Introduction

What is economics?

Economics is a study of choice and of human decision making in the face of scarce resources. Humans have virtually unlimited resources, but lack the meaning to satisfy these. Thus, economics is the study of why people/"economic agents" choose what they do. A firm, for instance, must decide:

- What to produce?
- How to produce it?
- Who to produce it for?

As a social science, economics aims to understand the choices of individuals and how these inform the behaviour of larger groups. Economics is, fundamentally, about human wellbeing. Wellbeing, from the perspective of an economist is the consumption of goods and services. These goods and services are produced using a variety of resources, including:

- Natural reosources
- Physical capital; machines, infrastructure
- Human capital; labour, intellectual labour, etc
- Time

Because these resources are finite, humanity needs to make decisions on the allocation of these resources to optimise wellbeing.

Decision Theory

An economic agent is always making choices; it is trying to select the best option based on a cost-benefit analysis.

$$\text{Net benefit } NB = \text{Total benefit } TB - \text{Total costs } TC$$

For example, a firm's goal is to maximise profits; they will minimise costs and maximise revenue to achieve this goal.

How do we measure costs?

While people are generally quite good at evaluating benefits, they sometimes struggle when trying to evaluate costs. Often, people will, when considering a purchase, simply consider the explicit cost; the price on the price tag. However, this ignores the opportunity cost; any purchase is to the exclusion of other purchases.

Example

Consider 2 individuals sharing a home, with two tasks that need to be completed, say cooking and laundry. If person A is good at laundry but poor at cooking, person B with the opposite skill set, it is obviously advantageous for them to trade; to each attend to their favoured task. However, consider the scenario when person A is better at both.
We can model this as a "production possibilities frontier"; modelling the amount of each good they can produce if they perform a mixture of the two tasks for a certain time. This will form a linear relationship tracking from the $100:0$ time spent state through the $50:50$ to the $0:100$ state. Depending on the exact relationship between their capabilities, trade may nonetheless be advantageous for both parties; the yield for A may be substantially greater when say, cooking, per unit time, compared to laundry, and thus, having B perform some of the laundry, even if less efficient, may increase the total consumption of both A and B, thus increasing both parties overall wellbeing.
To find this solution, A needed to consider the opportunity cost of performing laundry, which in fact proved to be greater than instead primarily cooking and trading with B to have the laundry performed.
In the language of economics, A has an *absolute advantage* in both cooking and doing laundry, however B has a *comparative advantage* in laundry.

Definitions

Absolute advantage is the ability to produce a good using fewer inputs than another producer.

Comparative advantage is the ability to produce a good at a lower opportunity cost than another producer.

Sunk Costs

When making a decision, one should ignore any costs that have been incurred prior to a decision. Because these resources have already be used, the perceived loss of them has no real bearing on the future outcome of a decision.

Opportunity Cost

Total opportunity costs are composed of two seperate parts:

- Direct Opportunity Costs: This is the cost of resources that will be used in the chosen alternative.
- Indirect Opportunity Costs: This is the benefits minus the explicit costs of the next best action.

Example

Say you have three options;

- Option A, worth \$3000, cost of \$2500
- Option B, worth \$500, cost \$200
- Option C, worth \$100, with a \$20 downpayment already payed

Thus, you would select Option A. As B is the next best option this is your indirect opportunity costs. Because B is worth \$300, the total opportunity cost is equal to $\$2500 + \$300 = \$2800$. Thus Option A is still worthwhile.

Marginal Analysis

Rather than focussing on total benefits and total costs, we should really focus on Marginal Benefits and costs. Consider whether consuming / producing n amount of units will be profitable or costing. i.e. as long as the Marginal Benefit of and action is greater than the Marginal Cost of that action, we should take that action as a rational agent.

Example

Say we are hiring workers for a store. These workers are payed \$20/hr. The first worker hired is expected to increased sales by \$60/hr, with additional workers diminishing in value by \$15/hr until they reach \$0/hr. Thus, the first worker increases net benefit by \$40/hr, the second by \$25/hr etc. So for the first worker, the marginal benefit will be \$60/hr, while the marginal cost is a constant, \$20/hr. So looking at the marginal benfit vs marginal costs for each worker, workers 1, 2 and 3 will have $MB > MC$ while worker 4 will have $MB < MC$, so we should hire 3 workers.

Calculating Benefit

Suppose $NB(x) = TB(x) - TC(x)$. To maximise $NB(x)$ using calculus, we can differentiate $NB(x)$ with respect to x and set this to 0.

$$\frac{dNB(x)}{dx} = \frac{dTBx}{dx} - \frac{dTC(x)}{dx} = 0$$

$$\frac{dNB(x)}{dx} = MB(x) - MC(x) = 0$$

Thus the optimal x is:

$$MB(x) = MC(x)$$

Microeconomic Theory

Microeconomics centres around creating models, creating "rational agents" built on axioms. These axioms are as follows: Individual actors are autonomous, individuals have freedom and that individuals matter. This theory is then compared with real world data and is validated or disproven.

The theory is thus useful for attempting to understand how individual agents can cooperate with (or counteract) each other within an economic system.

Prisoner's Dilemma

The prisoner's dilemma; that of two prisoners who are offered a light charge if neither confesses, a serious charge if both confess and absolution for the confessor if just one confesses. This model can (and has) been used to understand a variety of situations from board meetings, to economics to diplomacy. It highlights that the individual interest is not always aligned with that of the group.
Under the assumption that the only goal of each individual is personal benefit, it makes sense for both to choose to confess; if the other chooses not to confess, the confessor gains major benefit, if they choose confess, the result is indifferent. Thus, this is a model. However, it does not perfectly represent reality. Many agents are "conditional cooperators"; they want to split only when the other person also splits. Thus their action depends explicitly on what they believe the other party will do; just like for most people.

Lesson 1

This dilemma highlights that individual incentives can be exploited; the optimal for the prisoners here occurs when neither confesses, however it is optimal from a theoretical standpoint for both to confess. Thus, the system efficiently manages incentive to exploit the prisoners. This situation can be used as a model for the design of systems; those where individual incentives are at odds with a designers intent are likely to be unstable and lead to inefficiencies.

Example

A local government aiming to reduce carbon emissions by offering a 40% rebate on vehicles capable of using LNG, a lower emission fuel. However, their system was flawed in that it had no usage requirement; consumers simply purchased

$1000 dollar secondary fuel tanks and where rebated $20,000+ without actually using the lower emission alternative.
Thus, this program was a financial and ecological disaster.

