Bilkent University
Econ 101 - Fall 2023
Chapter 8: Competitive Equilibrium

A. Arda Gitmez Nuh Aygün Dalkıran

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Contents

This chapter brings everything we built together; namely, the *demand* and *supply*. We consider a market for a particular good, and study the equilibrium of this market. As you know by now, a market is an infrastructure that facilitates the interaction of economic agents. In a simple consumption/production setup, it facilitates the trade of a certain group of buyers and sellers in a certain amount of time for a certain good.

We will consider a *perfectly competitive market* for consumers and producers. As I discussed previously, a **perfectly competitive market** is the one where no participant in the market has the ability to affect the price. Therefore, every consumer and producer is a **price-taker**.

1 Competitive Equilibrium

Let's recall what we had in Chapter 1: broadly speaking, equilibrium is **the situation in which every agent is optimizing, so nobody would benefit personally by changing her behavior, given the choices of other agents**.

Now we are considering the equilibrium of a perfectly competitive market, and **competitive equilibrium** is just the equilibrium of this market. I will just tailor the broad definition so that it applies to this market.

Definition 1. *The* **competitive equilibrium** *of a market is a price P^{eq} and quantity traded Q^{eq} such that:*

1. *Given P^{eq}, each consumer in the market chooses the optimal quantity to demand.*
2. *Given P^{eq}, each producer in the market chooses the profit-maximizing quantity to supply.*
3. *The total quantity demanded is equal to the total quantity supplied at Q^{eq}, i.e. the market clears.*

Let's go through it step by step:

1. When every consumer chooses the optimal quantity, the aggregate behavior of consumers in the market is represented by the *demand curve*.
2. When every producer chooses the profit-maximizing quantity, the aggregate behavior of producers in the market is represented by the *supply curve*.
3. Therefore, we must have a demand curve and a supply curve. Moreover, the consumers and the producer face the same price P^{eq} and, moreover, the quantity supplied is equal to the quantity demanded. Therefore, the competitive equilibrium is just the **intersection of demand and supply curves.**

All in all, we have the Figure 1 illustrating the competitive equilibrium. This is it. This is the infamous figure. This is the one that comes up when you Google "Econ 101".

A couple of notes:

- This is sometimes also called the "free market" equilibrium.
- Some sources denote is with (P^*, Q^*). Some others denote it with (P^{CE}, Q^{CE}). We denote it with (P^{eq}, Q^{eq}). They all stand for the same thing.

1.1 The Single Price

One question you may ask at this point is: how come is there a single price for all the consumers and producers? After all, there are many consumers and producers in the market who are all trading with each other; how come we ensure that they all conduct the trade at the same price?

The very brief answer to that question is: ¯_(ツ)_/¯. We don't know, they somehow converge on a single price. This is the part of the model we do not really specify at the Econ 101 level.

- Maybe there is a huge message board that shows the price of each transaction (think of Wall Street).
- Maybe this is an online marketplace where people can search for other buyers and sellers easily, thereby forcing the sellers to post the same price (think of Hepsiburada).

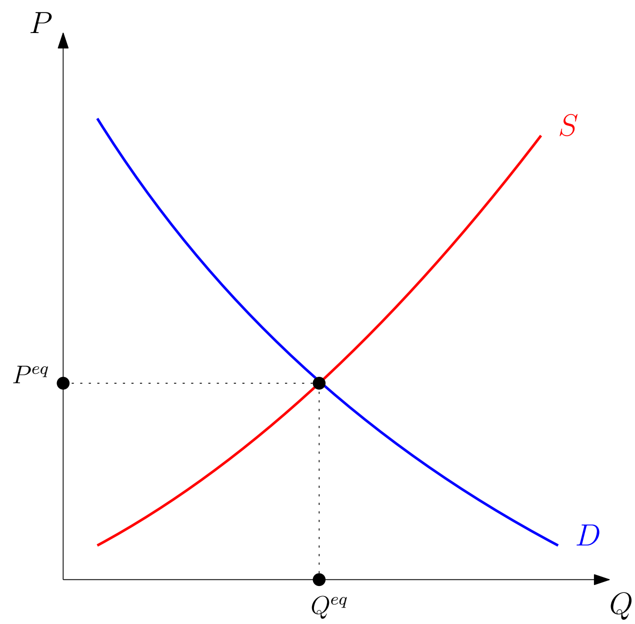


Figure 1: Competitive Equilibrium

- Maybe there are a few people who search for multiple sellers extensively and inform other consumers about the prices at different alternatives, thereby making sure the prices remain close to each other (think of my dad, or basically any retired relative of yours who spends all the Wednesday on finding the cheapest white cheese in the whole city).
- Presumably, buyers and sellers just communicate and exchange information with each other. In such cases, introduction of new communication technologies play a huge role in bringing prices closer.

  I am posting an article to Moodle, titled:

  > Jensen, Robert. "The Digital Provide: Information (Technology), Market Performance, and Welfare in the South Indian Fisheries Sector " *Quarterly Journal of Economics* 122. 3 (2007), pp. 879-924.

  This is a paper that investigates the introduction of cell phones to some fisheries in Southern India. Figure 2, taken from the paper, is one of the most remarkable figures in economics.

I want to point out an important, possibly confusing, part of a competitive market model. Who sets the price in a competitive market? The answer is: "No one, because this is a competitive market. But also, at the same time, everyone, collectively." As you can see, we imagine market as an aggregate monster who somehow decides on a price as a result in gazillions if tiny communications, and everyone obeys that price. This is the "invisible hand" of Adam Smith at work, choosing how much trade there will be and between whom by deciding the price. As I said, this process of price discovery is beyond the scope of Econ 101.

