Chapter 5

Demand and Supply

The sections on consumer, producer, and cost theory derive the demand and supply functions for a good. This chapter introduces the market equilibrium in terms of quantity demanded and supplied and outlines the effects of changes in demand and supply on market price and quantity.

There is an infinite number of demand and supply applications. Every time a good changes hands, it is likely due to the existence of a market for this good. Although most of this chapter's examples assess markets in isolation, that is, just for one good, it should be kept in mind that markets—even distant—interact. For example, there is an interaction of the markets for wind farms, airplanes, and high-end bicycles as illustrated in the article Carbon fibre shortage could impact on high-end bike sales published in *BikeBiz* on June 5, 2005:

> *"How does the building of the Airbus 380 and the rapid spread of upland wind-farms impact on the bicycle trade? A shortage of carbon-fibre, that's how."*

5.1 Demand Curve

The quantity demanded for a good or service is the number of units that all buyers in a market would choose to buy over a given time period and given the constraints that they face. The chapter on consumer theory demonstrates the negative relationship between price and quantity demanded with prices for the two goods and income as the main determinants of demand. In reality, there are many more factors influencing demand such as taxes, subsidies, or weather.

A key demand determinant are prices of substitutes and complements. Substitutes are goods that are similar to each other and can serve as an alternative. Examples are tea and coffee, choices among streaming services, or car versus public transportation. Complements are goods that are bought together such as hotels and flights or cars and tires. The Constant Elasticity Substitution utility presented in consumer theory is able to model two goods as either substitutes or complements depending on the value of the parameter ρ.

Before getting into the mechanics of the demand (and supply function for that matter), remember from previous sections that the price and quantity of a good are on the vertical and horizontal axis, respectively. Thus, the expression of the demand function as $Q = f(P)$ deviates from the conventional mathematical notation that would label the x- and y-axis with P and Q, respectively. To draw a demand function of the form $Q = f(P)$, it needs to be converted into the inverse demand function written as $P = f(Q)$.

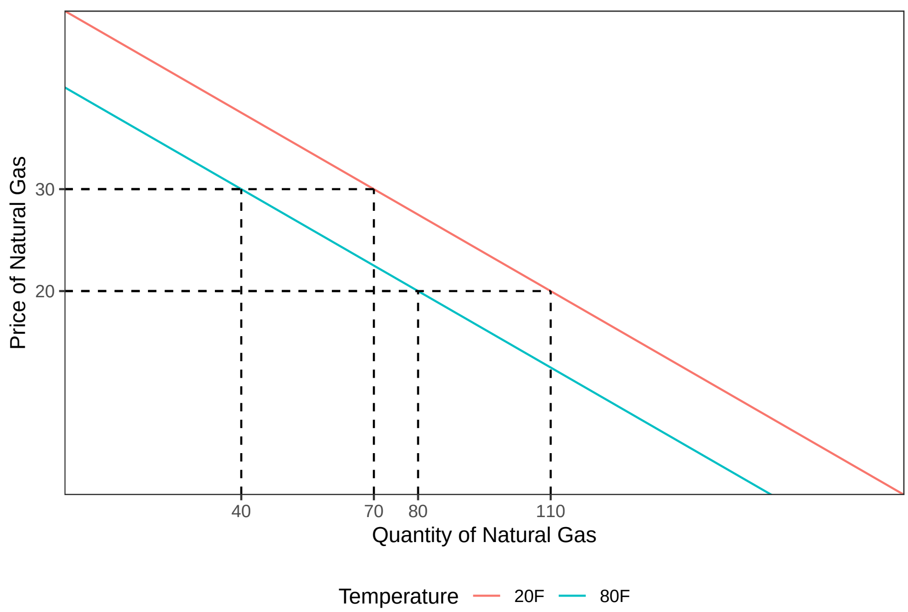

Figure 5.1: Demand for natural gas as a function of price and temperature. A change in the price given a certain temperature level results in a movement along the demand curve. A change in temperature results in a shift of the demand function.

