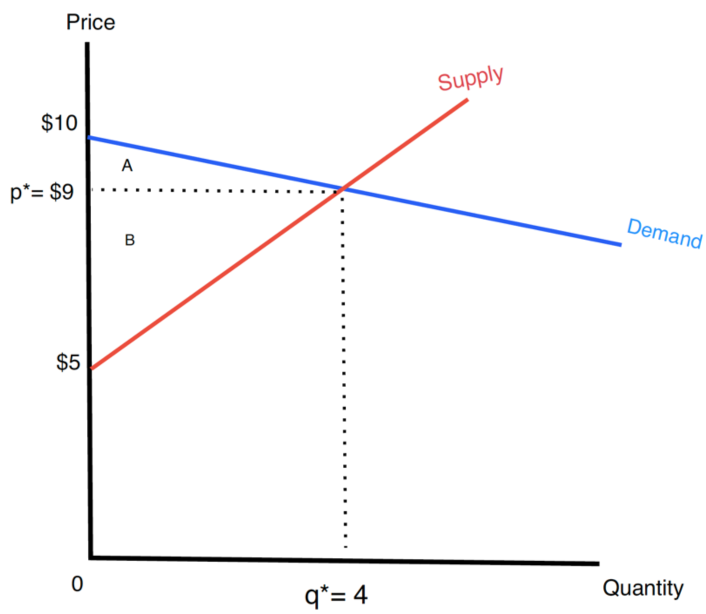
Intro to Markets: Supply & Demand Calculation Basics

Consider the market for craft beers in Brooklyn on a Saturday night. Quantity demanded (which is ***elastic*** or "flexible" in this example) is given by the equation $\mathbf{Q_D = 40 - 4p}$ and quantity supplied is given by $\mathbf{Q_S = p - 5}$.

We can solve this two different ways: by setting $\mathbf{Q_S = Q_D}$ and then solving for $\mathbf{p}$, or by re-organizing these equations to obtain $\mathbf{P = 10 - Q_D/4}$ for demand and $\mathbf{P = Q_S + 5}$ for supply. In market equilibrium (the one point where the supply curve and demand curve intersect) the price will be the same for both and the quantity will be the same for both. Solving either of the sets of equations above, we will obtain the **equilibrium quantity** ***q*= 4*** and **equilibrium price** ***p*= $9*** for this market.



One way to think about these equations intuitively is observing that this directly implies the first person buying a beer is willing to pay $9.75 or less for it, and the second person is willing to pay at most $9.50, the third is willing to pay at most $9.25, the fourth potential buyer is willing to pay at most $9.00, and the fifth potential buyer is only willing to pay $8.75 or less. On the seller side, the first supplier is willing to sell for $6 or more, the second would sell for $7 or more, the third would sell for $8 or more, the fourth seller would agree to sell for $9 or more, and the fifth potential seller would only agree to sell for $10 or more. There are more consumers willing to buy beers for less than $9 and more producers willing to sell beers for above $9, but only people with a WTP **(willingness to pay)** of at least $9 will actually purchase a beer. Only producers with a WTS **(willingness to sell)** below or equal to $9 will sell. When everyone willing to buy at or above price p* is able to buy and everyone willing to sell at or below p* is also able to sell, then *"the market clears".* The basic intuition of markets is extremely similar to that of international trade: exchanges or transactions will only occur when both sides benefit from it.

