Intro to Economics: Efficiency and Equilibrium

1.0 Introduction

Recall our objective in this introduction to microeconomics is to gain some understanding of the following concepts:

- Supply and demand functions
- Consumers surplus
- Producers surplus
- Market efficiency
- Market equilibrium
- Competitive equilibrium

We have discussed supply and demand functions and consumers and producers surplus. Now we turn to market efficiency. As before, much of the below material was adapted from standard economics textbooks [1, 2, 3].

2.0 Pareto optimality

Consider that you are a very nice person that likes to help people, and there are two different families in particular that you desire to assist. You have an extra $1000 to use in assisting these two families. Both families are quite poor.

Family 1 consists of an elder husband and wife. Family 2 consists of a young husband and wife with 4 children.

You reason that you can allocate the dollars in many ways, as long as you satisfy

$$x_1+x_2\leq 1000$$

Now we could choose to allocate \$400 to each family. Let's call this solution A. However, if our objectives are to maximize benefit to the two families, a better solution is to allocate \$400 to family 1 and \$500 to family 2. This solution, let's call it B, is a better one in that family 2 is better off than they were before and family 1 is no worse off than they were before.

You can think of a still better solution: allocate \$500 to each family. Call this solution C. Relative to A, both families are better off. Relative to B, only family 1 is better off, but family 2 is no worse off.

Solution C, you reason, is a good solution. Why is it a good solution? It is a good solution because there are no ways you can improve the situation for one family without making the situation worse for the other family.

Is solution C the best solution? Hmmm.

What about solution D, where family 1 has $400 and family 2 has $600. This might be better because it gives more to the larger family. But it might not be better because the elderly couple need some expensive medical attention. So it is hard to say….

But one thing you know: solution D is a good solution in that there are, once again, no ways you can improve the situation for one family without making the situation worse for the other family.

This quality of solutions whereby one “objective” cannot be improved without degrading the other “objective” is an important criterion that occurs whenever you have a multiobjective optimization problem, and the objectives *conflict*. Conflicting objectives exist when improvement in one objective occurs at the expense of the other.

Solutions which satisfy the above criterion, i.e., that one objective cannot be further improved without degrading the other objective, are called Pareto-optimal solutions.

And the set of Pareto-Optimal solutions is called the Pareto-Optimal front (or frontier).

Figure 1 below plots the Pareto-Optimal front for the problem we have been discussing. There are many possible solutions on the line and underneath the line, but only the solutions on the line are "good" ones.

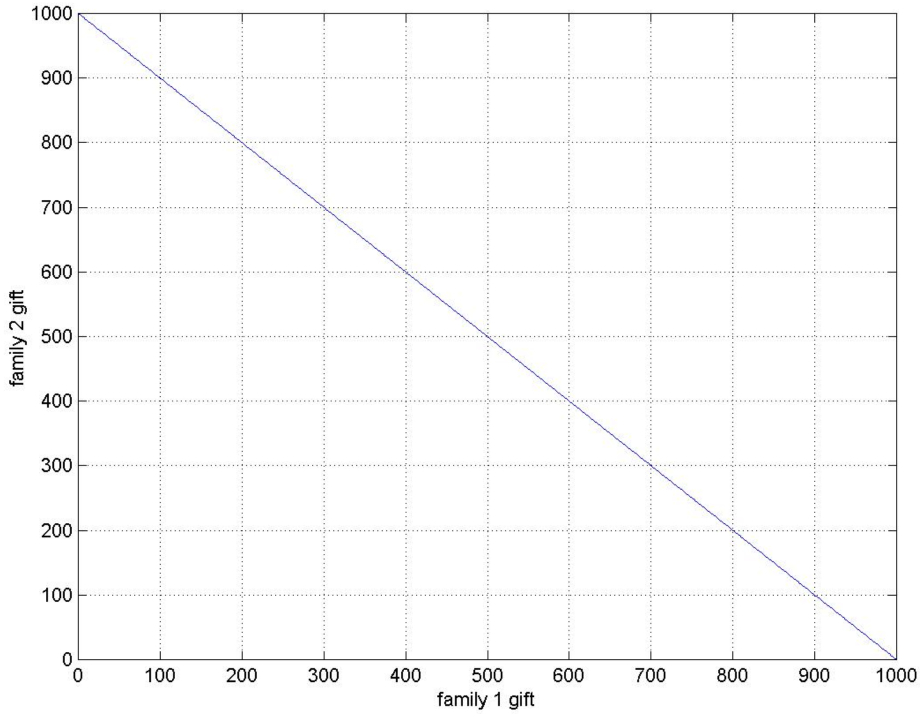

Fig. 1: Pareto-optimal front

2.0 Efficiency

We all understand the notion of efficiency in power and energy engineering. It is a measure of the amount of output energy we obtain for every unit of input energy we provide.

$$\eta = \frac{Output}{Input}$$

We say an energy conversion system is efficient if it is producing a high output for a given input.