To illustrate the working of the demand function in terms of change in demand versus change in the quantity demanded, consider the demand for natural gas as a function of price (P) and temperature (T):

$$Q^d = 200 - 4 \cdot P - \frac{T}{2}$$

The inverse demand is written as follows:

$$P = 50 - \frac{T}{8} - \frac{Q^d}{4}$$

Given the demand for natural gas in Figure 5.1, the difference between a change in demand (i.e., shift of the function) and a movement along the curve can be illustrated using prices of \$20 and \$30 as well as summer (80F) and winter (20F) temperatures. The law of demand states that when the price of a good increases (decreases) and everything else remaining the same, e.g., temperature in the case of natural gas, the quantity demanded of the good decreases (increases). In economics, "…everything else remains the same…" is called *ceteris paribus*. A change in any variable that affects demand, except for the good's price, causes the demand curve to shift. Put differently, the price changing from \$20 to \$30 in the winter, results in a movement along the demand curve decreasing the quantity demanded from $Q = 110$ to $Q = 70$. If, on the other hand, the temperature increases from $T = 20$ to $T = 80$, the demand function shifts. For the price of \$20, less natural gas is demanded if the temperature is higher. At the price of \$20, 110 units of natural gas are demanded in the winter whereas only 80 units are demanded in the summer.

A common factor that shifts the demand curve includes changes in income, where an increase moves the demand function to the right and a decrease moves it to the left. The price of substitutes also plays a role, with higher (lower) substitute prices shifting demand to the right (left). Conversely, the price of complements has the opposite effect, as an increase in the price of complements shifts the demand curve to the left and a decrease shifts it to the right. Population changes similarly influence demand, with growth shifting the curve to the right and decline shifting it to the left.

5.2 Supply Curve

The quantity supplied is the number of units of a good that all sellers in the market choose to sell over some time period, given the constraints they face. The quantity supplied maximizes producer profits and supply is usually function of output price, input prices (e.g., interest rates, wages), and other factors such as taxes or subsidies. The law of supply states that when the price of a good rises and all other factors remain the same, the quantity of the good supplied will increase. In the case of a price change, a decrease in price results in a movement to the left along the supply curve, while an increase in price results in a movement to the right along the curve.

To understand the shifts in demand, it is best to remember that the market supply curve represents the marginal cost aggregated across firms. So, for example, if the price of inputs increases, this makes production more expensive resulting in an upward shift (or shift to the left) of the supply function. At the aggregate level, if the number of firms increases, then the supply function shifts to the right since for the same price, more firms are providing the good.

5.3 Market Equilibrium

A market is a group of buyers and sellers with the potential to trade with each other. The equilibrium price is determined by the intersection of demand and supply, i.e., a price at which the quantity demanded and supplied is equal. Figure 5.2 provides examples of changes in market equilibrium such as (1) shift in demand, (2) shift in supply, and (3) shift in demand and supply. The example could be the market for corn given changes in biofuel policy (affecting demand) and/or the price of fertilizer (affecting supply).