> "Economics is a highly sophisticated field of thought that is superb at explaining to policymakers precisely why the choices they made in the past were wrong. About the future, not so much..."
> "However, careful economic analysis does have one important benefit, which is that it can help kill ideas that are completely logically inconsistent or wildly at variance with the data. This insight covers at least 90 percent of proposed economic policies."
> – Ben Bernanke

Lesson 2

In addition, this problem can help us to understand that people will adapt to imperfect systems: over time, people will come to understand what action they should take in a situation and thus they will create outcomes that may align with the expected outcome of theory.

Lesson 3

In economic systems, we can never know the true, underlying preferences and decision making process of an individual; they have private information. This can make it difficult to design effective centralised systems.
Thus, it can be more efficient to pursue decentralised systems such as markets, where people act in perfect self interest, thus revealing their underlying incentives, which inform their behaviour.

Markets

What is a market?

A market is a mechanism through which buyers and sellers trade a particular good or service with near-identical characteristics. These characteristics can include:

- Type
- Delivery Location
- Grade and Quality
- Time

For example, oil varies considerably in chemical compoisition (e.g. sulphur content) and density; usually the "Brent" crude oil price is discussed when the price of oil is referred to; it represents an independent market with a very specific set of characteristics.

In a market, buyers supply demand and sellers offer supply. Both agents must consider marginal cost and benefit when evaluating a transaction. As they are rational economic agents, they will only transact when $MB \geq MC$ for both buyer and seller.

In an indealised perfectly competitive market, there are many buyers and sellers trading exactly identical goods. These factors inform competition because buyers are aware that they can choose from a variety of sellers with no differentiation of products. In this setting, an individual does not have the ability to manipulate the market through their individual actions; the individual seller is a "price-taker", accepting the market price. Although real markets tend not to be *perfectly* competitive, they are often highly competitive.

Demand

The demand curve will map the number of units for which there is demand at a given price. In general, as price decreases, demand will increase. This is the thesis of the "Law of Demand". Other factors can, however, also inform demand includings:

- Price
- Tastes
- Price and quality of alternative goods
- Income
- Future price expectations
- Number of buyers

How can changes in income alter the characteristics of a demand curve?

- For a *normal good*, demand is usually proportional to income.
- For an *inferior good*, demand is inversely related to income.
- When income changes, we see a *shift* in the demand curve.

How about the prices of other goods?

- For *substitutes* such as butter and margerine, the price of one good is proportional to demand for the other.
- *Complements* have a negative correlation between the price of one good and a complement good.

When these prices change, we see a shift in the demand curve.

Supply

Supply is the complement to demand, representing the quantity of goods sellers have on offer for buyers. For a supply curve, price and quantity in general be positively correlated.

Supply can be affected by factors such as technology advances improving manufacturing efficiency, shifting the supply curve to greater supply. Inversely, supply might be negatively impacted by rising prices for input goods (such as commodities).

Market Equilibrium

Market equilibrium describes a situation when supply and demand are in balance; when the quantity supplied is equal to the quantity demanded. This can be observed graphically as the intersection of the demand and supply curves.

This is an equilibrium because neither buyers nor sellers have an incentive to change their behaviour; if price where to increase, the additional goods would not be sold; if it were to decrease, suppliers would not find it worthwhile to produce the demanded goods.

Example

If Q_D is quantity demanded and Q_S is quantity supplied, given by these equations:

$$Q_D = 120 - 20P$$

$$Q_S = 20P$$

We can solve the system for equilibrium by setting $Q_D = Q_S$:

$$120 - 20P = 20P \Rightarrow 120 = 40P \Rightarrow P = 3$$

$$Q_D = 120 - 60 = 60$$

Thus, market equilibrium for this system is found at:

$$P^* = 3$$

$$Q^* = 60$$

What happens when the market is not at equilibrium? Well, when $P \neq P^*$, competition will tend to drive P toward P^*. To identify this equilibrium, we can observe what would happen if P where to change; if a point is at equilibrium, it will return to that state after a disturbance.

For example, if the price is too high, demand will be lower. Thus, manufacturers will have excess stock and will be incentivised to lower their prices to move their goods, and as rational agents, will do so.

Comparative Statics

Comparative statics refer to comparing static snapshots of supply/demand curves and the effects of market shocks, such as e.g. COVID19 on the supply/demand of hand sanitiser. COVID19 is an example of a positive shock increasing the demand curve; shifting it to the right and thus increasing demand at every price point, and causing an increase in P^*. This is referred to as an *exogenous* effect; i.e. it comes from a source external to the system.

Positive supply shocks increase supply at ever price point; an example of an *exogenous* effect causing this might be a technological advance making it more affordable to supply goods. The reverse might happen if some disaster occured such as storms wiping out banana crops in Queensland.

In the case of both a positive supply shock and a positive demand shock of equivalent magnitude, the intersection will tend to simply increase in quantity. The increasing supply places negative pressure on the price while the increasing demand places positive pressure, thus maintaining P^*. If we don't know the relative magnitudes, we can still say that there will unambiguosly be an increase in demand, but we can't say for sure what will happen to the price.

An example of a long term shift could be lobster. Historically, they were seen as a disgusting low grade food which was extremely plentiful. However, over time they became more respected and seen as a restaurant delicacy, and they were overharvested leading to a reduction in supply. Thus, the demand has increasing radically increasing price and the supply has dropped significantly, also driving up the price. This is how a meal that was \$4 in 1870 might cost \$30 or more today. Because of the competing forces on quantity, it is difficult to be sure of how $Q*$ has changed.

Elasticity

Elasticity measures the responsiveness of quantity demanded to it's determinants. This allows us to analyse in detail how markets will respond to a given shock, i.e. magnitude in addition to direction.

Demand

Price elasticity of demand measures the responsiveness of quantity demanded to a change in price. If ΔP denotes change in price and ΔQ_D denotes change in quantity demanded then $\frac{\Delta P}{P}$ yields percentage change in price and likewise $\frac{\Delta Q_D}{Q_D}$ yields percentage change in Q_D.

Elasticity for Q_D is then given by:

$$\epsilon_D = \left| \frac{\Delta P / P}{\Delta Q_D / Q_D} \right|$$

By convention, it is a positive number. We can take a derivative to determine *point-price elasticity*. Knowing that the rate of change of Q_D with respect to P is given by $\frac{dQ_D}{dP}$:

$$\epsilon_D = \left| \frac{dQ_D}{dP} \frac{P}{Q_D} \right|$$

This is the elasticity at a particular price, rather than for the entire demand curve.