Economic efficiency may be thought of in a similar way. We can say, rather loosely, that a market is efficient if we are obtaining the maximum benefit for a given cost. What we want to do in the remainder of these notes is to provide a more explicit understanding of economic efficiency.

Let’s consider the notion of a dictator. The word “dictator” conjures up negative images for most of us, e.g., Adolf Hitler, Benito Mussolini, Idi Amin, Manuel Noriega. These people had absolute authority, and they used it very badly.

Let’s consider now that someone can have absolute authority and use it very well. But “very well,” we mean they use it for the benefit of society. In terms of economic efficiency, we mean they maximize the benefits for their people using the resources they have at their disposal. We will call such a ruler 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

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

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,

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

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:

$$\max_{P} \quad \{v(P) + m - C(P)\} \tag{3a}$$

But m is just a constant, therefore (3a) is identical to

$$\max_{P} \quad \{v(P) + C(P)\} \tag{3b}$$

Taking first order conditions:

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

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

or

$$v'(P) = C'(P) \tag{4}$$

Equation (4) 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 (3b), and call it *F*:

$$F(P) = v(P) - C(P) \qquad (5)$$

Now add and subtract *pP* to it:

$$F(P) = v(P) - C(P) - pP + pP \qquad (6)$$

Move the –*pP*+*pP* terms to the left:

$$F(P) = v(P) - pP + pP - C(P) \qquad (7)$$

Group terms:

$$F(P) = \left(v(P) - pP\right) + \left(pP - C(P)\right) \qquad (8)$$

The first term in the parentheses of (8) 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. This can be seen analytically from eq. (13) of the IntroEcon1 notes (on consumer surplus), repeated here for convenience:

$$CS(P) = vP - v(0) - pP \qquad (9)$$

The second term in the parentheses of (8) 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. This can be seen analytically from eq. (4) of the IntroEcon2 notes (on producer surplus), repeated here for convenience:

$$PS(P) = pP - (C(P) - C(0)) \qquad (10)$$

If we assume in (9) that the utility of getting no energy is zero, i.e,. *v(0)=0*, and in (10) that the cost of producing no energy is zero, i.e., *C(0)=0*, then (9) and (10) become:

$$CS(P) = v(P) - pP \tag{11}$$

$$PS(P) = pP - C(P) \tag{12}$$

Substitution of (11) and (12) into (8) results in

$$F(P) = CS(P) + PS(P) \tag{13}$$

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 (4) is met, i.e., when the marginal utility *v'(P)* is equal to the marginal cost *C'(P)*.

The interpretation is this:

- If willingness to pay for an additional unit of energy is higher than its cost of production, BD can increase the social surplus by producing one more unit.
- If willingness to pay for an additional unit of energy is lower than its cost of production, then we could increase social surplus by producing one unit less.
- It is only when the willingness to pay for an additional unit of energy equals the cost of producing one additional unit can we be maximizing the social surplus.

Example: Consider having a utility function of $v(P) = 60P - P^2$ and a cost function of $C(P) = P^2$. Find the amount of supply and demand, and the corresponding price, that optimizes social surplus.

Solution: $v'(P) = 60 - 2P$, $C'(P) = 2P$

Solving *v'(P)=C'(P)* results in

$60 - 2P = 2P \Rightarrow 60 = 4P \Rightarrow P = 15$

The situation is illustrated in Fig. 1.