1.2 Shortage and Surplus

Now that we convinces ourselves of a single price, the next question is: how come is the quantity demanded equal to the quantity supplied?

- Suppose quantity demanded is larger than quantity supplied. This happens when the market price is lower than P^{eq}, such as P_2 in Figure 3. In this case, a lot of consumers cannot find the good they are willing to consume at price P_2. But then, some consumers would find some producers and start offering them higher prices in the hope of getting the good. This will drive the market price up, increasing the quantity supplied and decreasing the quantity demanded. The process will end when

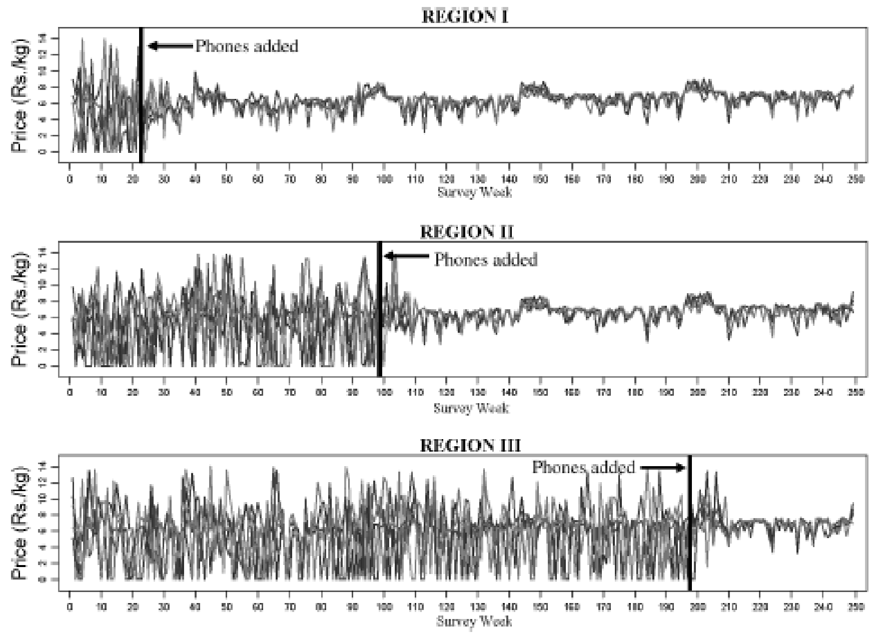


FIGURE IV
Prices and Mobile Phone Service in Kerala
Data from the Kerala Fisherman Survey conducted by the author. The price series represent the average 7:30–8:00 A.M. beach price for average sardines. All prices in 2001 Rs.

Figure 2: Figure IV of Jensen (2007)

they equalize each other.

- Suppose quantity supplied is larger than quantity demanded. This happens when the market price is higher than P^{eq}, such as P_1 in Figure 3. In this case, a lot of producers cannot find the consumers to sell the goods. But then, some producers would start offering lower prices to be able to sell the good. This will drive the market price down, decreasing the quantity supplied and increasing the quantity demanded. The process will end when they equalize each other.

1.3 An Example

Consider a perfectly competitive market, where the market supply is given by

$$Q^S = 10P - 100 \tag{1}$$

This is the equation for **supply curve**. It says: if the price producers face is $P = 10$, they supply a quantity of $Q^S = 10 \cdot 10 - 100 = 0$. Beyond this price, for every unit increase in price, the quantity supplied increases by 10 units.

The market demand is given by

$$Q^D = 200 - 5P \tag{2}$$

This is the equation for **demand curve**. It says: if the price consumers face is $P = 0$, they demand a quantity of $Q^D = 200 - 5 \cdot 0 = 200$. For every unit increase in price, the quantity demanded increases by 5 units.

Let's start by finding the competitive equilibrium price and quantity. There are two methods for doing this, both are equally valid.

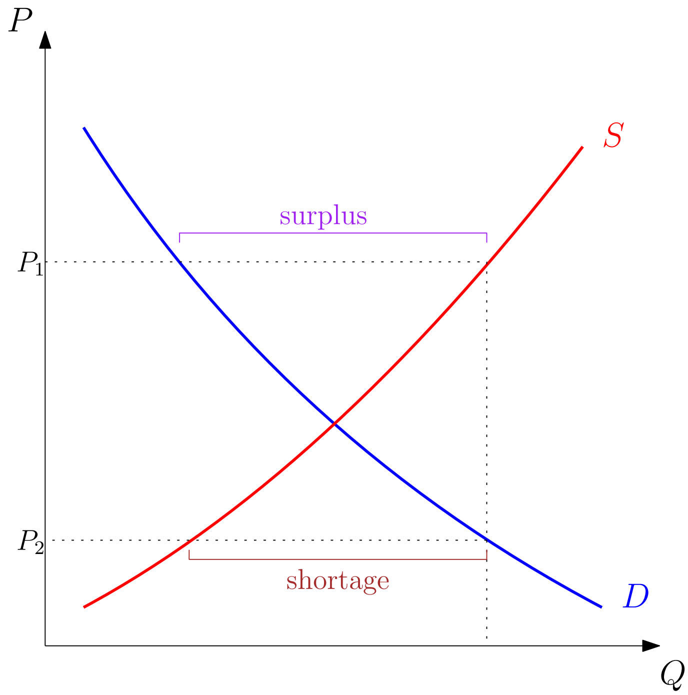


Figure 3: Shortage and Surplus

1. The straightforward method uses the following idea. We know that, in a competitive equilibrium, consumers and producers face the competitive equilibrium price, i.e., $P = P^{eq}$. Therefore, Equations (1) and (2) can be written as:

$$Q^S = 10P^{eq} - 100$$
$$Q^D = 200 - 5P^{eq}$$

   We also know that markets clear in a competitive equilibrium. That is, there is no shortage or surplus, and quantity demanded equals quantity supplied. Therefore, $Q^S = Q^D = Q^{eq}$. Using the equations above, this implies:

$$10P^{eq} - 100 = 200 - 5P^{eq} \implies P^{eq} = 20$$

   To find the equilibrium quantity, you can use the supply equation or demand equation – they will give the same answer by construction. Let's use the supply equation. Then,

$$Q^{eq} = 10P^{eq} - 100 = 10 \cdot 20 - 100 = 100$$

   If we used the demand equation instead, we would have

$$Q^{eq} = 200 - 5P^{eq} = 200 - 5 \cdot 20 = 100$$

   In any case, we find $P^{eq} = 20$ and $Q^{eq} = 100$.

2. An alternative way to find the competitive equilibrium price and quantity is to find Q^{eq} first and then P^{eq}. Needless to say, this will give the exact same answer, through a slightly longer path. To do this, we write the supply and demand equations in a way that looks like P is a function of Q, rather than the other way around.

   Take the equation for supply curve (1) and rearrange it to get:

$$P = 10 + \frac{Q^S}{10} \tag{3}$$

This is the equation for what we call an **inverse supply curve**. ("Inverse" because it now looks like P is a function of Q^S. Of course, we know that nothing is a function of another: both the supply curve and the inverse supply curve are just a list of (P, Q^S) that constitute the optimal decisions of producers.) The inverse supply curve says: to produce a quantity $Q^S = 0$, the producers ask for a price of $P = 10$. For every extra unit of quantity supplied, the producers ask for $\frac{1}{10}$ extra units of price. This is because the marginal cost of the marginal producer increases linearly in Q^S with a slope of $\frac{1}{10}$.

Similarly, take the equation for demand curve (2) and rearrange to get:

$$P = 40 - \frac{Q^D}{5} \tag{4}$$

This is the equation for an *inverse demand curve*. It says that the marginal benefit of the consumers for Q^D'th unit is $40 - Q^D/5$.

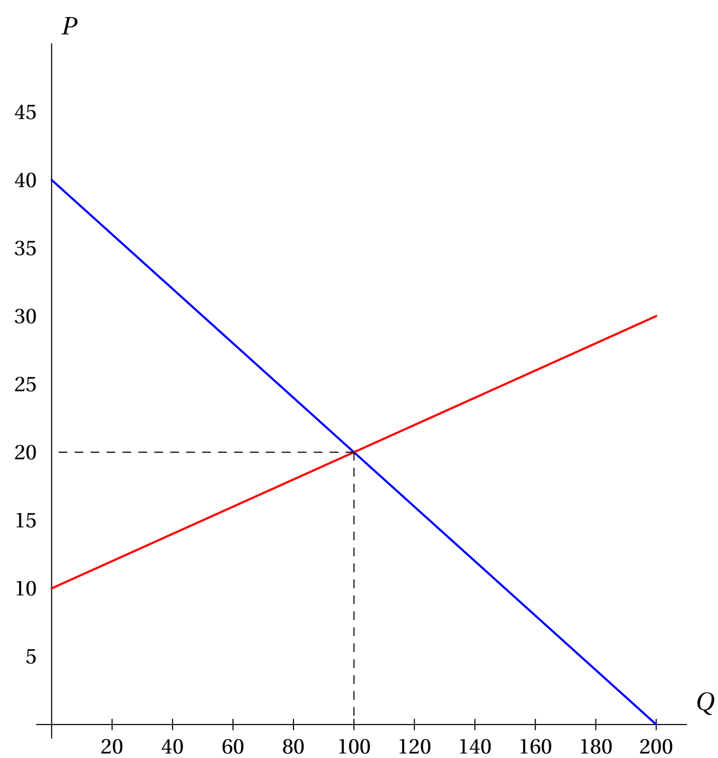
Now, using $Q^S = Q^D = Q^{eq}$ and $P = P^{eq}$ and substituting into (3) and (4) yields:

$$10 + \frac{Q^{eq}}{10} = 40 - \frac{Q^{eq}}{5} \implies Q^{eq} = 100$$

and

$$P^{eq} = 10 + \frac{Q^{eq}}{10} = 20$$

Now, let's draw the graph corresponding to the competitive equilibrium by drawing the curves. (And this is the reason why deriving the equations for *inverse supply* and *inverse demand* curves may be a good idea, because the curves are easier to draw when you have those equations.) See the figure below.



2 Structural Changes in the Economy

Here comes the fun part: what happens to the equilibrium price and quantity if there are some structural changes in the economy (so that demand or supply curves shift)? We can conduct a graphical analysis of these cases. I will show a few examples here, but the general insight is that you can "mix-and-match": you have shifted demand and supply curves separately, now the only thing to be added is showing them on the same graph.