The difference between the WTP and market price represents "***consumer surplus"*** for a buyer, who is happy to obtain an item for less than the value they place on it. The difference between the WTS and market price represent "***producer surplus***" for the seller. The total consumer surplus in this market (area of triangle A) is obtained by calculating [½ * base * height] = [½ * 4 * ($10 – $9)] = **2.** The total producer surplus in this market (area of triangle B) is [½ * 4 * ($9 - $5)] = **8.**

Notice that consumer surplus is relatively small and producer surplus is relatively larger in this example: this is due to the fact that the demand shown here is *elastic* since consumers are very flexible with so many options for purchasing drinks in Brooklyn on a Saturday night. When these transactions occur, the buyer is paying almost as much as her "true maximum willingness to pay" (only at most a dollar more than the market price) but the first seller would have been willing to agree to a sale for any price at or above $6 ... the supply curve here is steeper (more inelastic) so the sellers capture more relative benefit in this market. (Note that if there was a tax on the transaction, then these inelastic sellers would incur more of the loss than the highly flexible buyers who might go drink wine instead…)

The slope of the demand curve represents the ***price elasticity of demand*** (responsiveness in quantity demanded to price changes) and is defined mathematically as the percentage change in quantity demanded divided by the percentage change in price. The ***price elasticity of supply*** (responsiveness in quantity supplied to price changes) is mathematically defined as the percentage change in quantity supplied divided by the percentage change in price.

Supply curves are more ***inelastic*** (or "inflexible", where quantity supplied is less responsive to changes in the market price) when inputs are hard to get or when it is not easy to adjust the scale of operations. There is almost never a real scenario with *perfectly elastic supply* (this would be a totally horizontal supply curve with a slope of 0) but in general a supply curve will be more elastic when it is easy to adjust the business operations for output changes, generally meaning easier to expand production in response to a price increase in order to quickly sell more goods on the market.

Demand curves are more **inelastic** (quantity demanded is less responsive to changes in the market price) in the case of *inflexible* preferences: examples would be addictive substances, essential medications, energy and critical infrastructure, and a variety of things that do not have substitute products easily available…

Shifts in supply and demand curves are driven by a "shock" or sudden unanticipated change to the market conditions. **If consumer preferences change, then demand will shift**. If consumer utility functions for avocado change and avocado is expected to bring them more utility than before, then demand for avocados will shift out, which will result in a higher equilibrium price and quantity. If it is announced that protein powder is suspected to cause stomach cancer, then consumer utility functions would change since they suddenly place less value on protein powder, and this would shift the demand for protein powder inwards, reducing the equilibrium price and quantity.

If the availability of inputs or the cost or difficulty of production change, then supply will shift. Taxes directly on inputs of production and stricter regulations on a product generally shift the supply curve left, and this reduction in supply raises the equilibrium price and decreases the equilibrium quantity. Intuitively, the way to understand this is to imagine that some firms will stop producing and do something else if the conditions become less favorable. Increases to costs of production are often "shifted onto consumers" as producers raise prices and reduce output.

Determinants and Logic of Supply & Demand: Covid Vaccine Example

Let's look at the US market for Covid vaccines. First let's suppose random person R's utility function for vaccines is given by $\mathbf{U_R(v) = -v^3 + 3v}$. We can determine the optimal consumption amount for person R with a standard utility optimization approach. In this case, we should assume vaccines are not a divisible good and we cannot consume negative amounts, so we start with zero and try positive integers until we find the highest utility value:

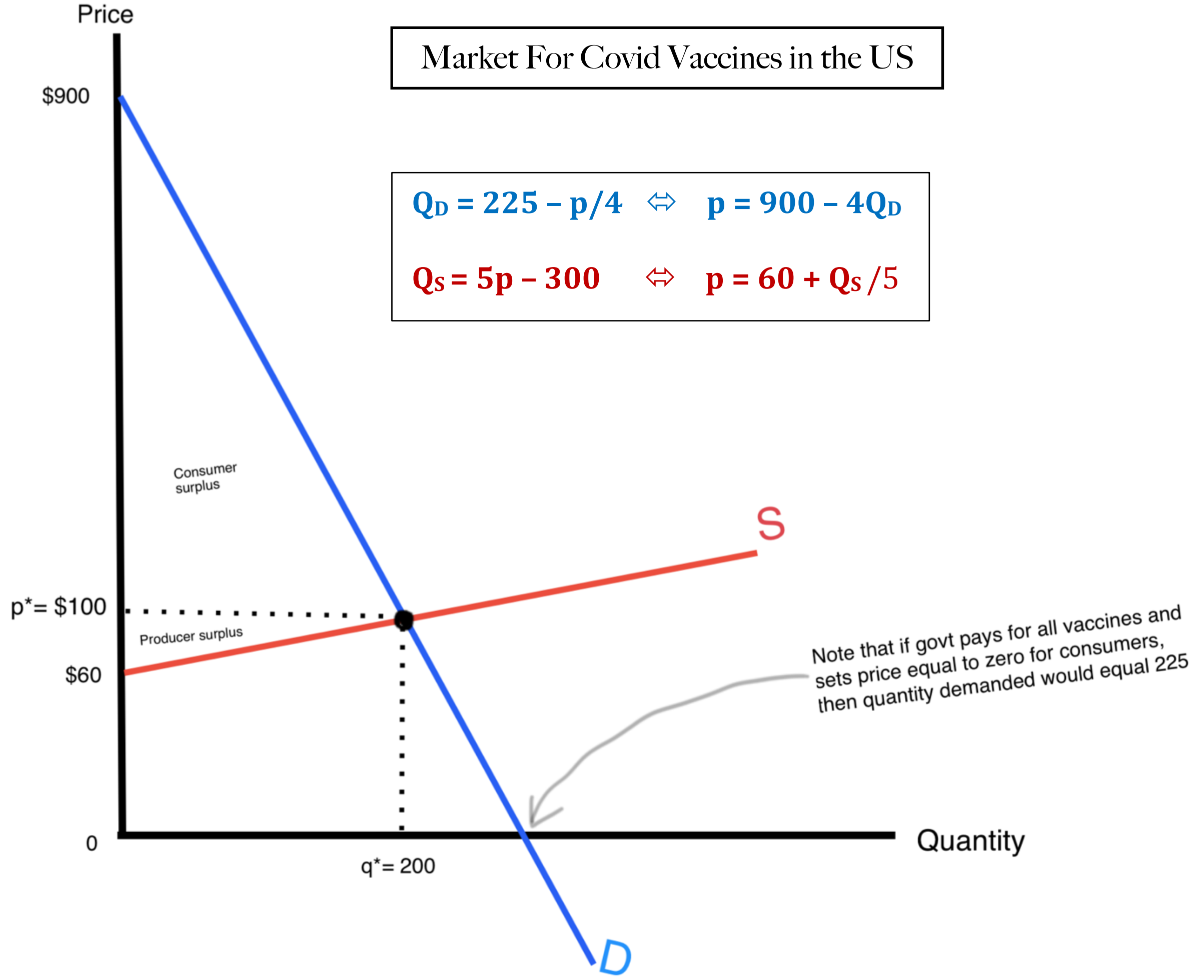
$U(0) = -(0)^3 + 3(0) = 0$
$U(1) = -(1)^3 + 3(1) = 2$
$U(2) = -(2)^3 + 3(2) = -2$
$U(3) = -(3)^3 + 3(3) = -18$

The optimal number of vaccines to consume is 1 for each person, maximizing utility at 2 "util" units. In reality, different people obviously have different utility functions for vaccines and for money… so there are very different levels of willingness to pay for vaccines throughout the population. Even if everyone did have the same utility function from vaccine consumption, differences in utility over money could drive disparities in the amount of dollars that different people are willing to trade for a vaccine. Someone who is more cautious or in a more vulnerable health situation would probably get more relative increase in their utility from a vaccine and therefore probably be willing to pay more. With different values placed on vaccines by different people, we get a demand curve: a "schedule" of different "willingness to pay" points for all of the potential consumers.