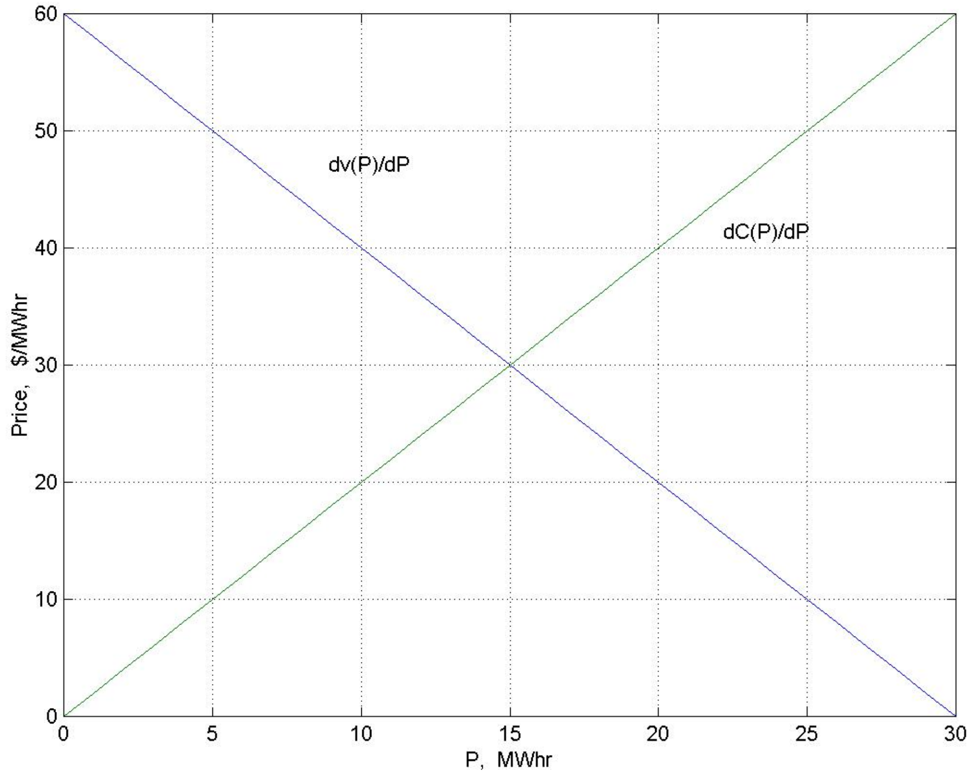

Fig. 1: Efficient Level of Output, *P*=15.

From Fig. 1, we can observe a graphical interpretation of the social surplus. It is the area enclosed by the triangle to the left. Fig. 2 illustrates this more clearly.

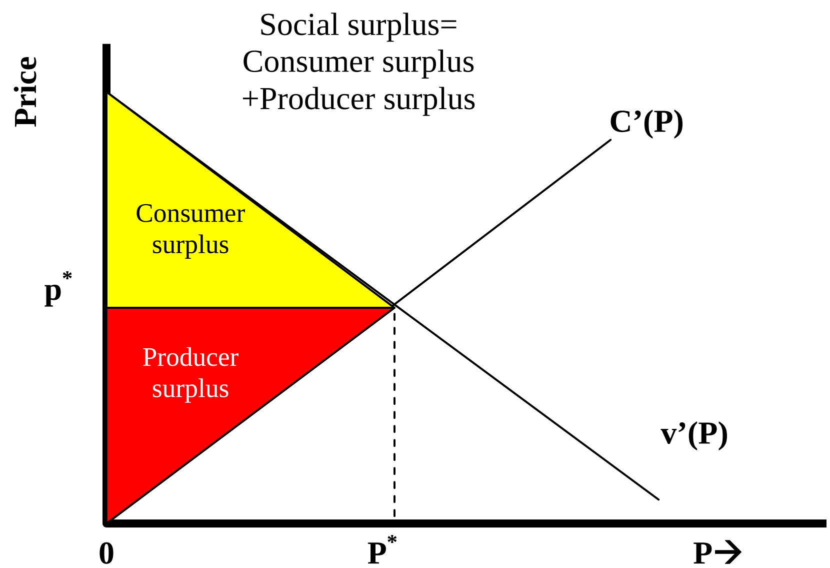

Fig. 2: Social Surplus

We note the social surplus of Fig. 2 is the sum of the two colored areas. Now as long as the BD chooses to produce P^* units of energy, s\he can redistribute social surplus in many different ways (after all, the BD does have authority to do it). Each way will be "good" in that the overall social surplus is maximized.