Example

Consider a demand curve of $Q_D = 120 - 20P$. Find the point-price elasticity at $Q_D = 20$:

$$\frac{dQ_D}{dP} = -20$$

$$\epsilon_D = \left| \frac{dQ_D}{dP} \frac{P}{Q_D} \right| = \left| -20(\frac{5}{20}) \right| = 5)$$

and at $Q_D = 100$:

$$\epsilon_D = \left| \frac{dQ_D}{dP} \frac{P}{Q_D} \right| = \left| -20(\frac{1}{100}) \right| = \frac{1}{5})$$

Common Elasticities

- Perfectly inelastic: $\epsilon_D = 0$
- Inelastic: $1 > \epsilon_D > 0$
- Unit elastic: $\epsilon_D = 1$
- Elastic: $\infty > \epsilon_D > 1$
- Perfectly elastic: $\epsilon_D = \infty$

Factors of Elasticity

A variety of factors can affect elasticity, such as degree of necessity; if a product is necessary, it's price will affect demand little. Availability of substitutes is another factor; if a product can be easily replaced by another product, it's likely to be highly elastic.

Elasticity can be used to consider change in revenue cause by a change in price. Understanding that a shift upward in price causes a shift downward in demand allows us to see that an increase in price will lead to more revenue only if the effect of that change is more significant than the effect of the lost demand. Understanding that elasticity denotes how responsive a quantity is to the change of it's inputs allows us to derive the folowing:

$$MR(P) = (1 - \epsilon_D)Q_D$$

Thus, the total revenue is maximised at $\epsilon_D = 1$. For example, increasing price when $\epsilon_D = 0.8$ is likely to yield an increase in revenue while doing the same at $\epsilon_D = 1.8$ is likely to reduce revenue.

Elasticity can be considered not only for price, but also for other factors such as income. Income elasticity is denoted ϵ_γ. In general, normal goods have $\epsilon_\gamma > 0$ while inferior goods have $\epsilon_\gamma < 0$; demand for normal goods increases with income, while inferior goods obey the opposite. Necessary goods have $1 > \epsilon > 0$, while luxury goods have $\epsilon_\gamma > 1$, which makes sense; only when income is high will most people consider buying luxury goods, so elasticity is high.

Cross-price elasticity considers the demand for one good with respect to the price of another good. For substitutes, $\epsilon_{AB} > 0$ while for complements, $\epsilon_{AB} < 0$; if the xbox gets cheaper, playstation demand increases; if the xbox price increases, demand for xbox games decreases.

Behaviours of Perfectly Competitive Markets

When a price is fixed, the area between the demand curve and the price line is the total surplus gained by consumers in the market created. In a perfectly competitive market, this is the area above P^* under the demand curve. For a producer, the area under P^* above the supply curve. For a society, the sum of these areas is described as the total surplus; the total benefit derived from this market for society. This concept is linked to welfare.

Consider an example of market behaviours in the shift of a market after the legalization of marijuana. While illegal, marijuana has a relatively high marginal cost because it has to be imported or produced in secret, and distributed as such. We would also expect demand to be reasonably low, due to the potential for arrest and criminal offences. Thus we would expect a relatively high P^* and a relatively low Q^*. With the introduction of legal marijuana, we see a seperate but closely related market emerge; one with lower marginal cost (in general) than the illegal market, and which, being legal, has substantially higher demand. We would then expect an increase in Q^*, but would be unable to tell for sure the effect on P^*, as although demand has increased, the marginal cost of supply has probably also been lowered. The introduction of this legal market does not necessarily mean the end of the illegal market; a group may exist for which illegal marijuana is fine as long as it is cheaper than the legal variety. Thus, the market will endure a massive demand shock resulting in a new equilibrium with significantly lower P^* and Q^*.

Some groups thus have an incentive to oppose legalisation; pharmaceutical companies who produce substitutes will oppose the policy as it will decrease demand for their product; alcohol groups for similar reasons.

In an perfectly competitive market, the equilibrium quantity is always going to be the most efficient outcome in terms of maximising total surplus. Thus, even a market where all actors are perfectly selfish maximises total surplus for society.

Government Intervention

Indirect Interventions

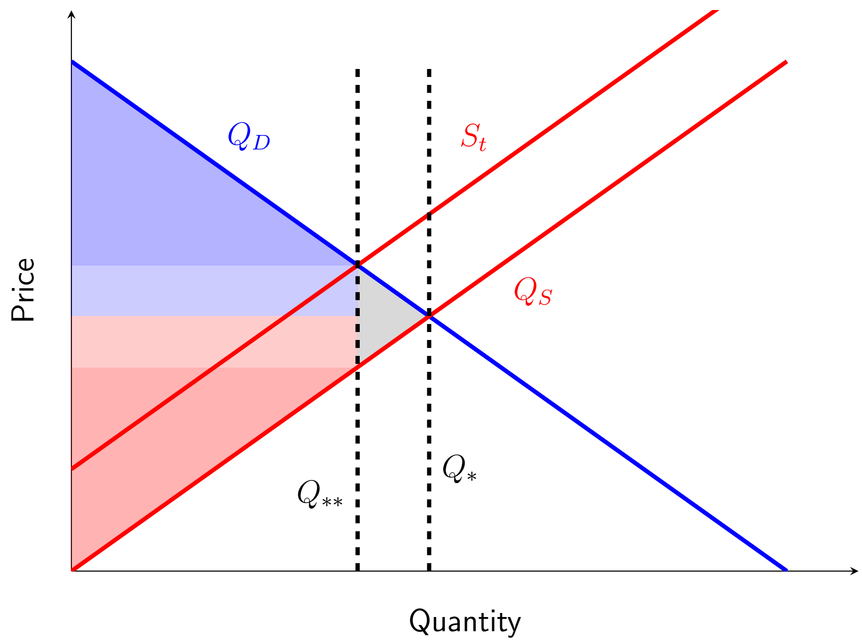
Indirect interventions describe factors like taxes or subsidies. Taxation is usually used by governments to raise revenue. It introduces a *tax wedge* between price paid by buyer and the price received by sellers. If the tax is imposed on the seller, sellers are only willing to sell if the price they receive is $\$t$ higher than their cost, so the supply curve shifts to the left; $MC = MC + t$. t can be a constant or percentage; it doesn't make much difference conceptually. Thus, taxation will increase P^* and decrease Q^*. Because of the reduction of demand, the seller is unable to pass the entire costs of the taxation to the buyer.

If the taxation is on the buyers side, we instead have the demand curve shifting to the left $MB = MB - t$. Thus, we experience a decrease in Q^* and therefore in P^*. Thus resulting in the same outcome as the seller tax in terms of effect on total surplus. Tax is given in all cases by $t = P_D - P_S$ where P_D is demand price and P_S is the seller price.

A subsidy is essentially a negative tax; $s = P_S - P_D$. It incentivises trade in the market. If applied to a seller, it will drive the supply curve down, lower price and increasing quantity. If applied to a buyer, it will drive the demand curve up, increasing demand and price.

