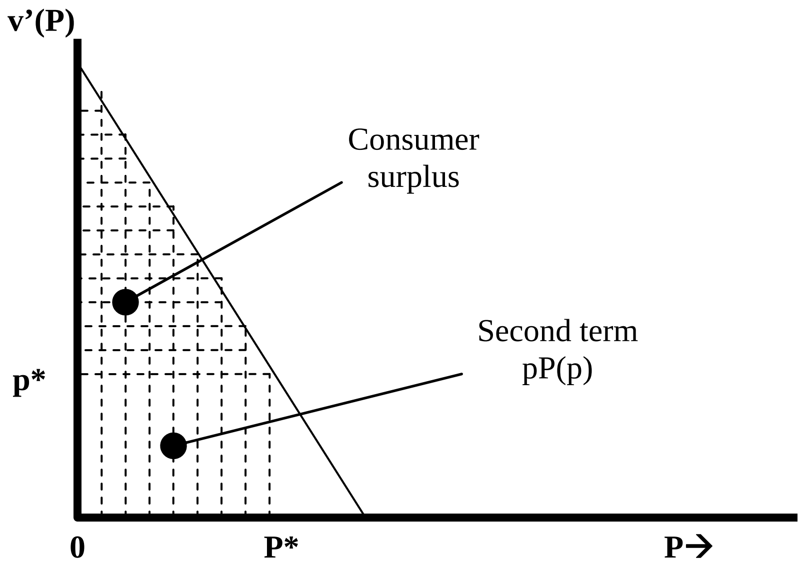


Fig. 2: Consumer surplus

The consumer surplus is the gap, or difference, between the total utility of the energy and its total market value. The surplus arises because we "get more than we pay for."

The reason we "get more than we pay for" is because the price we pay is equal to the value to us of the last unit of energy (the marginal value).

3.0 Producer's surplus

A supply curve characterizes the manner in which the supply of a good will change as its price changes, holding constant all other factors that influence producers' willingness or ability to supply the good.

What might a supply curve for electric energy look like for a large generation owner that participates in the market? Figure 3 illustrates a supplier where,

- below 20 $/MWhr, they shut down the power plant
- at 20 $/MWhr, they produce up to 4 MW in an hour;
- if the price goes to 30 $/MWhr, they produce up to 7 MW in an hour;
- if the price goes up to 50 $/MWhr, they produce up to 8 MW in an hour.

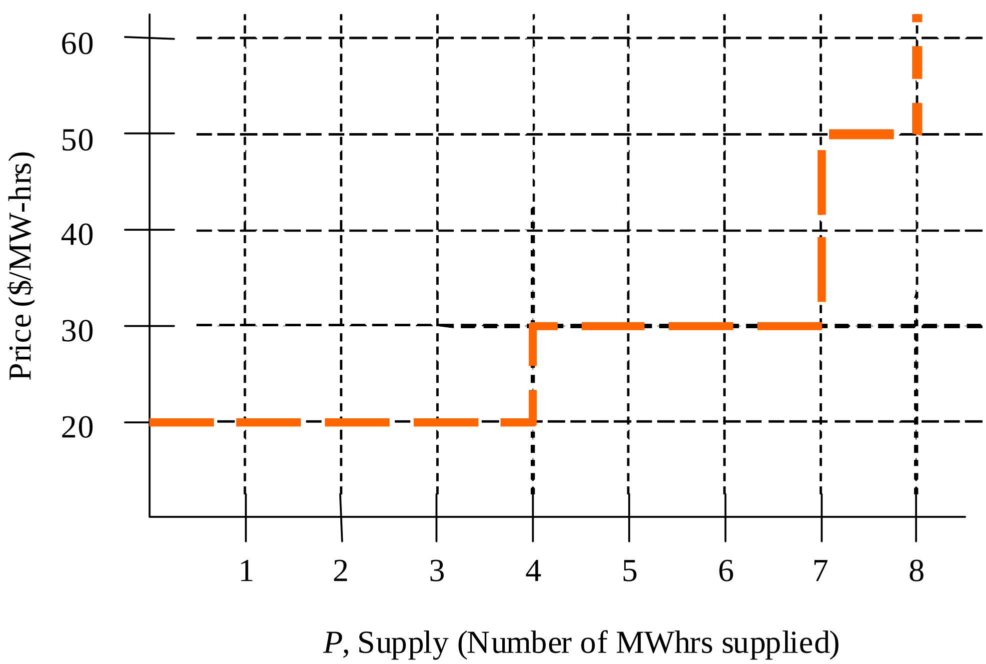


Fig. 3: Elastic Supply

Let's consider now[2] that we have the hourly cost function for a power producer *C* as a function of the amount of power it produces *P*. Two cautions here:

1. Be careful to distinguish between price *p* and power produced *P*.
2. You can equivalently consider *C* to be in $/hr, and *P* to be in MW, or you can consider *C* to be $, and power *P* to be MWhr. Since we previously considered demand *x* to be MWhr, we will consider *P* to also be MWhr.

We assume *C* to be convex.

The value *C(P)* is the amount of money the producer needs to spend in order to produce *P* MWhr. And we know its derivative is *C'*, the incremental cost, or, the marginal cost of energy. It represents the rate at which the cost of production increases due to a small increase in the production of energy.

Assume that the energy price is *p*, and the producer desires the production level which maximizes profits. Therefore, the producer solves the following:

$$\begin{aligned} &\max_P \{pP - C(P)\} \\ &\text{s.t.} \quad 0 \le P \ge P_{\max} \end{aligned} \tag{7}$$

[2] The remainder of this section was adapted from notes developed by Oscar Volij of Iowa State University.

To solve this, we apply first order conditions to the expression inside the curly brackets to obtain:

$$\frac{\partial F\left(pP - C(P)\right)}{\partial P} = p - \frac{\partial C(P)}{\partial P} = 0 \Rightarrow \frac{\partial C(P)}{\partial P} = p \quad (8)$$

And so, when the producer sees a price *p*, s/he should produce the amount of energy *P* which results in

$$\mathrm{C}'(P) = p \quad (9)$$

<u>Question</u>: Consider that the producer has a choice of participating in the electric energy market or not. Will it benefit by doing so?

The answer to this question depends on the difference between its profits when it participates and its profits when it does not, where profits are *pP-C(P),* the objective in (7).

If it does participate, and the energy price is *p*, then it produces *P*, it gets paid *pP*, and it incurs a cost *C(P)*. If it does not participate, then it produces 0, it gets paid 0, and it incurs a cost *C(0)*. The difference in profits is therefore the *producer's surplus* at price *p*, denoted as *PS(p)*. With a little work (see Appendix B), we express it as:

$$PS(p_0) = pP - \int_0^P C'(P)dP \quad (10)$$

Equation (10) has a nice graphical interpretation illustrated by Fig. 4, where we assume a price *p** results in a supply *P**.

- The first term of (10) corresponds to the total "box," shaded by vertical lines, lower side *0:P** and left-hand-side *0:p**.
- The second term of (10) corresponds to the area under the *p=C'(P)* curve from 0 to *P**, which is the area shaded by horizontal lines.

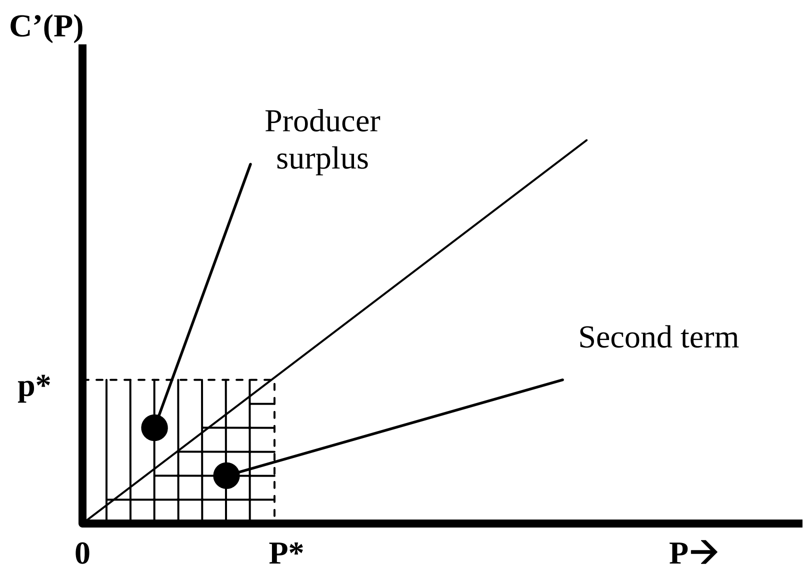


Fig. 4: Producer surplus

Whereas consumer surplus may have been a little bit of a new idea for us ("you get more than you pay for"), the interpretation of producer surplus, profits, should be pretty familiar.