But, relative to the situation illustrated in Fig. 2, there are no ways the BD can improve the situation for the entire society, i.e., if the consumers are helped, then necessarily the suppliers are hurt. And if the suppliers are helped, then necessarily the consumers are hurt. The solution identified in Fig. 2 is, then, a Pareto-Optimal solution.

3.0 Competitive Equilibrium

The notion of the "Benevolent Dictator" is akin to the notion of the "Centralized Planner." Socialized societies such as those in place in communist countries are somewhat like that.

The monopolistic electric industry of the pre-1990's may also have been an industry with centralized planning attributes, and even today, of course, the centralized planner has a role to play in the delicate coordination required by our complicated machine called the electric power grid. The ISO largely plays this role, both in terms of operations and in terms of planning.

In capitalistic countries like the US, the laissez-faire[1] approach for most commodities lets the market set supply and demand with no interference. In this case, there is no BD attempting to optimize the output of the entire economy, but rather, there are a large group of players (call them "economic agents" or "market agents"), each of whom is simply trying to optimize their own particular situation. Buyers are trying to maximize their utility, and sellers are trying to maximize their profits.

[1] French for "let happen."

The question is, **how will the overall solution, or equilibrium, of this situation,** where individual agents are acting autonomously and strictly in their own self-interest (selfishly!), **compare to the equilibrium achieved by the BD**?

We consider the case where we have a single consumer and a single producer.

In the IntroEcon1 notes on consumer surplus, we saw that the consumer will respond to a market price *p* by buying an amount of energy *P* according to:

$$v'(P) = p \tag{14}$$

In the IntroEcon2 notes on producer surplus, we saw that the producer will respond to a market price *p* by selling an amount of energy *P* according to:

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

We have seen that the BD will see that the quantity and price established is (P^*, p^*), and that this quantity, price combination will maximize social surplus.

Suppose in the competitive market, that the price is $p_1 < p^*$. The situation would be as shown in Fig. 3.

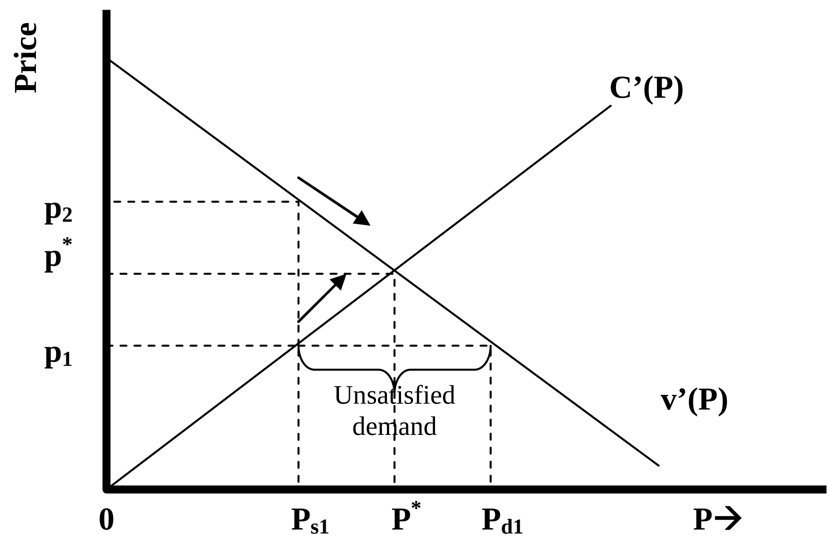

Fig. 3: $p_1 < p^*$

At the price p_1, the producer is producing P_{s1} and the consumer is buying this amount.

But the consumer would be willing to pay the higher price p_2 for this amount of energy, or, alternately, at a price p_1, the consumer wants to increase their consumption all the way to P_{d1}.

As the consumer makes it known that they want more energy, the producer reciprocates and produces more energy, yet to cover costs, the producer must raise the price.

These two things continue, the consumer buying more and more, and the producer producing more and more, with each increase at a slightly higher price than before. This trend is indicated by the arrows in Fig. 3.

However, when the price hits p^*, the consumer sees that the utility from any further increase in energy consumption will be less than the price to pay for that energy consumption.

Likewise, when the price hits p^*, the producer sees that the cost of further increase in energy consumption will exceed the present price that can be obtained for that energy, i.e., the producer will lost money.

And so the "system" of the consumer and the producer, settles in at the **equilibrium** (P^*, p^*).