Interventions and Welfare

The effect of taxation thus is to introduce a *deadweight loss*, a decrease in the total market surplus. This is because the perfect efficiency of the equilibrium is disrupted. In the case of a tax, this happens because the increased price of goods causes people to not purchase goods they would otherwise buy, resulting in a loss of utility. In the case of a subsidy, consumers purchase goods they would not otherwise purchase, resulting in the sale of goods for below their production price, the difference in costs making up the deadweight loss.



This is illustrated in the above chart. The line S_t shows the supply curve under a tax on suppliers, with Q_{**} indicating the new equilibrium quantity traded. The lighter coloured block here shows taxation revenue for the government, which contributes to total surplus but is paid for by consumers and supplies. The blue section of this block is payed for by consumers, while the red section is payed by suppliers. The inefficiency introduced by taxation is apparent in the grey shaded triangle, representing deadweight loss of the system due to the tax.

Tax Burden

The effect of a tax will tend to be heavier on the side of the market which has the lower elasticity. This is intuitive when we consider that those for who price has little relevance to quantity will continue to interact in much the same way after a tax, while those with higher elasticity will be more likely to reduce quantity due to a tax.

The impact of a subsidy can be understood in much the same way. When a subsidy is applied, the supply curve is lowered. Thus Q_{**} will be larger than Q_* and the equilibrium price will be lower. An additional surplus will be introduced for suppliers and consumers, payed for by the government. The side with more elasticity will derive more benefit from the subsidy than the side with lower elasticity. Although the subsidy will create a surplus for consumers and producers, it will cost more than this surplus and thus net a deadweight loss.

Price Controls

Direct market controls can take the form of a price floor or price ceiling. For each of these, they are *binding* when they are set so as to affect the equilibrium price, so when they are above the equilibrium price in the case of floors and below in the case of ceilings. If they are not binding, price controls have no effect.

In the case of a binding price floor, an excess supply will be created due to the lower equilibrium quantity. This will lower the equilibrium quantity force and result in a loss of consumer surplus, due to reduced competition, and a change to supplier surplus, with a loss of volume but an increase of margin. It will introduce a deadweight loss, as the increase in supplier surplus will be less than the less of consumer surplus.

For a price ceiling, the inverse will occur, with an excess demand created. Once again, the equilibrium quantity will decrease and this will result in a loss of supplier surplus and a change to consumer surplus, suffering a loss of volume but increase in value per transaction. A deadweight loss is introduced in the lost volume.

Quotas

A quota imposes a maximum quantity traded for a good or service. To be binding, a quota must be below the equilibrium quantity. This will have the effect of setting the quantity to the quantity specified by the quota, thus increasing price to the relevant point on the supply curve. This results in a decrease in consumer surplus and a change in consumer surplus, having essentially the same effect as a price floor. Once again, it creates a deadweight loss.

Trade

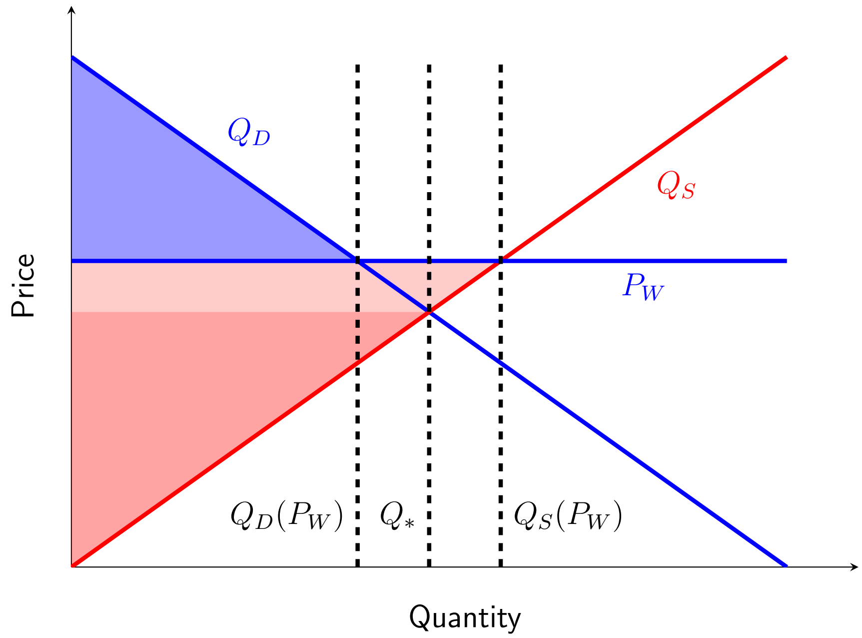
Countries trade because they have different resource endowments; some countries have a comparative or absolute advantage in certain industries, which allows them to produce these goods more efficiently, providing opportunities to increase total surplus through trade.

Despite the various benefits of trade, its impacts are not equally distributed; it can lead to inequalities, domination of smaller economies by larger ones causing national security issues, etc.

Comparative advantage arises when an entity can produce goods at a lower opportunity cost than their competition, while absolute advantage arises when a good can be produced with fewer inputs than used by their competition. In general, countries will produce more of the goods in which they have a comparative advantage, and export the excess, while they produce less of goods in which they suffer a comparative disadvantage.

Countries isolated from international trade are said to be in *Autarky*. This means that only domestic trade is possible in their economies. By considering a country in Autarky and comparing this to the resultant market after introduction of trade, we can understand the effect of trade on a market. The world market will usually be essentially pre-determined, making an individual country a price-taker, because it is too small to significantly effect the global market.

In the case that P_W, the world price is greater than P^*, the local equilibrium price, sellers who were selling at P^* will be able to export and so the local price P^* must rise to match P_W.



For local suppliers, this is excellent, as can be seem on the above graph. Their surplus has increased by the area of the light red section, with the section under Q_D to the left of $Q_D(P_W)$ coming directly out of local consumer surplus, and remainder constituting the surplus acquired through international trade.

In this case, the total added surplus for the local market is equal to the area of the small triangle in the centre. The gains made by the suppliers outweigh the losses of the consumers.

Intuitively, in the case that $P_W < P^*$, consumers will be bettered by imports of goods for which the country is at a comparative disadvantage, while producers will be harmed by the necessary reduction of P^* to P^W. Once again, the total surplus rises, though in this case at the cost of producers rather than consumers.

Trade and Interventions

An import tariff is a tax applied to goods imported from overseas. This reduces the comparative advantage of overseas goods, moving the market price closer to the Autarky price in the case of $P_W < P^*$. This will result in an increase of local supply of the good, by artificially making local goods more competitive.

This will be good for suppliers, but bad for producers. This tariff inevitably introduces a deadweight loss into the system, in addition to taxation revenue for the government.