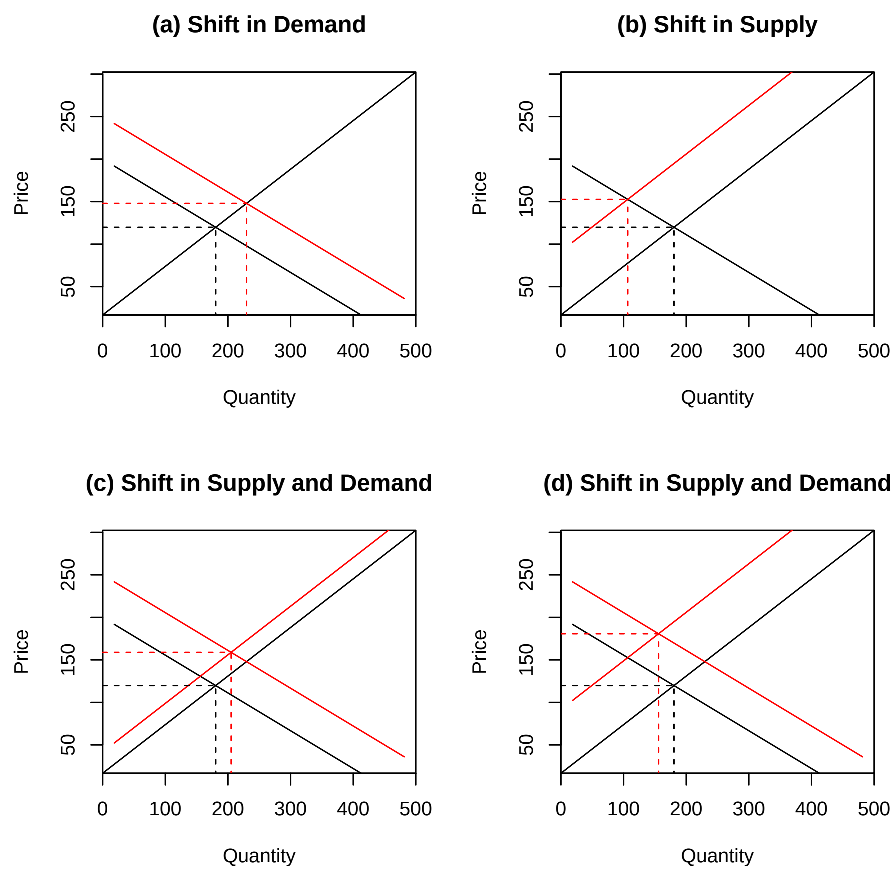

Figure 5.2: Panels (a) and (b) represent a shift in demand or supply, respectively. The resulting change in price and quantity is unambiguous. Panels (c) and (d) represent a simultanous shift in demand and supply. The resulting effect on price is unambiguous, i.e., leading to an increase. The quantity depends on the magnitude of the shifts and cannot be determined without the use of mathematical models.

Simultaneous shift of demand and supply leads to ambiguous effect on price and quantity. If both curves shift, the effect of quantity and price is ambiguous. To determine the exact effect, we need mathematics. When both supply and demand shift at the same time, it is generally possible to determine the direction of change for either price or quantity, but not both. This indeterminacy arises because the two forces move the market equilibrium in different ways, and their combined effects depend on the relative magnitude of the shifts. For example, if demand increases while supply decreases, the equilibrium price will certainly rise, but the effect on quantity is ambiguous since demand pushes it upward while supply pushes it downward. Conversely, if supply increases and demand decreases, the equilibrium quantity will certainly fall, but the price effect is unclear because supply pressures it downward while demand puts upward pressure on it. Real-world illustrations include housing markets, where rising demand from population growth coincides with restricted supply due to zoning laws, resulting in clearly higher prices but uncertain changes in the number of houses sold, or agricultural markets, where a bumper harvest (higher supply) coincides with weaker consumer demand, leading to a definite increase in sales volume but uncertain effects on price.

5.3.1 Market Equilibrium Examples

There are many examples of market equilibrium. For example, a severe drought hit farmers and cropland in the United States in 2012. The British News Magazine The Economist had at least two articles on this subject titled The 2012 drought will dent farm profits and push up food prices and Supply shocks: Feeling a drought which summarizes the effects on agricultural markets. The world price of corn increased by 30% because the U.S. is responsible for 52.5% of world corn exports.

Consider a numerical example of market equilibrium. Assume demand is a function of price (P) and income (I), i.e., $Q^D = 300 - 2 \cdot P + 4 \cdot I$, and that the supply function is $Q^S = 3 \cdot P - 50$. If $I = 25$, then the market equilibrium is determined by the following equation:

$$300 - 2 \cdot P + 4 \cdot 25 = 3 \cdot P - 50$$

Solving for P leads to an equilibrium price of $P = 90$. If income increases to \$50, the equilibrium price increases to $P = 110$.

Consider the demand and supply for U.S. wheat in 1998:

$$Q^D = 3244 - 283 \cdot P$$
$$Q^s = 1944 + 207 \cdot P$$

This situation leads to an equilibrium price of $P = 2.65$. At the end of 1998, Indonesia and Brazil opened their market for U.S. wheat, i.e., 200 million bushels of additional demand. Thus, the demand function becomes $Q^D = 3444 - 283 \cdot P$ resulting in an equilibrium price of $P = 3.06$.

5.4 Elasticity

Elasticity measures the percentage change in one variable (y) divided by the percentage change in some other variable (x). Formally, it is written as follows:

$$\epsilon = \frac{\%\Delta \text{Dependent variable}}{\%\Delta \text{Independent variable}}$$

The Δ represents the change in the variable. Since this equation is not very intuitive, let us first consider an example how to use elasticity and then calculate elasticity based on a linear demand function. For example, if the demand elasticity of a good is -0.6, then if the price of that good increases by 1%, the quantity demanded for the good will decrease by $-0.6 \cdot 1\% = -0.6\%$. The elasticity works for small percentage changes in price. Given the elasticity of -0.6, if the price of that good decreases by 3%, the quantity demanded for the good will increase by $-0.6 \cdot -3\% = 1.8\%$.