Likewise, we can show that if the price is $p_2>p^*$, the consumer and producer will make adjustments so that the "system" arrives at this same equilibrium (P^*, p^*), according to Fig. 4 below. You should try and reason out how this occurs for yourself.

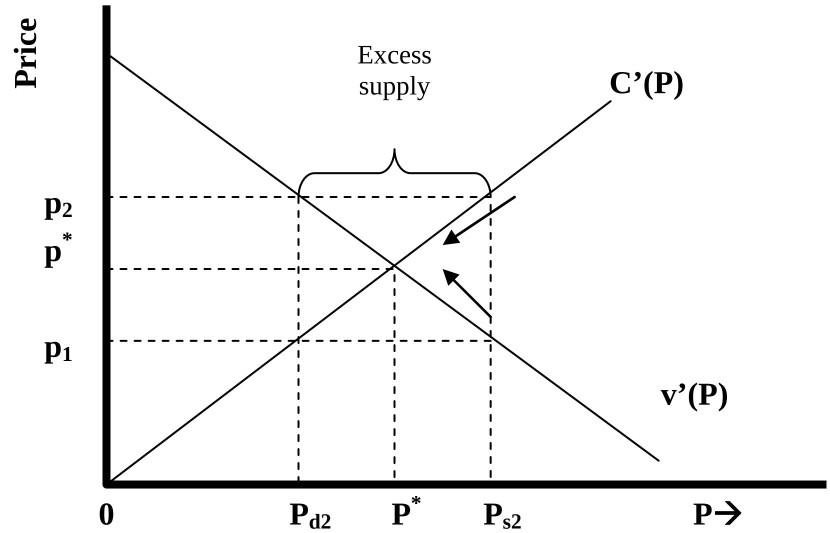

Fig. 4: $p_2 > p^*$

The point of this exercise is 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.

There are two issues that we should consider before we leave this topic.

- What happens when you have a number of market players as opposed to just two?
- What does it mean to have a market that is not "perfectly competitive" ?

4.0 Equilibrium with many agents

In our previous discussions, we have assumed just a single consumer and a single producer. We now want to consider the case where we have a very large number of consumers and a very large number of producers. Such is the case in our electricity markets.

To consider the simplest of these cases, let's look at the situation where we have two consumers and two producers. Once we see how we can extend our thinking to this situation, it will then be easy to see how it extends to the situation of the very large number of consumers and producers.

Each of our two consumers will have their own demand functions, which will result in a composite demand function, shown in Fig. 5.

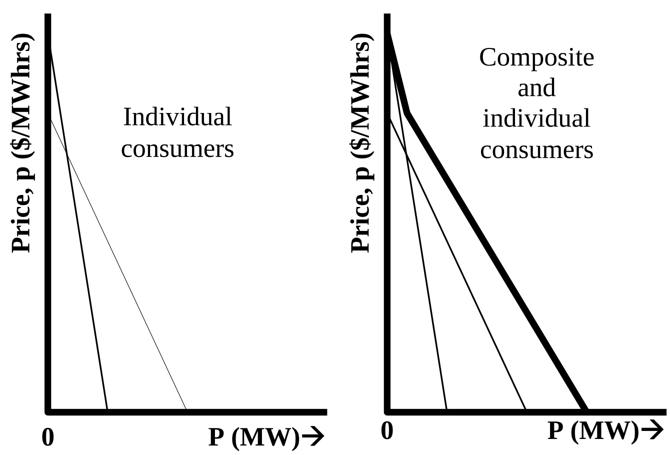

Fig. 5: Two consumers

The composite curve of Fig. 5 is obtained by adding the energy consumed from the two consumers for a given price.

Now we also consider the situation of having two consumers. Each will have their own supply function, which will result in a composite supply function, as shown in Fig. 6.

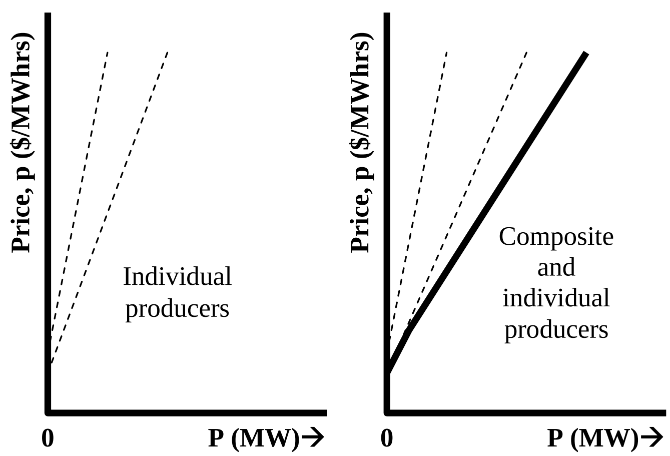

Fig. 6: Two producers

The composite curve of Fig. 6 is obtained by adding the energy produced by the two producers for a given price.