Quotas have the effect of fixing the maximum quantity of good that can be imported. If a binding quota is applied to a good, it has the effect of setting the price of a good for a quantity up to the maximum of the quota, at which stage the normal local market behaviour resumes (in the case $P_W < P^*$). Thus, it will result in a lower price, but one which is less significant than is there was no quota. This results in a reduction in consumer surplus and an increase in producer surplus when compared with the equilibrium. There is a deadweight loss when compared with the unrestricted market. A quota introduces a benefit for those who have permission to fill the quota; because this is limited, not all everyone can benefit from it. A quota has essentially the same impact as a tariff, in that the losses are in the imports which don't occur due to reduced foreign comparative advantage.

Market Failure

We have seen thus far the perfectly competitive markets generate perfectly efficient outcomes, while government interventions tend to result in deadweight losses. However, the reality is that markets operating in an unfettered fashion often result in outcomes that are socially and or economically undesirable. An assortment of causes can cause market failures:

- Externalities
- Asymmetric information
- Imperfect competition
- Public goods

Externalities

A *negative externality* causes costs of others which aren't borne by the agent. This could be something like a consumer deciding to smoke in public; this can cause cancer for the people around them for which the smoker needn't pay. A *positive externality* occurs when a decision-maker's action causes benefits for others, which the decision-maker doesn't receive. An example could be vaccinations; if someone gets vaccinated, they protect not only themselves but those they come into contact with are saved from a disease. Because the costs of these actions are not borne by the decision-maker, they are often not considered when making decisions.

When considering a market, we look at the *private* benefits and costs of the individual. Thus, we can interpret demand as *private marginal benefit* (PMB) and supply as *private marginal cost* (PMC). Thus market equilibrium occurs at $PMB = PMC$ and Q^* maximises private net benefits. To consider a society's broader perspective, we can add *social* marginal benefits and marginal costs, to arrive at a socially optimal outcome Q^{**}. If $PMB = SMB$ and $PMC = SMC$, the market equilibrium is socially efficient. This balance can be disrupted by externalities. The following types of externalities can occur:

- Positive externality in production ($SMC < PMC$), such as between a beekeeper and orchardist. The more honey the beekeeper produces, the more efficient the orchardists farm. Thus, the beekeeper is effecting a net good for the orchardist, the benefits of which they don't see.

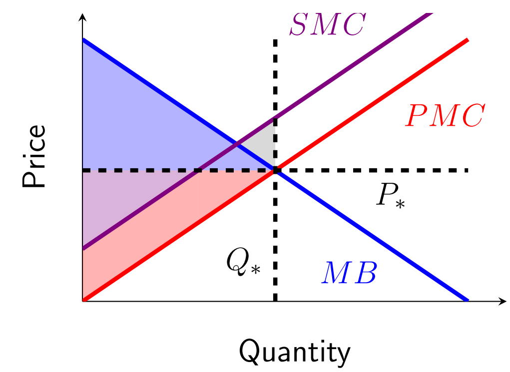
- Negative externality in production ($SMC > PMC$), such as in the case of industrial pollution. A dye factory may pollute a river system, reducing the efficiency of the downstream fishery causing social marginal cost to be higher than the private marginal cost of the polluter.

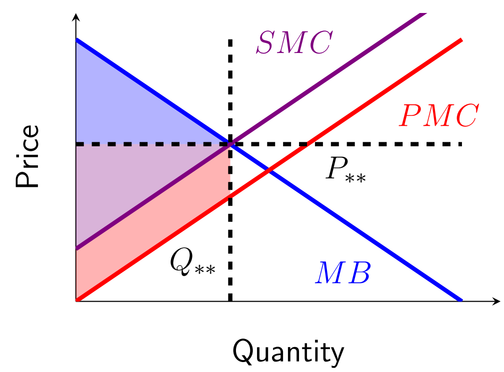
- Positive externality in consumption ($SMB > PMB$), for example vaccination. When one gets a vaccination, they contribute to heard immunity, a societal good.

- Negative externality in consumption ($SMB < PMB$), like smoking causing unpleasantness for those around them or incurring health care costs through a socialised health care system.

Example

In the above plots, the purple area represents social producer surplus; the surplus generated when considering social marginal cost, adding this to the red area yields the surplus considering private marginal cost of suppliers and the blue area is the marginal benefit of consumers (and society, as $PMB = SMB$





for this example). In this case, social loss caused by a negative externality is given by the sum of the areas where $PMC < SMC$. In the first case, that of market equilibrium (Q_*), there is a significant social cost, visible as the grey shaded region. This deadweight loss eats into the total surplus of the society. In the second case, Q_{**} or social equilibrium, the price is dependent on the social marginal cost of production, and thus the total social surplus is conserved, with no deadweight societal loss. Thus, it is clear that the perfectly efficient market doesn't necessarily result in the maximum social surplus. This is an example of how a negative production externality might leave to market failure.

For a different example, consider a postitive externality in consumption. In this case, there will be a deadweight loss at the market equilibrium because individual agents will lack the incentive to perform an action that will increase social surplus but not private surplus.

Accounting for Externalities

To coerce the market into behaving in a socially optimal fashion, a government can encourage people to internalise an externality; get agents to consider the social costs and benefits of their actions. If more force is required, a government can directly intervene in a market, through taxes, subsidies, quotas, etc. Here, a government is rectifying an inefficiency introduced by a free market, rather than distorting an efficient market as we have previously observed.

An example of such an intervention to rectify the case of a negative production externality is a *Pigouvian tax*. This is a tax on a producer equal to the difference between the social marginal cost and the private marginal cost, thus forcing the market into the social equilibrium state, though in this case with a slice of total surplus benefitting government rather than producers or suppliers. To be efficient, a Pigouvian must be *exactly* equal to the externality it aims to resolve.

Asymmetric Information

Asymmetric information occurs when one agent knows more than another. Because in an ideal market, both sides have perfect information, when this is not the case issues can arise. When there are goods of varying qualities and some sections of a market know more about these than others, market failures can arise. Goods are categorised into three categories for the purposes of information.

- *Search goods* have characteristics which are easy to evaluate pre-purchase, such as commodities, groceries or toys.
- *Experience goods* have important characteristics which are not easily observable at time of purchase, but which teh consumer learns about over time. These include used cards, haircuts and travel.
- *Credence goods* are goods where quality is both difficult to determine at time of purchase, and continue to be mysterious, such as vitamins, plumbing or education.

For experience goods, the seller generally has more information about the goods than the buyer. This creates asymmetry. Sellers with lower-quality goods may be more eager to sell goods than those with higher-quality goods, creating a situation known as *adverse selection*. This is where an offer from an informed party (usually the seller) reveals negative information about the product on offer.