4.0 Social surplus

We want to examine the conditions under which a market "works well."

Let's consider the notion of a "benevolent dictator," (BD); we will assume that this person has complete control over our "economy," (our electricity market), i.e., s/he can require any amount of electricity to be demanded and supplied. You might think of the BD as the market operator, or as a planner in the US Department of Energy.

Now let's assume the BD has the following information:

- There is a supplier having a cost function $C(P)$.
- The consumers in the economy have (all of them together) m units of money.
- The consumers utility function, expressing their satisfaction, is

$$U(P, y) = v(P) + y \tag{11}$$

where $v(P)$ quantifies, in dollars, the satisfaction associated with the amount of energy consumed, P, and y is the money available to the consumer after paying (to the supplier) for the energy x at a price p, i.e,

$$y=m-pP \tag{12}$$

Now thinking as the BD would think, where all money in the economy, and all decisions, are at the disposal of the BD, what should the BD do if s/he wants to maximize overall happiness?

The BD does not really care about the shift of money from the consumers to the supplier that occurs via *pP*, because this money stays in the economy. But the expenditures associated with the producer, *C(P)*, leave the economy, and so the BD does care about them. And of course the BD cares about the satisfaction obtained from the energy *v(P)*.

Therefore, the BD wants to maximize *v(P)* and the total amount of money in the economy, *m-C(P)*. In other words, the BD wants to solve the following problem:

$$\max_{P} \left\{ v(P) + m - C(P) \right\} \tag{13}$$

But *m* is just a constant, therefore (13) is identical to

$$\max_{P} \left\{ v(P) - C(P) \right\} \qquad (14)^{3}$$

Taking first order conditions:

[3] Equivalently, we can say BD wants to maximize the sum of utility: v(P)+m-pP, and profit: pP-C(P), which is v(P)+m-pP+pP-C(P)=v(P)+m-C(P).

$$\frac{\mathrm{d}\left\{v(P)-C(P)\right\}}{dP}=0$$

$$\Rightarrow v'(P)-C'(P)=0$$

or

$$v'(P)=C'(P) \tag{15}$$

Equation (15) expresses the condition on consumption and production that the BD needs to satisfy in order to maximize the happiness for the people, and that is:

> The optimal level of consumption and supply, *P*, is obtained when the marginal utility *v'(P)* is equal to the marginal cost *C'(P)*.

We can think of this condition in another way. Let's reconsider our objective function (14), and call it *F*:

$$F(P)=v(P)-C(P) \tag{16}$$

Now add and subtract *pP* to it:

$$F(P)=v(P)-C(P)-pP+pP \tag{17}$$

Move the *–pP+pP* terms to the left:

$$F(P)=v(P)-pP+pP-C(P) \tag{18}$$

Group terms:

$$F(P)=\left(v(P)-pP\right)+\left(pP-C(P)\right) \tag{19}$$

The first term in the parentheses of (19) is the utility of the energy less the price paid by the consumer for the energy, a term we recognize as the consumer's surplus from (6), repeated here for convenience:

$$CS(p) = \int_0^{P(p)} v'(P)dP - pP(p) \qquad (6)$$

where

$$v(P) = \int_0^{P(p)} v'(P)dP$$

The second term in the parentheses of (19) is the price paid to the producer for the energy less the production cost of that energy, a term we recognize as the producer's surplus from (10), repeated here for convenience:

$$PS(p_0) = pP - \int_0^{P} C'(P)dP \qquad (10)$$

where

$$C(p) = \int_0^{P} C'(P)dP$$

Therefore (19) becomes:

$$F(P) = CS(P) + PS(P) \qquad (20)$$

Definition: The sum of the consumer surplus and the producer surplus is called the *social surplus*. It is a measure of the total benefit seen by an economy and it is what the BD wants to maximize.