Figures 5 and 6 show that aggregation of consumers and producers curves result in two composite functions, and Figure 7 shows that these two composite functions may be treated in exactly the same way that we treated the one consumer, one producer situation.

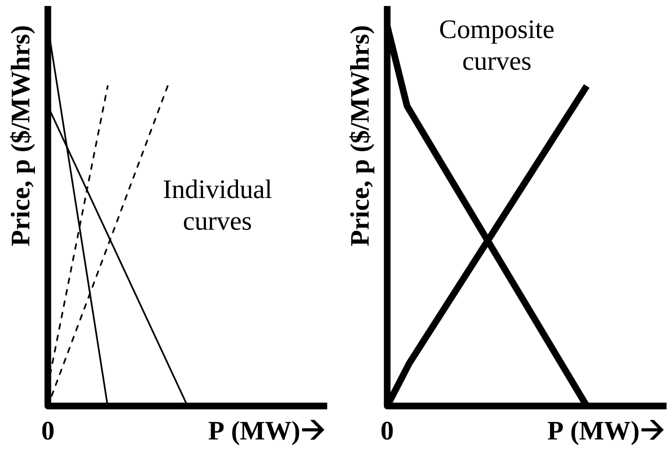

Fig. 7: Individual and composite functions

In conclusion, we see that we may characterize a situation of two consumers and two producers with a composite demand function and a composite supply function.

We may similarly characterize a particular *economy* of multiple consumers and multiple producers with composite functions.

Having large numbers of consumers and producers is one criterion for a healthy, competitive market. The notion of what is a healthy competitive market is important because one must be able to recognize attributes that would lead to an unhealthy market. This is the subject of the next section.

5.0 Perfect competition

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 [3]:

1. Numerous small producers and consumers
2. Homogeneity of supply
3. Freedom of entry and exit
4. Perfect information

We discuss each of these in what follows, concluding with comments on "price takers" and some examples.

5.1 Numerous small producers and consumers

Producers and consumers must be small relative to the size of the market. The production or consumption of any individual agent must comprise only a very small percentage of the total production or consumption. So changes in production or consumption by any one agent must have negligible effect on the total market supply or consumption and therefore have negligible effect on price.

5.2 Production homogeneity

All units of production from any producer must be identical. That is, each unit of production must be a perfect substitute for another unit. One unit must be indistinguishable from another unit. As a result, consumers have no preference regarding producer.

5.3 Freedom of entry and exit

Producers and suppliers must both be free to participate, or not participate in the market. There must be no barriers to enter or to exit 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.

5.4 Perfect information

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

5.5 Price taker [3]

Under perfect competition, each agent is a *price-taker*. This means 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 in a perfectly competitive market, there are so many agents, and the quantity bought or sold by any individual agent is a small fraction of the whole.

You may think of this in the following way. As we increase the number of consumers, adding the quantity each is willing to buy at each price, the demand function moves further and further to the right. A similar statement is true for the supply function. Figure 8 illustrates.