Example

A classical example of adverse selection is the market for lemons, or used cars. In a situation where there are three grades of car:

- High, 10% chance of failure
- Medium, 50% chance of failure

- Low, 90% change of failure

And buyers value a working car at \$10000 and a non-working car at \$0, while sellers value cars at \$1000 less than the buyers. We then have these prices for cars in a market with perfect information:

Quality	Buyers	Sellers
High	\$9000	\$8000
Medium	\$5000	\$4000
Low	\$1000	\$0

Thus, we will essentially have three markets transacting at the buyer price for each car type. A total surplus of \$1000 per car will exist. Even if neither side knows what grade a car is in, we still have symmetric information. The value of a car becomes:

$$\frac{\$9000 + \$5000 + \$1000}{3} = \$5000$$
$$\frac{\$8000 + \$4000 + \$0}{3} = \$4000$$

And so, assuming that both sides are risk-neutral; that is they are happy to transact based on expected value, the three smaller markets combine into one larger market for all qualities of cars, essentially at random. Symmetry is retained, as is the surplus of \$1000 per car.

However, let us now consider an environment where sellers know the grade of their cars, but not buyers, one with asymmetric information. Buyers have the same valuation of a random car of \$5000, and so this would be the market price. However, sellers with high quality cars will not transact at \$5000, because they value their cars at \$8000. Thus, the market can contain only medium and low quality cars, changing the value to a buyer to $(\$5000 + \$1000) \div 2 = \$3000$. Disaster! As this is below the seller value of a medium quality car, they will also refuse to transact, and the market will be left selling only low quality cars, at a market price of \$1000. The total surplus will be only a third of what it would be if all cars where transacted. Total welfare drops and only the lowest quality goods are traded. This is adverse selection.

Accounting for Adverse Selection

A variety of mechanisms exist for government intervention to protect against adverse selection. These include:

- Legal systems (lemon laws in the US protect purchasers of new cars)
- Quality inspections and certifications
- Reputation systems, such as those used on eBay or Amazon
- Signals such as warranties and service agreements

Adverse selection is also prevalent in insurance; when purchasing insurance, the insuree generally has more information than the insurer. The insurer will be incentivised to price their insurance at the average cost for all people, which will disincentivise low risk individuals from purchasing insurance, thus driving up costs as the average risk of a customer increases. This disincentivises slightly less row risk people, and the death spiral has begun. Governments often resolve this issue in car insurance by mandating its purchase, thus forcing even the lowest risk drivers to purchase it. In the case of health insurance, universal health care can be an alternative that doesn't suffer this issue.

Moral Hazard

Moral hazard arises when one agent engages in risky behaviour because the other agent bears the consequences of this action. This is an issue in markets like insurance. For example, after obtaining health insurance one might (perhaps unwisely) take up unhealthy behaviours because the insurer will foot the bill for any medical issues. Moral hazard is another example of an issue with asymmetric information; the seller cannot monitor the buyers actions.

One way to resolve this is by transferring some responsibility to the buyer. If a car dealer offers a full warranty, and a driver enjoys driving recklessly, increasing the risk of the car breaking down, then the driver will do so as it costs them nothing for the duration of the warranty, and the cost to the dealer is increased. However, if the dealer instead offers a partial insurance, meaning that they will pay some portion of the costs associated with a broken car, but the buyer will also pay some, the driver is now disincentivised from driving recklessly and is more likely to drive safely. Thus the risk for the dealer is reduced and the incentive for bad behaviour from the buyer is removed. These systems are seen in practice in places such as:

- Insurance deductables, where insurees pay some fees upon a claim

- CEO payment schemes, where salary is perfomance dependent
- Grades, where students are incentivised to study

Firms

In the examinations of markets to date, we have generally considered small, independent buyers and sellers, a construct which aligns poorly with the reality of massive corporations. To remedy this, we now examine firms as a concept.

The role of a firm is to produce; to utilise inputs to produce outputs to sell onward to consumers. Firms offer a means of coordinating work. They have numerous benefits. They eliminate the need to negotiate each task a worker undertakes. They can internalise externalities in different layers of a production process, reducing losses. There are many varieties of firms, from single proprietor entities to larger corporations.

The most basic fact of a firm is, speaking economically, its *technology*, the method through which it transforms inputs into outputs. These inputs might include labour, capital or raw materials.

Example

Consider a bookbinding firm. The books are bound by a machine, an item of capital, which can bind 36 books per minute with a crew of 6 people. With less workers, more books can be output. The following table describes the quantity produced for each number of workers:

Workers	Output	$F(1, L)$
1	10	10
2	18	18
3	24	24
4	30	30
5	34	34
6	36	36
7	34	36
8	32	36
9	30	36
10	26	36

This is a *production function*, which describes the highest output (denoted Q) a firm can produce for every specified combination of inputs. While firms can use a wide variety of inputs, here we will consider labour (L) and capital (K). Thus, the production function, shown for $K = 1$ in the third column is:

$$Q = F(K, L)$$

As we add machines, the maximum productivity for higher numbers of workers will increase. While in this example the production function is discrete, in general we consider the production function as outputting an average, and so represent the production function as a continuous multi-variable function.

If we plot capital against labour, we can draw curves of $F(K, L) = n$ which show how a given quantity can be produced with different combinations of capital and labour. When describing productivity, we use the constructs of total and marginal product. Total product (TP) describes the total quantity of outputs given some inputs. Marginal product (MP) describes the increase in production from an additional unit of input. In the example of $F(K, L)$, we can find the productivity of labour by holding capital as a constant and taking the limit of L, i.e. take the partial derivative of F with respect to L.

$$MP_L = \frac{\partial F(K, L)}{\partial L}$$

We could do the reverse to find the marginal product of capital. In general, we assume that the law of diminishing returns applies to both quantities.

The profit of a firm is given by subtracting its total costs, what it pays for its input, from its total revenue, what it is paid for its outputs. The goal of a firm is to maximise this value. Let us assume a firm can sell each unit of output for p, must pay w for each unit of labour and r for each unit of capital. Then:

$$pF(K, L) - wL - rK$$

This is the equation which the firm seeks to optimise. While for a simple equation this is fairly simple, it will be more complex in a more realistic scenario. We can simplify the problem by considering that:

$$\pi(Q) = TR(Q) - TC(Q)$$

Where $\pi(Q)$ is the total profit for a given quantity. Here, $TR(Q)$ is simply pQ. However, it is a little more difficult to find a function $TC(Q)$. For this purpose we can look to our production functions. We can plug in the costs of each unit of production and capital to our production function and define $TC(Q)$ to be the lowest cost combination of different inputs to the production function to produce Q units.

The slope of this function will be governed by the relative costs of capital and labour. If the two are roughly in balance the function will track $x = y$, if labour is more expensive it will favour capital, etc.