We see that the BD achieves the goal, i.e., the social surplus is maximized, when (15) is met, i.e., when marginal utility *v'(P)* equals marginal cost *C'(P)*, i.e., when willingness to pay for an additional unit of energy equals cost of producing one additional unit.

The social surplus is illustrated as the area enclosed by the triangle to the left of Fig. 5.

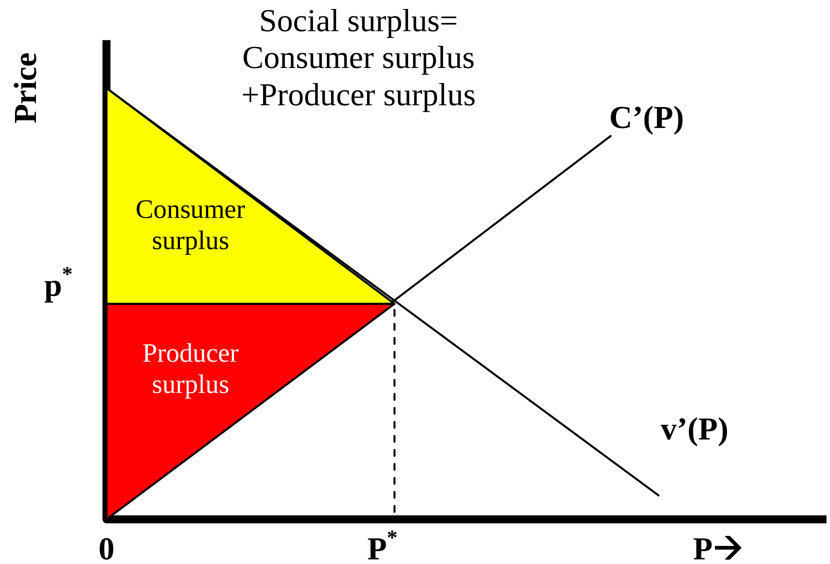
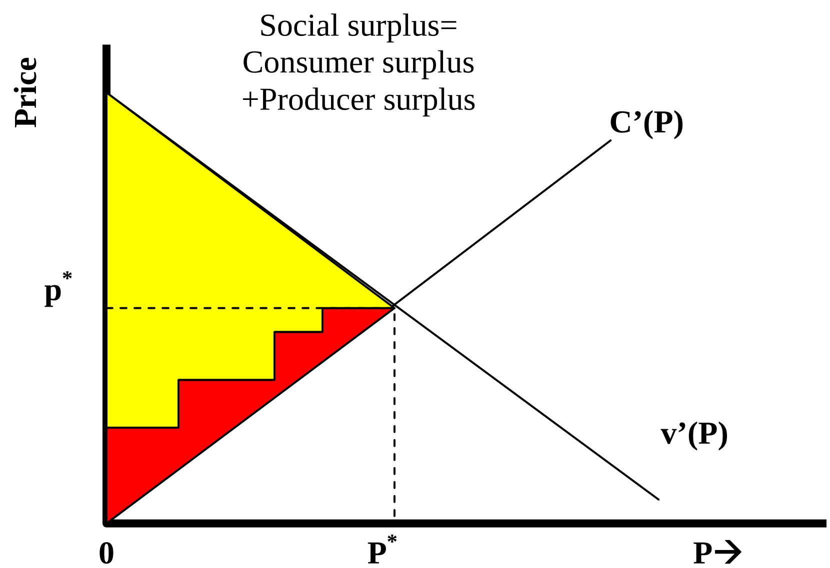


Fig. 5: Social Surplus

Question: What does this say about Mr. Johnson's suggestion to regulate generation to their costs?

- He wants to redistribute the surplus so that consumer's get more. This amounts to some kind of tax on the least expensive units.



- This might work while retaining a market structure
  - as long as the marginal units are not taxed; otherwise we change p*, and
  - as long as generation companies make enough profit to cover their fixed costs and their costs of building additional units.
- One way to ensure generation companies remain viable is to watch them carefully and move the "tax" up and down as needed. If we think of the "tax" as the difference between what they could earn and an "allowable rate of return," we are back to the old regulated approach to electric systems.

5.0 Perfect competition

Of course, markets do not really have BDs. What then? It is possible to show that a *perfectly competitive* market, where agents behave autonomously and self-interestedly, will achieve the exact same equilibrium point as that achieved by the BD. This is a fundamental point in economic theory, and the obtained equilibrium point is called the *competitive equilibrium*.