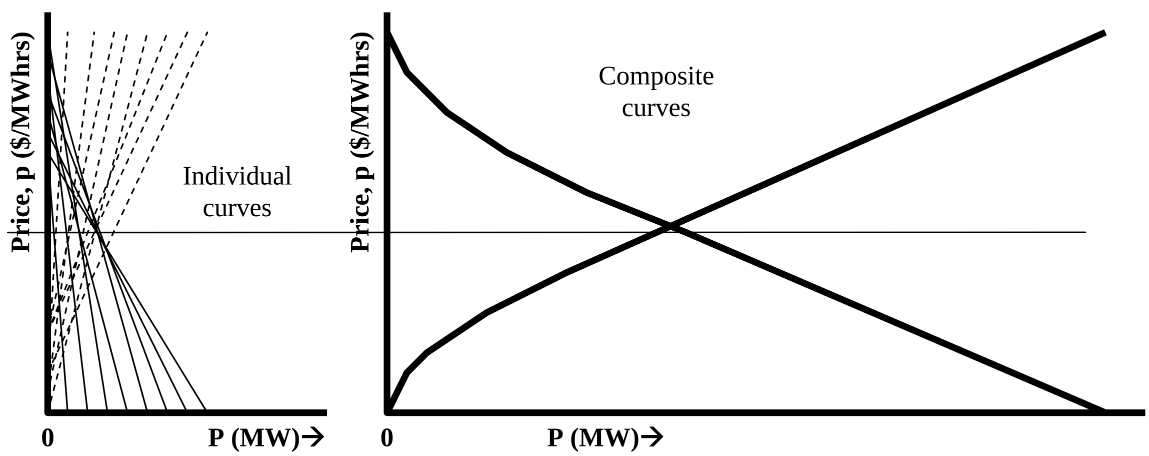

Fig. 8: Individual and composite functions

Note in Fig. 8 that as one moves from left to right, the slope of both curves moves towards zero, i.e., both curves become flatter. The curves are at their flattest at their intersection, which corresponds to the competitive equilibrium. Imagine if we had 20000 consumers and producers. In this case, the two curves would slopes so close to 0 at the competitive equilibrium that we could say there *are* flat.

This flatness at the competitive equilibrium implies that when one or even a few agents change their consumption or production in such a market, the price remains unchanged. It takes a very large number of agents to change their consumption or production in order for the price to change. This is the reason why, under perfect competition, all agents are called *price takers*.

5.6 Some market examples

There are very few markets that completely satisfy the perfect competition requirements. Examples of markets that come closest include:

- Common stock: There are millions and millions of buyers and sellers of GE stock, all shares are exactly alike, anyone can buy or sell them, and all relevant information is available in the newspaper.

- Corn farming: There are many farmers, corn is very similar, farmers can switch into it or out of it, and there are many publications with information.

6.0 Falling short of perfect competition

The three most important ways that markets can fall short of perfect competition are [1]:

- 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.

7.0 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 the websites are clearly accessible to all, there can be 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, it 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, or the exercise of a group of participants' collective market power.

- At best, it gives companies the ability to unfairly increase profits.

As a result, FERC requires ISOs to have a market monitoring function, and a number of ISU students have been hired into groups responsible for this function.

The California crisis of 2001 provides good illustrations of agent behavior that is or at least borders on use of market power. I have placed an excellent paper on the web site that describes the California crisis in some detail [4]. Although this paper is written by attorneys and is quite long (80 pages), it is of value to us for three main reasons:

- Readability: It is written in relatively plain language, avoiding overuse of legal and technical jargon. Its length is hugely exacerbated by the detailed footnotes provided which you can ignore.

- History: It provides an excellent summary of the history of the electric power industry, beginning with its inception, relating that history to the developments in California (Section I: A, B). It also details exactly what happened in California that led to the 2001 crisis, a historical event in itself that is worth understanding (Section I: C).
- Market architecture: It well summarizes the architecture of the market employed in California before the 2001 crisis. This market contained features that are similar to the markets of today and therefore provides a tangible illustration of electricity market attributes (Section I: C). Of course, this market also had some significant problems, and in that sense, the paper provides a tangible illustration of what to not do (Section III).
- Economic principles: It lays out some of these same basic economic principles that we have described, and discusses how they are operable within electricity markets, and it identifies some of the unique difficulties in their operability (Section II).
- Market power: It describes how market power may be exercised within electricity markets (Section III-I).
- Antitrust laws: It summarizes the various laws designed to restrict agents within the electric power industry from exercising market power (Section IV).

- More market power: It describes the ways that companies, particularly Enron, attempted to manipulate prices in California (Section IV: A, B, C).
- FERC's SMD: It summarizes the elements of FERC's standard market design which discusses means to address the market power abuses previously described (Section V). And so I have provided a homework assignment to read this paper. See website.

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[1] P. Samuelson and W. Nordhaus, "Economics," 17th edition, McGraw-Hill, 2001.

[2] A. Dillingham, N. Skaggs, and J. Carlson, "Economics: Individual Choice and its Consequences," Allyn and Bacon, 1992.

[3] W. Baumol and A. Blinder, "Economics: Principles and Policy," Dryden Press, 1994.

[4] 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.