2.1 Case Study: Fracking

Natural gas extraction is a challenging and difficult process. In mid-to-late 2000s, the industry has perfected a method called hydraulic fracturing ("fracking") to extract natural gas and crude oil from resources. According to BBC,[1] "Fracking is the process of drilling down into the earth before a high-pressure water mixture is directed at the rock to release the gas inside. Water, sand and chemicals are injected into the rock at high pressure which allows the gas to flow out to the head of the well." It is still a controversial technology because its environmental impacts are yet to be figured out.[2] Still, the use of fracking in the United States has increased tremendously since 2007.

The effect of fracking on the price and quantity of natural gas can be illustrated on a graph. Fracking is a "technological breakthrough", which leads to a southeastern shift on the supply curve. Presumably, it does not have any significant effects on the demand. Then, the new intersection of supply and demand curves will be to the southeast of the old intersection. That is, the price of natural gas will decrease and the quantity traded will increase. See Figure 4: the supply curve shifts from S to S'. As a consequence, the equilibrium price reduces to $(P^{eq})' < P^{eq}$ and the equilibrium quantity increases to $(Q^{eq})' > Q^{eq}$.

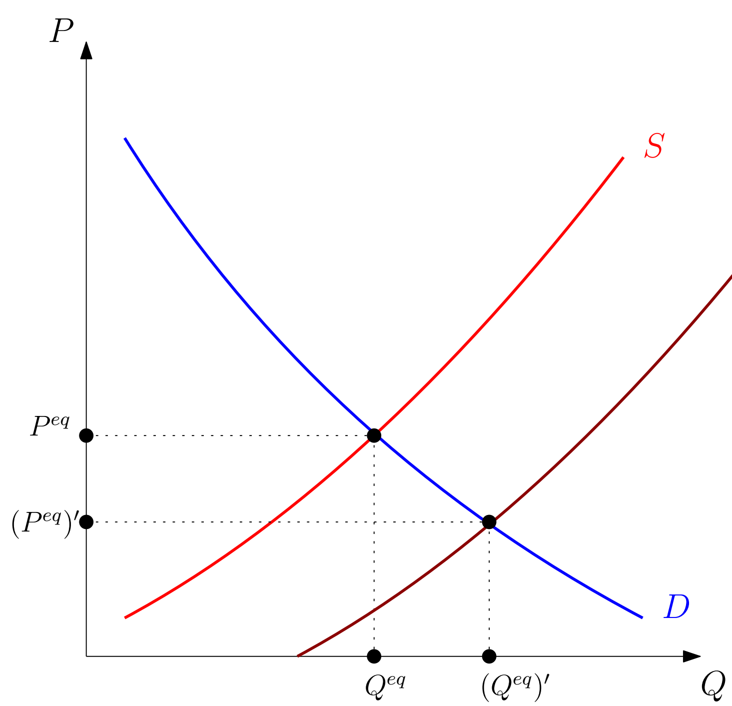


Figure 4: Effects of fracking on the market for natural gas.

Does this argument has merit? Looks so. Figure 5 plots the natural gas prices (in dollars) since 1997. Note the stable trend of declining prices after 2007!

Moreover, Figure 6 plots the production of natural gas in the United States (which proxies for quantity traded). Note the uptick since 2007!

[1] https://www.bbc.com/news/uk-14432401

[2] https://www.nationalgeographic.com/environment/article/how-has-fracking-changed-our-future

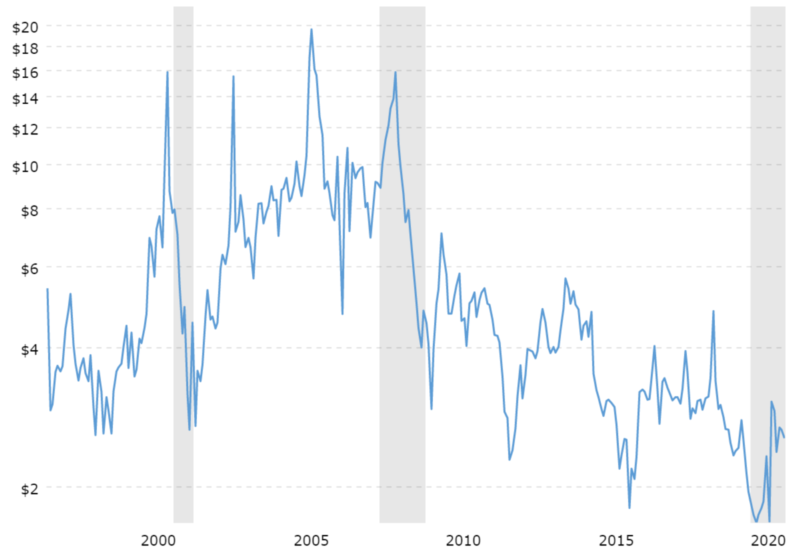


Figure 5: Natural Gas Prices

2.2 Case Study: Ridesharing

Uber is a ridesharing platform which brings people looking for a ride (consumers of a ride) and people who are willing to provide a ride (producers of a ride) together. For all purposes of Econ 101, this is a market for ridesharing. It is a brilliant example of a modern marketplace, and one that gets economists very excited (it is very unfortunate that it doesn't exist in Turkey in the manner it exists elsewhere).

One interesting bit about Uber is that, unlike many competitive markets, the price-setting mechanism is pretty transparent. Basically, at any point in a particular location, Uber sets the price of a ride between the consumer and the producer. Uber's objective while setting the price is ensuring that the market clears. This suggests the existence of an interesting laboratory where we can test the principles of Econ 101.