There is one issue that we should consider before we leave this topic: What does it mean to have a market that is "perfectly competitive"?

Markets work best under the condition of perfect competition. What does this mean? A market is said to operate under perfect competition when the following four conditions are satisfied [5]:

1. Numerous small producers & consumers: It must be the case that changes in production or consumption by any one agent must have negligible effect on total market supply or consumption and therefore have negligible effect on price. This means each agent is a price-taker - it has no choice but to accept the price that has been market-determined, i.e., no agent has control over the price it pays or charges. This is because there are so many agents, and the

quantity bought or sold by any individual agent is a small fraction of the whole.

2. Homogeneity of supply: Each unit of production must be a perfect substitute for another unit so that consumers have no preference regarding producer.

3. Freedom of entry and exit: Producers and suppliers must both be free to participate, or not participate in the market. If someone is losing money, they must be able to get out, without penalty. If someone is making large profits, other agents must be able to enter the market to also share in such profits.

4. Perfect information: Each agent must have equal access to information relevant to competing in the market, including market rules, available products, and their prices.

5.0 Falling short of perfect competition

The three most important ways that markets can fall short of perfect competition are [3]:

- Monopoly elements: If one producer is so large, relative to the market, that people have to buy from it or go without, then that producer has monopolistic features. For example, Microsoft has monopolistic features for selling operating systems.
- Externalities: These are effects of market transactions that are not directly accounted for via the transaction. They are sometimes referred to as

spillover effects. When you buy a haircut, the barber receives the entire value for his or her time, skills, and rent. But when you buy an air ticket, although the airlines receives their value for that service, the neighbors living next to the airport are not compensated for the noise they must endure. Likewise, when you purchase electric energy, the power company receives value for the energy, but no one compensates the human race for the effects of greenhouse gasses in the stratosphere. The noise, for the airline ticket, and the greenhouse gases, for the electric energy, are both considered to be externalities. *Externalities occur when producers or consumers impose* ***costs*** *on others outside the marketplace.*

- Public goods: The definition of externalities given above is for ***negative*** externalities, when ***costs*** are imposed on others outside the marketplace. Externalities may also be ***positive***, when ***benefits*** are imposed on others outside the marketplace. For example, when AT&T researchers invented the transistor, many, many producers and consumers eventually benefited, but AT&T profits only increased by a very small fraction of that overall benefit. The extreme form of a positive externality is called a *public good*. Public goods are commodities for which

- the cost of extending the service to an additional person (or agent) is zero and
- it is difficult to exclude individuals (or agents) from enjoying.

Some examples of public goods are national defense, lighthouses, interstate highways, and national weather service. Typically, public goods are funded via some organization independent of the market, most commonly the government. In the electric energy markets, transmission has public good features, and so transmission operations and upgrades are typically financed via a sort of tax on all market agents.

6.0 What about electricity markets?

Although electricity markets have lots of market participants, the MWhr seems to be a homogeneous product precisely the same for everyone, rules can be developed to facilitate entry and exit, and websites are clearly accessible to all, there are some problems.

One problem in regards to electricity markets is the fact that not all MWhrs are really the same, due to the additional services associated with the generators that produce them. For example, the ability to ramp is different from one generator to another. And so it is not possible to operate a power system entirely with traditional coal-fired and nuclear plants. Gas turbine plants are required because of their ability to quickly ramp up and down and thus follow peaks. This issue has been addressed by establishing ancillary services markets to pay owners for this service.

Another problem in regards to electricity markets is the ability of one or more producers to exert *market power*. Market power is the ability of an agent to alter price without losing all customers to competitors. At worst, market power gives companies ability to engage in anti-competitive behavior, including predatory pricing (selling at very low price to drive competitors out of the market) and creation of overcapacity (ability to flood the market if other producers try to enter) as a barrier to entry. If no individual participant in the market has significant market power, then anti-competitive behavior can take place only through collusion (exercise of a group of participants' collective market power).

As a result, FERC requires ISOs to have a market monitoring function.
The California crisis of 2001 provides good illustrations of agent behavior that is or at least borders on use of market power. An excellent discussion of this historical incident which I strongly recommend to you is [6].