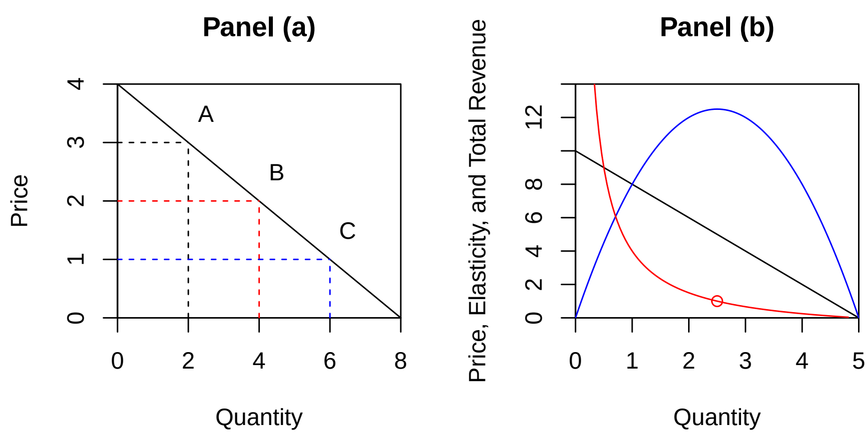

Figure 5.3: Panel (a): Determination of elasticity for a linear demand function. Panel (b): Relationship between elasticity and total revenue

The demand elasticity for a good is also known as the own-price elasticity, which is the change in quantity demanded of good i with respect to the price of good i:

$$\epsilon_P = \frac{\%\Delta Q_i}{\%\Delta P_i} = \frac{P_i}{Q_i}\frac{\Delta Q_i}{\Delta P_i}$$

To apply this equation, consider the linear demand function $Q = 8 - 2 \cdot P$ (Figure 5.3). In the case of a linear demand function, we have

$$\text{constant} = \frac{\Delta Q_i}{\Delta P_i}$$

To understand this property, assume an initial situation where the price is \$3 and the quantity demanded is 2. When the price decreases from \$3 to \$1, the new quantity demanded rises to 6. This represents a price change of -\$2 and an increase in quantity of 4, i.e., moving from 2 to 6. Dividing the change in quantity by the change in price yields 4 divided by -\$2, which equals negative 2. Note that the elasticity has no unit and that the \$ sign is only used for ease of explanation. This exercise can be repeated for the other price-quantity pairs in Panel (a) of Figure 5.3 and the results is always -2.

For the three price-quantity pairs depicted in Panel (a) of Figure 5.3, the following elasticities can be calculated:

$$\epsilon^A = \frac{P^A}{Q^A}\frac{\Delta Q^A}{\Delta P^A} = \frac{3}{2} \cdot -2 = -3$$
$$\epsilon^B = \frac{P^B}{Q^B}\frac{\Delta Q^B}{\Delta P^B} = \frac{2}{4} \cdot -2 = -1$$
$$\epsilon^C = \frac{P^C}{Q^C}\frac{\Delta Q^C}{\Delta P^C} = \frac{1}{3} \cdot -2 = -1/3$$

Note that the elasticity for a linear demand function is not constant. Demand is elastic if the percentage change in quantity is greater than the percentage change in price, i.e., smaller than -1 (Point A). Demand is inelastic if $-1 < \epsilon < 0$ (Point C). Demand is unit elastic if the percentage change in quantity is equal to the percentage change in price (Point B).