Suppose, for instance, that there is a sudden increase in the number of consumers in a certain location. This may happen, for instance, in national holidays, when a match or concert ends, around 5pm on a workday, etc. We can represent this with a northeastern shift in the demand curve. See Figure 7: the demand curve shifts from D to D'. As a consequence, the equilibrium price increases to $(P^{eq})' > P^{eq}$ and the equilibrium quantity increases to $(Q^{eq})' > Q^{eq}$. In practice, to match the increase in quantity demanded, Uber increases the price of a ride. This attracts more drivers to the market, thereby increasing the quantity supplied and preventing shortage. The procedure of charging high prices during times of high demand is called "surge pricing."

Can we see these ideas in action? Of course. The following examples are taken from a discussion paper I am posting to Moodle.

> Hall, Jonathan, Cory Kendrick and Chris Nosko. "The Effects of Uber's Surge Pricing: A Case Study".

Hall, Kendrick, and Nosko consider a particular example of a sudden shift in demand: the end of a sold-out Ariana Grande[3] concert in Madison Square Garden on March 21, 2015. As you can imagine, by the end of the concert (roughly 10:30pm), there was a huge spike in the ridesharing requests. See Figure 8.

To match the increase in demand, Uber started surge pricing: the time where surge pricing applies is illustrated with the yellow region in Figure 8 (between 10:30pm and 11:45pm). You can imagine that high prices will attract more drivers, and thus the quantity supplied will increase. This is illustrated in Figure 9.

[3] QWEEN.

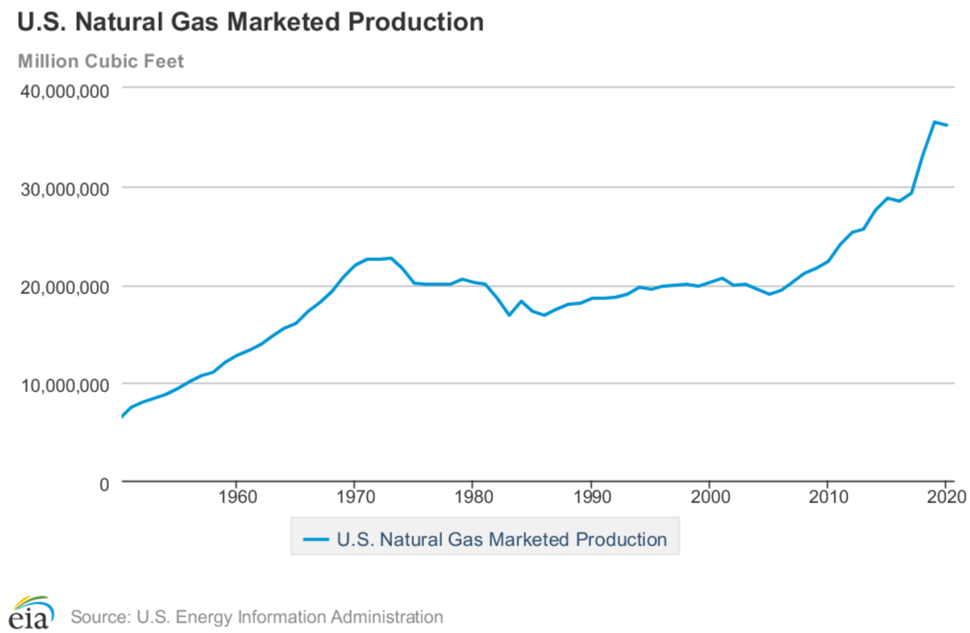


Figure 6: Natural Gas Production

The increase in supply matches the increase in demand in equilibrium, so that the completion rate remains at 100% even though ridesharing requests almost double. In other words, market clears as a result of surge pricing. See Figure 10.

2.2.1 Shortage in a Ridesharing Market

What happens if Uber fails to set the market-clearing price? This happens, for instance, when the Uber algorithm "forgets" about the increase in the number of consumers and keeps charging the usual price for a ride. The end result will be a **shortage** as we discussed before. See Figure 11. In this figure, the demand shifts from D to D'. When Uber keeps charging the old price P, the quantity demanded Q^D is larger than quantity supplied Q^S, which results in a shortage. As a consequence, many riders will not be able to find a ride (which, take my word for it, is a very frustrating experience).

We actually have an example for such shortage! During New Year's Eve in 2015' Uber's pricing algorithm had a glitch, which resulted in a "surge outage" for 26 minutes. That is, Uber kept charging the "usual price" to the consumers and producers instead of the higher price. See Figure 12.

The resulting shortage due to this glitch led to a dramatic decrease in the completion rate, which went below 20% during the surge outage. This is illustrated in Figure 13.

2.3 Application: Market for Corn

You may actually go one step further and think about structural changes that affect both demand and supply curves. Consider, for instance, a city that primarily produces and consumes corn. Suppose, due to some policy that mandates the increase in minimum wage, the wages in the city increases. This will affect both curves.

- On the demand side, the demand curve will shift because consumers' income increases. If corn is a normal good, this will lead to a northeastern shift in the demand curve.
- On the supply side, the cost of a vital input in the corn production (labor) increases. This will lead to a northwestern shift in the supply curve.