Appendix A: Derivation of Consumer Surplus

Question: Consider that the company has a choice of participating in the electric energy market or not. Will it benefit by doing so?

The answer to this question depends on the difference between its total utility when it participates and its total utility when it does not, where total utility is given by (1), repeated here for convenience:

$$U(x,y) = v(x) + y \qquad \text{(A1)}$$

Let's denote the total utility when

- it participates in the market: $U_{par}(x,y)$,
- it does not participate in the market: $U_{not}(x,y)$

If it does participate, and the energy price is *p*, then it obtains an amount of energy equal to *x(p)*, and the amount of money it will have is, by *y=m-px(p)*. Then the company's total utility, i.e., its *(x,y)* bundle, is given by:

$$U_{par}(x,y) = U\big(x(p), m - px(p)\big) \qquad \text{(A2)}$$

If it does not participate, then it receives no electric energy, and it has *m* dollars. And so the company's total utility, i.e., its *(x,y)* bundle, is given by *U(0, m)*.

$$U_{not}(x,y) = U(0,m) \qquad \text{(A3)}$$

The difference, then, is given by the *consumer surplus* at price *p*. We will denote the consumer surplus as *CS(p)*. It is expressed as the difference between (A2) and (A3):

$$\begin{aligned} CS(p) &= U_{par}(x,y) - U_{not}(x,y) \\ &= U\big(x(p), m - px(p)\big) - U(0,m) \end{aligned} \qquad \text{(A4)}$$

Using (1) above, we can express (10) as

$$CS(p) = \underbrace{v(x(p)) + m - px(p)}_{U(x(p),m-px(p))} - (\underbrace{v(0) + m}_{U(0,m)}) \qquad \text{(A5)}$$

Observing the addition and subtraction of *m*,

$$CS(p) = v(x(p)) - px(p) - v(0) \qquad \text{(A6)}$$

Rearranging,

$$CS(p) = v(x(p)) - v(0) - px(p) \qquad \text{(A7)}$$

Recall the fundamental theorem of calculus:

$$F(b) - F(a) = \int_a^b F'(x)dx$$

This allows us to write the first two terms of (A7) as

$$v(x(p)) - v(0) = \int_0^{x(p)} v'(x)dx \qquad \text{(A8)}$$

Substitution of (A8) into (A7) results in

$$CS(p) = \int_0^{x(p)} v'(x)dx - px(p) \qquad \text{(A9)}$$

Appendix B: Derivation of Producer's Surplus

Question: Consider that the producer has a choice of participating in the electric energy market or not. Will it benefit by doing so?

The answer to this question depends on the difference between its profits when it participates and its profits utility when it does not, where profits are *pP-C(P)*.

If it does participate, and the energy price is *p*, then it produces *P*, it gets paid *pP*, and it incurs a cost *C(P)*. If it does not participate, then it produces 0, it gets paid 0, and it incurs a cost *C(0)*. The difference in profits is therefore the producer's surplus:

$$\begin{aligned} PS(p_0) &= pP - C(P) - \left(0 - C(0)\right) \\ &= pP - (C(P) - C(0)) \\ &= pP - \int_0^P C'(P)dP \end{aligned} \tag{B1}$$

where the last step is taken according to the Fundamental Theorem of Calculus.

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[1] M. Schnurman, "Give Deregulation A Nod For Some Things," Dallas-Forth Worth Star-Telegram, Aug. 24, 2008.

[2] J. Johnson, "Deregulation: No one wants to talk much about the underlying pricing issue," Dallas-Forth Worth Star-Telegram, Sept. 7, 2008, available at http://www.star-telegram.com/245/story/888021.html.
[3] P. Samuelson and W. Nordhaus, "Economics," 17th edition, McGraw-Hill, 2001.
[4] A. Dillingham, N. Skaggs, and J. Carlson, "Economics: Individual Choice and its Consequences," Allyn and Bacon, 1992.
[5] W. Baumol and A. Blinder, "Economics: Principles and Policy," Dryden Press, 1994.
[6] D. Bush and C. Mayne, "In (Reluctant) Defense of Enron: Why Bad Regulation is to Blame for California's Power Woes (or Why Antitrust Laws Fail to Protect Against Market Power When the Market Rules Encourage its Use)," The Oregon Law Review, Vol 83, 2004.