Besides the own-price elasticity, we also have the income elasticity and cross-price elasticity. Income elasticity is the change in quantity demanded of good i with respect to income:

$$\epsilon_I = \frac{\%\Delta Q_i}{\%\Delta I} = \frac{I}{Q}\frac{\Delta Q}{\Delta I}$$

Income elasticity of demand measures how the quantity demanded of a good responds to changes in consumer income. A positive income elasticity indicates a normal good, where higher incomes increase demand, while a negative income elasticity characterizes an inferior good, where higher incomes reduce demand. The magnitude of the elasticity matters as well, since luxury goods often have values greater than one, reflecting that demand grows more than proportionally with income, whereas necessities typically have values between zero and one. Applications of income elasticity include forecasting consumer spending patterns as economies grow, evaluating how demand for various goods shifts during recessions, and guiding businesses in targeting products to specific income groups. Policymakers also use it to anticipate how changes in income distribution affect overall consumption and market dynamics.

And the cross-price elasticity is the change in quantity demanded of good i with respect to price of good j:

$$\epsilon_C = \frac{\%\Delta Q_i}{\%\Delta P_j} = \frac{P_j}{Q_i}\frac{\Delta Q_i}{\Delta P_j}$$

Cross-price elasticity of demand measures how the quantity demanded of one good responds to changes in the price of another good. A positive cross-price elasticity suggests that the two goods are substitutes, such as tea and coffee, while a negative value indicates that they are complements, such as gasoline and cars. This measure helps firms understand competitive pressures and potential market opportunities, for example, by assessing whether raising the price of one product might increase sales of a substitute. Policymakers also use cross-price elasticities to evaluate tax impacts, such as how higher fuel taxes affect demand for public transportation. In addition, businesses employ these estimates in pricing strategies, product differentiation, and identifying opportunities for bundling complementary goods. This can have important implications in anti-trust cases where the market power of a firm needs to be determined. Companies who have had troubles in the past are Office Depot and Staples (test in 40 cities), Alcoa (aluminum market), DuPont (cellophane), or Continental Can (acquiring a glass manufacturer) to name a few. There are also some special cases of elasticity depicted in Figure 5.4.

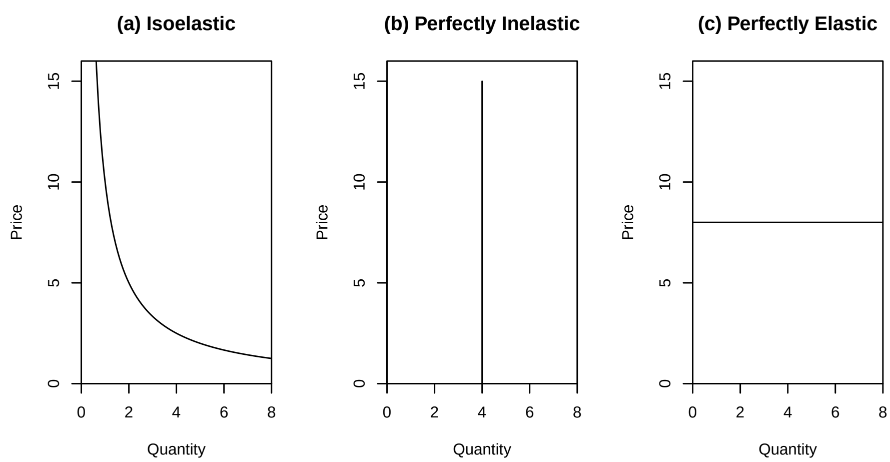

Figure 5.4: Panel (a) depicts an isoelastic demand function. As opposed to the linear demand function, the elasticity does not change as price moves along the function. Panels (b) and (c) represent perfectly inelastic and elastic demand functions, respectively. An example for a perfectly inelastic demand would be a life-saving medication.

The relationship between elasticity and revenue can also be explained with a demand function graph and the area in terms of revenue change (Panel (b), Figure5.3). The relationship between elasticity and revenue depends on how responsive consumers are to price changes. When demand is elastic, meaning the absolute value of the price elasticity of demand is greater than one, a decrease in price leads to a proportionally larger increase in quantity demanded, so total revenue rises. Conversely, if the price increases under elastic demand, the drop in quantity demanded is proportionally larger, and revenue falls. When demand is inelastic, with an elasticity between zero and one, the opposite occurs: a price increase causes only a small decline in quantity demanded, so revenue increases, while a price cut reduces revenue. In the special case of unit elastic demand, where elasticity equals one, changes in price and quantity offset each other exactly, leaving total revenue unchanged. This relationship is crucial for businesses and policymakers, since it guides pricing strategies, tax policies, and expectations about how markets will react to price adjustments. Consider, for example, services such as public transportation or the U.S. Postal Service. Very often the discussion centers around whether a price increase results in an increase or decrease in revenue. An argument can be made for both cases. Thus, it is important to know if prices are in the elastic or inelastic section of the demand.