To maximise $\pi(Q)$, we can differentiate it.

$$\frac{d\pi(Q)}{dQ} = \frac{dTR(Q)}{dQ} - \frac{dTC(Q)}{dQ} = MR(Q) - MC(Q)$$

If we set this equal to 0 to maximise the function, we find that

$$MR(Q^*) = MC(Q^*)$$

Time and Costs

While conceptually we can simply try and maximise this function, in reality it can be difficult to vary inputs like capital. Thus, we define two *time horizons*. In the short term, only one variable can be changed, usually labour, while in the long term, all variables can be changed. The function examined previously was for the long term, as it was assumed that all inputs could be adjusted.

In the short run, we have costs which do not vary with the level of output, as the input cannot be varied. These are fixed costs. In addition, we have variable costs, which are dependent on quantity.

$$SRTC(Q) = FC + VC(Q)$$

For our example of the bookbinder, we can consider a situation where the machines are rented on a yearly contract. Say that 2 machines have been rented for a 1 year period. Thus $F(2, L)$ will give the variable costs. Here, Q is capped at 72, because the maximum production for a single machine is 36. In this case, the short run function will only coincide with the long run function in the case that 2 units of capital is optimal. The long run function will always be less than or equal to the short run function, because it can always take the value of the short run function, but can additionally make other optimisations.

Firms generally operate in markets which are quite changeable over both the short and long runs. They are influenced by factors such as the behaviour of their competitors, the present market conditions and externalities. To maintain viability, they need to solve problems often revolving around these issues:

- What technology should the firm use?
- How much should the firm produce?
- When should the firm exit the market?

To answer these, the most useful tool is usually an accurate picture of the costs involved. We can use not only long-run total costs and short-run total costs, but a variety of other, more specialised costs.

- Long-run total costs ($LRTC(Q)$) are the total cost of producing a quantity Q units with the optimal technology and inputs.
- The long-run average total cost ($LRATC(Q)$) is the cost per unit for long-run costs. $LRATC(Q) = LRTC(Q) \div Q$
- Fixed costs (FC) are short run costs which cannot be changed and are not dependent on quantity, but can be recovered by shutting down the firm. Most often capital costs.
- Variable costs ($VC(Q)$) are the short run costs which vary with Q. These include things like labour and material costs.
- Short-run total costs ($SRTC(Q)$) describe the total cost of producing Q using the best possible combination of variable inputs. $SRTC(Q) = FC + VC(Q)$.
- Short-run marginal costs ($SRMC(Q)$) describe the cost to increase Q by 1 unit. This is given by the rate of change of the short-run total costs, or equivalently, the rate of change of the variable costs.
- Average fixed costs ($AFC(Q)$) are the average fixed cost per unit at a production level of Q units. $AFC(Q) = FC \div Q$
- Average variable costs ($AVC(Q)$) are the average variable costs per unit. $AVC(Q) = VC(Q) \div Q$

- Short-run average total cost ($SRATC(Q)$) describes the average cost per unit in the short run for Q units.
  $SRATC = SRTC(Q) \div Q = AFC(Q) + AVC(Q)$

- Sunk costs (SC) are costs that have already been paid and *cannot* be recovered by shutting down. As these costs are already lost, they have not influence on future decision making.

Choice of Technology

Let us consider first the behaviour of short-run average costs. This is a per unit measure, made up of the sum of the average fixed costs and average variable costs. Average fixed costs is a constant divided by Q, and thus must be a declining curve. Variable costs are usually increasing functions of Q, because of diminishing returns usually at an increasing rate. Thus, the shape of a short-run average cost curve is usually U-shaped, with high costs due to fixed costs at low Q values, and high costs due to inefficiencies in variable costs at high Q values. The lowest average cost is somewhere in between.

When a firm is considering which technology to use, the trade off is often between an option with a higher capital cost and a lower marginal cost and an option with a lower capital cost but higher marginal cost. Equivalently, it might be said that the first option has a constant marginal product while the second has a diminishing marginal product.

The case of an option with a lower capital cost and lower marginal product is defined by an increasing average variable cost and decreasing average fixed cost, resulting in the U-shape. In this case, the marginal cost will increase. This is because the slope of the average cost is increasing. This marginal cost function will eventually intersect with the short-run average total cost function at the minimum of the function. This is intuitive when we consider that the average total cost can only increase when the marginal cost of creating another unit is greater than the average cost of producing a unit.

For the case of a higher capital cost and a constant marginal product, the short run marginal cost and average variable cost will be constant over all quantities. In this case the short run average total costs will decline with increasing quantity.

In the long run, the firm can choose between either of these, and thus will choose the method with the lowest cost for a given quantity. Therefore, the long run average total cost for a given quantity is always less than or equal to the short run average total cost. In the example, for a low quantity the option with lower capital costs will be more efficient while for a high quantity the option with higher capital costs will be more efficient. The long run average total cost will be the minimum of the two.

In a general example, the restricting factor for short run average total cost is capital, and the ability to change this in the long term results in dramatically more flexibility. This means that while it might be inefficient in the short term to dramatically increase production, the long term capacity is significantly higher. Low quantities of production will tend to be inefficient because they struggle to justify their capital costs and extremely high production quantities will struggle to garner enough capital to produce efficiently. Thus the *efficient scale* will lie between the two.

Firms in Markets

We have examined how firms make decisions around technologies and inputs to minimise costs. Now we move on to consider how firms should act in the context of a market. How should the firm behave when a change in the market occurs? In a perfectly competitive market, there are many suppliers, with free entry and exit and essentially identical products. These characteristics essentially imply that firms are price takers.

A firm aims to produce the quantity Q^* which maximises the profit function $\pi(Q)$. Only when this value is positive will the firm operate. For a producer the demand curve is essentially flat at the optimal price P^*. Thus the total revenue of the firm is given by

$$TR(Q) = P^* \times Q$$

The rate of change of this value is the marginal revenue, and the average revenue is given by $TR(Q) \div Q$, which will simply be P^*. Because the additional revenue generated by selling one more unit is also P^*, we can see that

$$MR = AR = P^*$$

If we assume that the marginal costs of the firm are an increasing function, this function must intersect with the marginal revenue at some stage, which will be the optimal quantity for the firm to produce.

$$MR(Q^*) = P^* = MC(Q^*)$$

The total profits are then going to be given by $TR(Q) - TC(Q)$, or in per unit terms, the price minus the average total cost multiplied by the quantity:

$$\pi(Q^*) = Q^*(P^* - ATC(Q^*))$$

Considering that a firm will only operate when it can gain profit from doing so, we find that for a firm to be happy to operate in a market

$$TR(Q^*) \geq TC(Q^*)$$

These total costs reflect opportunity costs, but not sunk costs. These facts tell us that over any time frame, the firm should continue to operate as long as the market price is greater than its average total costs for that time frame. Thus, the supply curve is dependent on the marginal costs above the minimum average total costs in the short term.