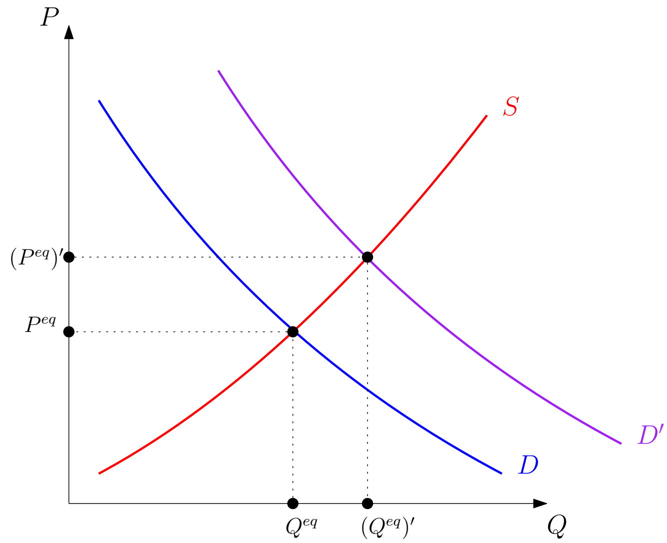


Figure 7: Effect of an increase in the number of consumers on the market for ridesharing.

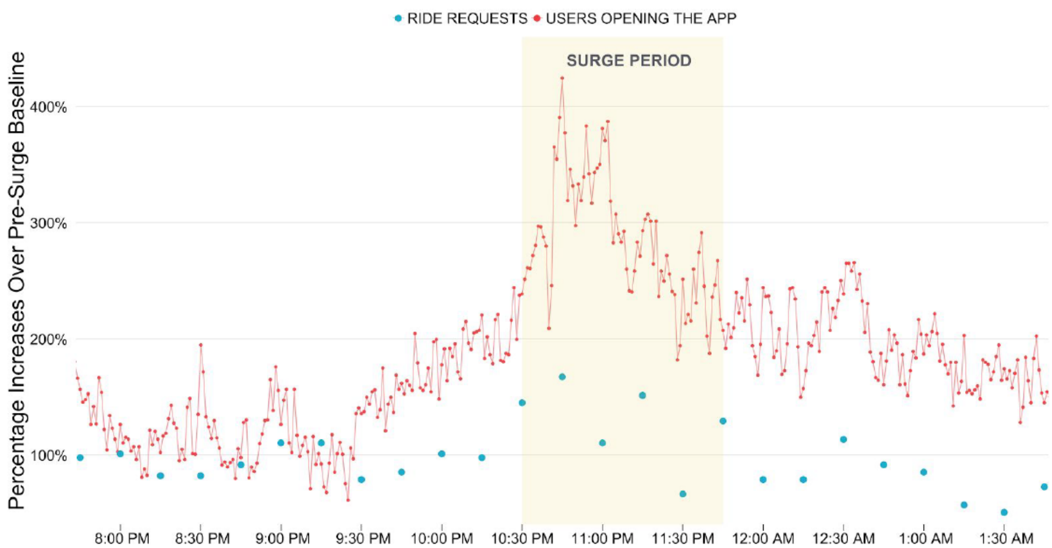
What will be the end result? We will definitely have an increase in the equilibrium price. The equilibrium quantity may increase (as in Figure 14) or decrease (as in Figure 15), depending on which effect is stronger.

2.4 Taking Stock

Overall, you may have realized the value of using the geographical notation to keep track of shifts. To make sure we are on the same page:

- If only one of the curves shift, the equilibrium will shift in the same direction.
  - If demand curve shifts northeast, the equilibrium also shifts northeast. That is, the equilibrium price will increase and quantity traded will increase.
  - If demand curve shifts southwest, the equilibrium also shifts southwest. That is, the equilibrium price will decrease and quantity traded will decrease.
  - If supply curve shifts southeast, the equilibrium also shifts southeast. That is, the equilibrium price will decrease and quantity traded will increase.
  - If supply curve shifts northwest, the equilibrium also shifts northwest. That is, the equilibrium price will increase and quantity traded will decrease.
- If both curves shift, we "add up" the effects.
  - If demand curve shifts northeast and supply curve shifts southeast, the equilibrium also shifts east, and it may shift north or south. That is, the quantity traded will increase and equilibrium price may increase or decrease.
  - If demand curve shifts northeast and supply curve shifts northwest, the equilibrium also shifts north, and it may shift east or west. That is, the equilibrium price will increase and quantity traded may increase or decrease.
  - ...

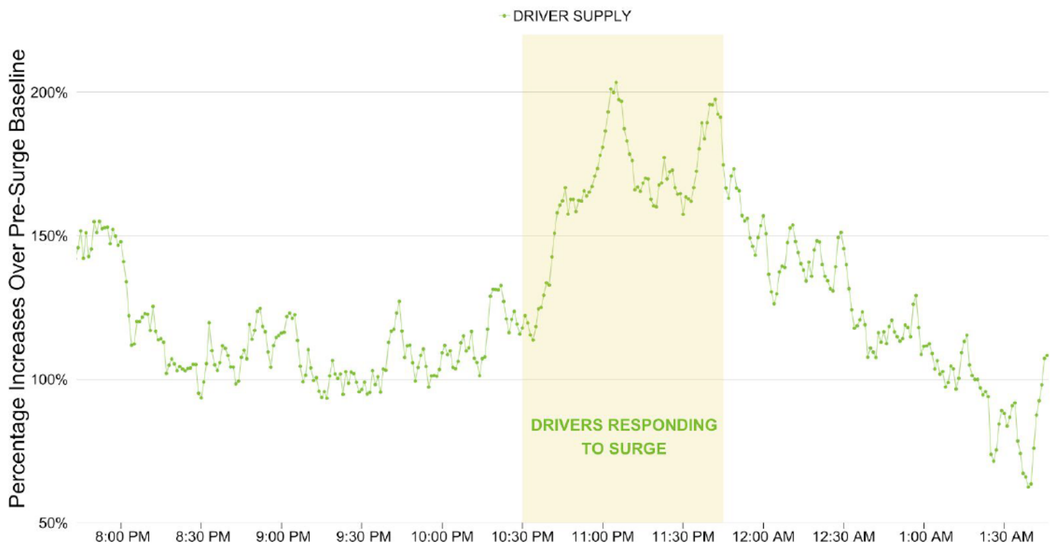
Figure 1: Demand for Uber Spikes Following Sold-Out Concert on March 21, 2015