In a 2005 article To Reduce the Cost of Teenage Temptation, Why Not Just Raise the Price of Sin? in the New York Times lists examples how an increase in the price of cigarette and alcohol taxes reduces the consumption of those goods by teenagers. Those consumers have a much higher elasticity with respect to consumption than adults. The article states that

> "In just about every state that increased beer taxes in recent years, teenage drinking soon dropped. The same happened in the early 1990's when Arizona, Maryland, New Jersey and a handful of other states passed zero-tolerance laws, which suspend the licenses of under-21 drivers who have any trace of alcohol in their blood. In states that waited until the late 90's to adopt zero tolerance, like Colorado, Indiana and South Carolina, the decline generally did not happen until after the law was in place. Teenagers, it turns out, are highly rational creatures in some ways. Budweisers and Marlboros are discretionary items, and their customers treat them as such."

5.5 Consumer and Producer Surplus

Consider a demand function of the form $Q = 10 - P$ and a supply function of the form $Q = P - 2$ (Figure 5.5. Consumer surplus is the difference between what buyers are willing to pay for a good and what they actually pay, representing the net benefit consumers gain from participating in the market. Producer surplus is the difference between the market price sellers receive and the minimum price at which they would be willing to sell, capturing the net benefit to producers. Taken together, consumer and producer surplus measure the total gains from trade in a market, which economists refer to as economic welfare. A higher combined surplus indicates that resources are being allocated efficiently and that the market is maximizing the benefits available to both buyers and sellers. This framework provides a foundation for evaluating the effects of policies, taxes, subsidies, and market interventions, since any change in consumer or producer surplus directly reflects changes in overall welfare.

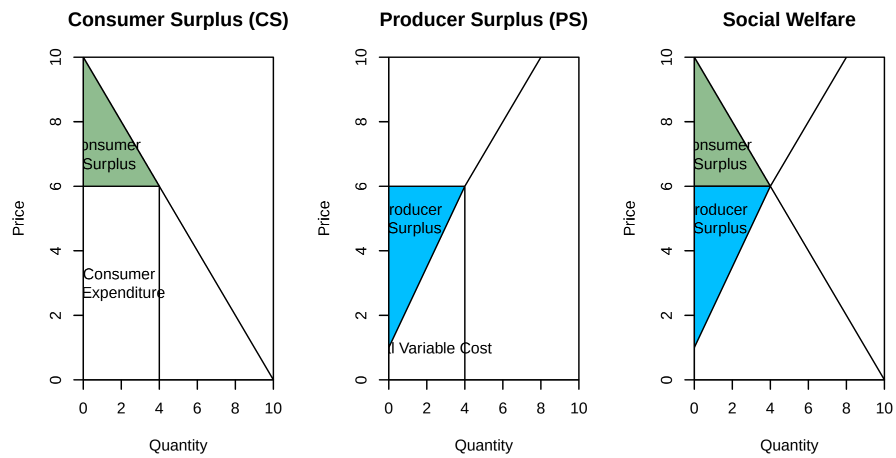

Figure 5.5: The sum of consumer surplus and producer surplus is called social welfare.

5.6 Exercises

1. ***Books*** (*): The demand for books is $Q^D = 81 - P$ and the supply of books is $Q^S = 8 \cdot P$. What is the equilibrium quantity and price?

2. ***Gasoline Demand*** (*): The demand for gasoline in the U.S. is very inelastic. Why do you think that is the case? Assume that it is -0.2. If gasoline prices decrease by 3%, by how many percent does the quantity demanded change?

3. ***Ice Cream Demand*** (**): The demand function for ice cream is $Q = T - 5 \cdot P - 40$ where Q, P, and T represent the quantity, price, and temperature, respectively.

   a. Draw the demand curve for $T = 80$.
   b. In your graph, show what happens if the temperature drops to 70. Does the demand curve shift or are we moving along the demand function?
   c. The price of ice cream decreases from \$4 to \$3 without a change in temperature ($T = 80$). In your graph, show how this effects the quantity demanded. Does the demand curve shift or are we moving along the demand function?