Now let's look at the structure of this market… ***Vaccines have highly inelastic demand*** because they are very important for staying healthy and getting past restrictions in society. This means people are "inflexible" with their need for the product, and more formally, inelastic demand specifically means that there is low responsiveness of quantity demanded to price. Even if the price of an inelastic good increases a large amount, the quantity demanded will only decrease a small amount.

On the supply side, we must first think about the reasoning of a producer/firm. Vaccines require a large amount of upfront ***fixed costs*** for expensive facilities and lab equipment to work with dangerous pathogens and chemicals. These costs are all incurred before a single vaccine can be sold. Once the first vaccine is made successfully, the *variable cost* of producing many more is relatively small: a graph of cost plotted over quantity produced would look extremely similar to the red supply curve we will use for this market. This is not a coincidence: ***the vaccine supply curve is elastic*** because of the cost structure of their production. There would be no production at all (q=0) if the market price was expected to be less than $60 in this example because the firm would not be able to generate any profit. As soon as there is one vaccine successfully created and ready for sale, however, it is cheap and easy to make many more, so the producer will have a very high responsiveness of quantity supplied to price. Looking at the diagram, we can see that if price was a little higher then the corresponding quantity value for the supply curve, representing the willingness to sell (WTS), would be much higher. This indicates that for a small price increase, producers will want to sell a lot more of the product. Tech products like software are similar in this regard and also generally have highly elastic or "flexible" supply curves. Customized products or expert services, for example, are more likely to have a less responsive "inelastic" supply curve as the willingness to sell more is inflexible: selling more units in that case substantially increases costs, so the WTS is not as responsive to price changes.

If we set the units in quantity to be *millions* of vaccines, then this supply & demand diagram is an accurate depiction of the real world, except at least 225 million Americans got vaccinated instead of the 200 million calculated in our equilibrium here. This is the result of our federal government using tax dollars to pay for all of the vaccines, making them "free" for all consumers. While technically the taxpayers are always indirectly paying for everything, the market price is now set to equal zero for all potential vaccine consumers. This means nobody will ever include any financial component in their utility function in making a decision about whether or not to consume a vaccine. The government's intention when implementing this policy was obviously to incentivize people to get vaccinated and increase the public's degree of protection from the virus. This policy also eliminates various inequality issues that would otherwise occur with a natural free market for vaccines! People who are situated to the right of the equilibrium point on the demand curve have a lower willingness to pay (WTP), which is likely to be correlated with poverty and other factors which might actually worsen the consequences of getting sick with Covid. Making the vaccines free, using the numbers in this example, allowed 25 million more people to get vaccinated compared to the equilibrium quantity in a free market.



In many examples of utility maximization problems we saw that people usually choose to consume more of something when it is free. If this was a market for shoes where consumers had monotonically increasing utility from shoes, then they would always want more and more… so any policy of making them totally free would never work because this infinite demand for free shoes would always be greater than zero. If everyone's vaccine utility function is some form of inverse parabola maximized at v=0 or v=1, then no one would never choose to consume more than one free vaccine because it would actually reduce their utility to do so.

The points below zero on the demand curve represent people with a *negative willingness to pay* for vaccines: these people actually need to be given money in order to get a vaccine. Governments in fact implemented policies to do exactly that because of the ***positive externalities*** associated with vaccination, such as the reduced future expected healthcare costs for society, a reduction in the spread of the disease to other people, and a reduction in expected constraints on the economy and healthcare system. The market is inefficient if there are externalities that are not addressed: individuals generally do not adequately account for these positive effects on others from vaccination since they do not directly individually benefit. For society overall, it is good to reduce hospital congestion and the possibility of conditions in old age which the government would have to pay for via Medicare (which insures most Americans over age 65)… individuals may fail to think about these things. One way to conceptualize that is a failure to include these benefits in the individual's utility function. The government should be willing to pay people some amount to get the vaccine to account for the value of positive externalities: precisely up to the point where the overall benefits of vaccination for society are equal to the costs of the vaccine plus compensation for the individual who does not want it.