Note: Figure reports the number of users opening the Uber app each minute over the course of March 21, 2015 (in red), as well as the sum of total requests for Uber rides in 15-minute intervals over the same time period (blue circles). Data is for a restricted geospatial bounding box containing Madison Square Garden in New York City, roughly 5 avenues long and 15 streets wide, for uberX vehicles only. Pure volume counts have been normalized to a pre-surge baseline, defined as the average of values between 9:00 and 9:30 PM that evening, before surge turned on. "Surge period" (yellow box) is the time over which the surge multiplier increased beyond 1.0x.

Figure 8: The increase in the number of consumers.

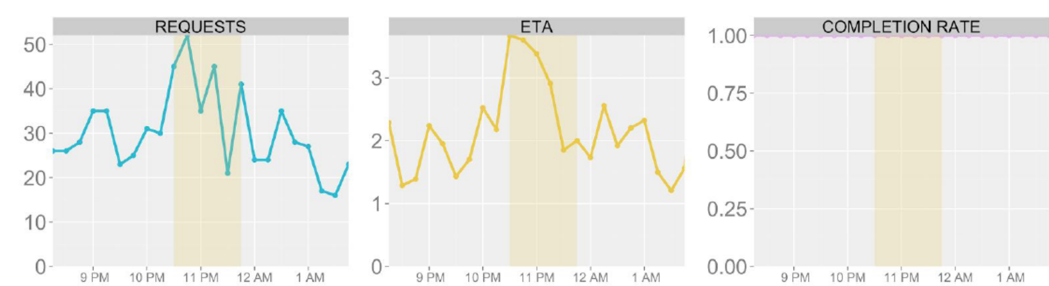
Figure 2: Uber Driver-Partner Supply Increases to Match Spike in Demand



Note: Figure reports the number of "active" uberX driver-partners within the same geospatial box (noted above) each minute over the course of March 21, 2015 (in green). In this case, "active" means they were either open and ready to accept a trip, en route to pick up a passenger, or on trip with a passenger. Pure volume counts have been normalized to a pre-surge baseline, defined as the average of values between 9:00 and 9:30 PM that evening, before surge turned on. The "surge period" (yellow box) is the time over which the surge multiplier increased beyond 1.0x.

Figure 9: The effect of higher price on the number of producers.

Figure 4: Vital Signs of Surge Pricing in Action on March 21, 2015



Note: All data above is for uberX vehicles from within the geospatial bounding box mentioned earlier, aggregated into 15 minute intervals over the course of the evening of March 21, 2015. "Requests" is the count of Uber trips requested during the 15 minute interval. "ETA" is the average wait time for a driver-partner to arrive, in minutes, over the 15 minute interval. "Completion rate" is the percentage of requests that are fulfilled (calculated as the number of completed trips within the 15 minute interval, divided by the sum of completed trips and unfulfilled trips). The yellow box indicates the same "surge period" highlighted in Figures 1-3.

Figure 10: Market clearing.

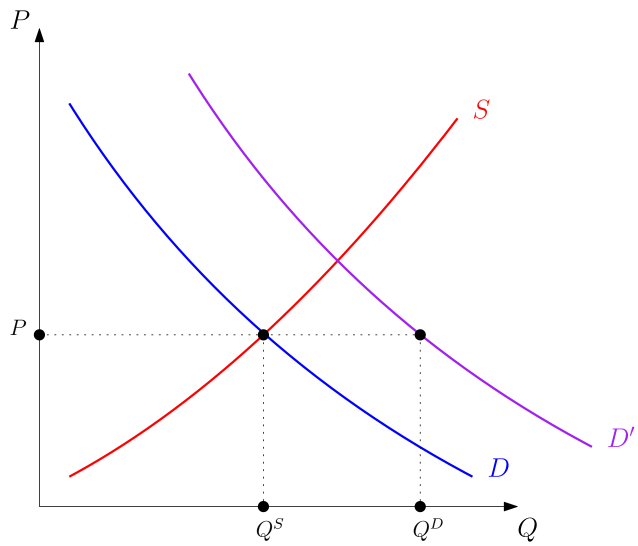


Figure 11: Shortage in a ridesharing market.