4. ***Societal Collapse*** (**): During the COVID-19 pandemic, a (non-economist) friend of mine was getting gasoline and noticed many nozzles had bags over them since the gas station was low on supply despite low prices. Fearing the beginning of societal collapse, he sent me a text message because he did not understand how prices and supply could be

low simultaneously. Draw a demand and supply graph starting with the pre-COVID equilibrium price and quantity. Then, show what happens if people change their driving behavior towards fewer trips. How would you have explained the situation to my friend? (It later turned out that the gas station simply forgot to put the restock order in with corporate.)

5. ***Feeling a Drought*** (***): The following is an extract of an article title Supply shocks: Feeling a drought from the British news magazine The Economist. Read the paragraph and answer the question below.

   > Much of America's agricultural heartland is in the grips of extreme to exceptional drought. It is becoming increasingly clear that this drought will take a significant toll on some of the nation's principal food crops, especially corn, wheat, and soybeans. As a result, food prices are soaring - the price of corn rose 23% in July - and those food price increases are beginning to make their way into official inflation figures. This morning, the Bureau of Labour Statistics released its July producer price index. Headline prices for finished goods rose 0.3% for the month, above expectations. The internals of the report show a sharp division between food price trends and the movement of prices for most other goods. Finished core prices rose a strong 0.4% to 0.5% for finished foods. But core prices for intermediate and crude goods actually fell in July, while intermediate and crude food indexes soared. Prices for crude food stuffs rose by 5.2% in July alone. The impact of the drought on production is quite clearly a supply shock; productive capacity has actually been diminished and prices have risen as a result. Other things equal, the economy will grow a bit less than expected before the scope of the drought became clear and inflation will be a bit higher.

   Corn is a significant input to the production of meat because a high proportion of livestock feed uses corn. I want you to draw two supply and demand graphs (i.e., two markets): One for corn and one for meat. Illustrate the effects of the drought on the market for corn and how this translates into the market for meat.

6. ***War on Drugs*** (***): Concerned about the high consumption of illegal, highly addictive drugs in the state, the governor solicits ideas to address the problem. State Representative Carson, a hardliner on drugs, suggests that the police should focus on reducing the number of drug dealers in the state. Representative Carter suggests an education campaign to inform potential consumers (e.g., high school students) about the adverse effects of using addictive drugs. To answer the question, assume that both proposals work in reality and have the desired effects. Using two supply and demand graphs for the drug market (i.e., one for each representative), illustrate the effects of the two proposals. Assume that the market for drugs is initially in equilibrium. Then proceed to show the effects of the policy

proposals. Based on your analysis, which policy would you recommend? Why?

7. ***Swiss Ski Resorts*** (***): Ski resorts in Switzerland and elsewhere are struggling. On one hand, population is increasing but on the other hand, climate change is increasing the altitude of the snowfall limit. See for example Ski resorts' era of plentiful snow may be over due to climate crisis, study finds published in *The Guardian* on March 2, 2024. Assume that initially, the number of ski areas is 500 and that demand is written as $Q = 600 - P/2$. What is the initial price and quantity? Illustrate in a graph. Next assume that 50 ski resorts are closing and that due to population increase, the demand with higher population is written as $Q = 625 - P/2$. In the same graph as before, draw the new demand and supply. What are the new equilibrium price and quantity?

8. ***Natural Gas and Food Safety*** (***): This exercise is based on an example in the book Material World by Edward Conway. Carbon dioxide (CO_2) is used in the food industry not only for fizzy water but also to preserve food. During the COVID pandemic and after the invasion of Ukraine by Russia, the British food industry faced a shortage of CO_2 due to the closure of two fertilizer plants. The industrial production of CO_2 is a by-product of ammonia, which heavy depends on natural gas. Since natural gas prices were high, the plants closed down interrupting the supply of CO_2. Draw the demand and supply curves for two markets: Carbon dioxide and fertilizer. Illustrate the effects (quantity and price) of an increase in the natural gas price on the fertilizer market. Next, consider how those effects translate into the market of CO_2 by keeping in mind that fertilizer production produces CO_2 as a by-product. For this exercise, do not illustrate the closure of the two fertilizer plants but simply assume that the chain of events starts with higher natural gas prices.