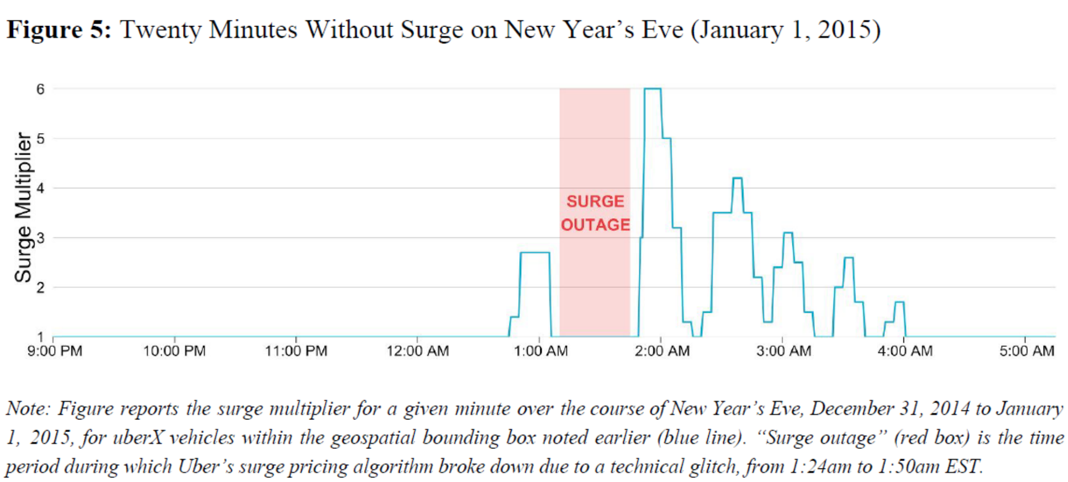
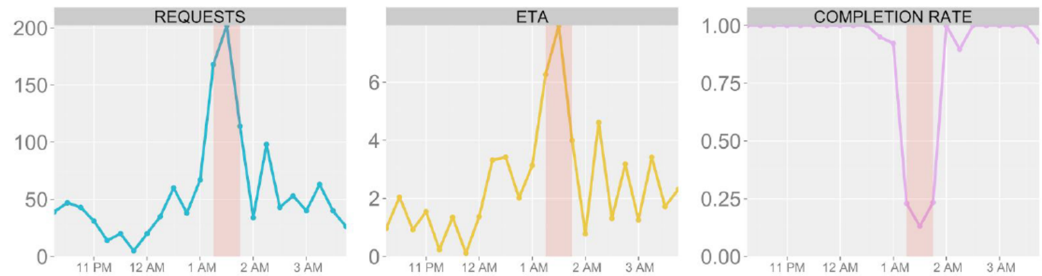


Figure 12: The surge outage.

Figure 7: Vital Signs of a Surge Pricing Disruption on New Year's Eve (January 1, 2015)



Note: All data above is for uberX vehicles from within the geospatial bounding box mentioned earlier, aggregated into 15 minute intervals over the course of New Year's Eve, December 31, 2014 to January 1, 2015. "Requests" is the count of Uber trips requested during the 15 minute interval. "ETA" is the average wait time for a driver-partner to arrive, in minutes, over the 15 minute interval. "Completion rate" is the percentage of requests that are fulfilled (calculated as the number of completed trips within the 15 minute interval, divided by the sum of completed trips and unfulfilled trips). The red box indicates the same "surge outage" highlighted in Figure 6.

Figure 13: Shortage as a result of the surge outage.

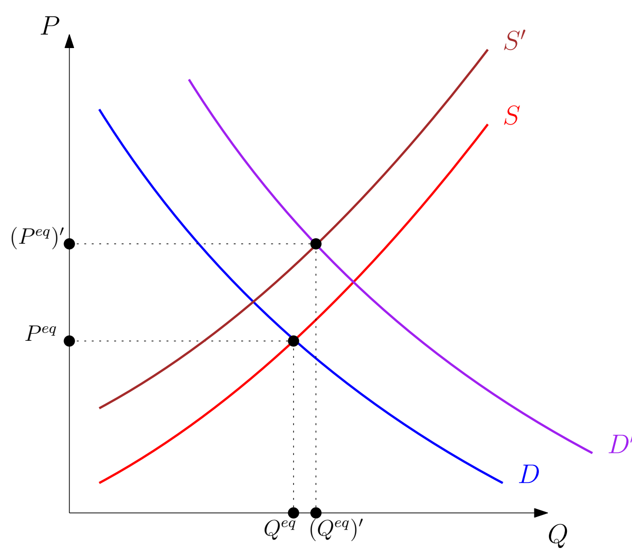


Figure 14: An increase in quantity traded in the market for corn.

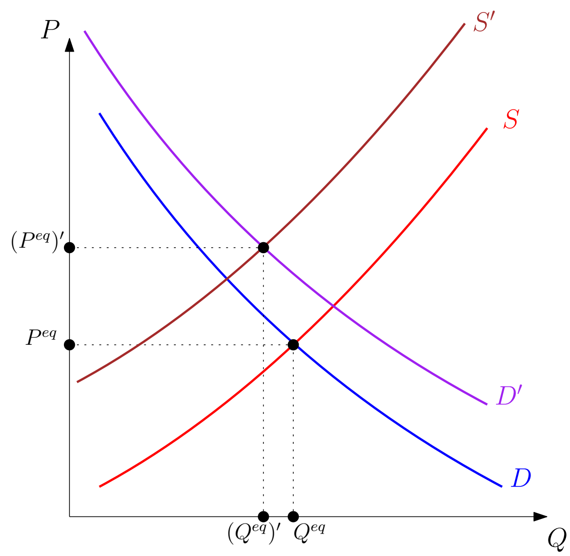


Figure 15: A decrease in quantity traded in the market for corn.