Using this understanding of the behaviour of a single firm, we can begin to consider how the market as a whole behaves as an aggregate of supplying firms. Once again, we need to make a distinction between short run and long run supply. In the short run, no firms can enter the market, and firms can adjust only their short run inputs. In the long run, any number of firms may enter the market and all inputs are variable. Thus, the total quantity supplied at a given price will be

$$Q_s(P^*) = \sum_{i=1}^{n} Q_i^* P^*$$

Because all of the individual firms have an upward sloping supply curve, the overall curve will share this behaviour. No firms will enter, and only firms that would prefer to shut down in the short run will close. Whether a firm i profits in the market is dependent on

$$P^* \lesseqgtr SRATC(Q_i^*)$$

i.e. whether the price is less or greater than the short run average total costs for the firm at its optimal price Q^*. If a firm shuts down, it will suffer accounting losses equal to its sunk costs. In the short run, the quantity supplied will match the quantity demanded, and this will yield P^* at intersection.

In the long run, the behaviour of the market is more flexible. If firms are profiting in the short run, additional firms will be incentivised to enter the market, increasing supply and lowering price. This process will continue until the final firm to enter the market has an economic profit of 0. In reverse, firms earning negative accounting profits will exit until the last remaining firm has 0 economic profit. This implies that in a long run market, with identical firms, each firm will make 0 profits and have a horizontal supply curve. A somewhat strange result.

We can understand this by considering the impact of a demand shock. If prices rise, in the short term profits will increase for all firms, but in the long term further firms will enter the market until the newest firm has a neutral profit. Thus a demand shock will, in the long run, induce a change in supply but no change in price. This only applys however, if all firms are identical. If a new firm have a higher $LRATC$ than older firms, prices will not fall back to old levels because the facilities do not exist to produce additional goods at the old price. Firms will have an increasing supply curve. If a new firm has a lower $LRATC$, then prices will fall below the initial price, and firms will have a decreasing supply curve.

Accounting Profit

Accounting costs and profits are distinct from economic costs and profits. This is because accounting costs include sunk costs. This lead to slightly different definitions of accounting costs and profit

- Accounting costs are given by $SC + FC + VC(Q)$
- Accounting profits are given by $PQ - SC - FC - VC(Q)$
- Opportunity or economic costs are $FC + VC(Q)$
- Economic profit is $PQ - FC - VC(Q) = Q(P - ATC(Q))$

Market Power

While thus far we have examined the behaviour of firms in perfectly competitive markets, we can also consider situations where firms have the ability to affect the market price; where they have *market power*. If a firm has market power, rather than being a price taker, they become a *price maker*. A variety of market structures can arise from different combinations of firms.

- Many firms with identical products create perfect competition, such as the market for wheat or milk.
- Many firms with differentiated products create monopolistic competition, such as in the case of novels or films.
- Few firms in a market create an oligopoly, such as for tennis balls or retail groceries.
- If a single firm is the only supplier, a monopoly exists such as for tap water or electricity.

The only market structure where a firm can't impact prices is one with perfect competition. This is precluded by barriers to entry; if a market is difficult or impossible to break into, the number of competitors is very limited, such as for airlines. The other factor that can create market power is product differentiation; if a firm can make their specific product more attractive they gain market power. An example is Apple's massive efforts at branding. We can see from this that market power is inversely related to competition.

A firm with high market power has a high potential to influence prices, which can be represented as a steep demand curve for the firms products, as compared to the horizontal demand curve for products in a highly competitive market. We can use an inverse demand curve to represent market power. As opposed to $Q(P) = 100 - 5P$ we can write $P(Q) = 20 - \frac{1}{5}Q$, which tells us the maximum price a firm could set for a given quantity. For a firm in this position, total revenue is given by

$$TR(Q) = P(Q) \times Q$$

Which tells us that average revenue is simply $P(Q)$ for a given Q. Because optimal quantity is given by $MR = MC$. We can take the derivative of total revenue to find marginal revenue:

$$MR(Q) = AR(Q) + Q\frac{dP(Q)}{dQ}$$

Because we know that the derivative of our demand curve is negative, this tells us that our marginal revenue is below our average revenue. We can find

$$P(Q) - MC(Q) = -Q\frac{dP(Q)}{dQ}$$

This statement represents the marginal gain from a single additional unit of quantity. Here, the statement on the right is the *inframarginal loss*; the loss of revenue from the decrease in price. If we divide through by $P(Q)$ we find

$$\frac{P(Q) - MC(Q)}{P(Q)} = \frac{1}{-\frac{dQ(P)}{dP}\frac{P(Q)}{Q}} = \frac{1}{\epsilon_D}$$

This equation is where we find our representation of market power. The left hand side term is the percentage amount that a firm can raise its prices above its marginal costs, its market power, known as the *Lerner Index*. This value is inversely proportional to the elasticity of demand, which makes sense. The more elastic a market, the less a firm can raise its prices.

An interesting property of this is that even though the company is a monopoly, fundamentally it must still produce a number of goods appropriate to the consumer demand. In the case of a monopoly no real supply curve exists; the firm should simply produce the appropriate amount for the demand.

A problem with a monopoly can arise; the goal of the monopoly firm is to maximise its individual surplus, not social surplus. Thus, it can often be in the firms interest to produce a lower quantity which increases its own surplus but reduces the consumer surplus, resulting in a deadweight loss to society. This is almost inevitable; monopolies create inefficiencies.

These issues can be addressed through a few means:

- Pro-competition policy, to promote competition.
- Direct regulation, breaking up monopolies through e.g. antitrusts.
- Public ownership of the monopoly.

An example policy is the pharmaceutical benefit scheme in Australia, which sets a price for new prescription drugs, and pays a subsidy to the monopoly producer to make up the losses incurred due to this maximum.

Price Discrimination

Thus far, we assumed that a firm sets a constant price for the same goods to all consumers. We know consider whether a firm with market power can increase profits by charging different prices to different consumers.

If a firm finds that certain groups, such as regions or countries, of consumers have a higher willingness to pay, they can sell their product to these groups at the highest price they're willing to pay for that specific region. Of course a firm can only set prices if they have high market power. The firm must also have information on consumer willingness to pay, in addition to distribution methods which allow for partitioning. In addition, arbritrage can undermine this segregation.

Price discrimination can increase overall welfare, because it allows a firm to make its maximal possible profits. However, it erodes consumer surplus because consumers will have the product priced based on their own willingness to pay. In this situation, each unit of product is sold to the customer who values it the most, and at the maximum price that customer is willing to pay. The efficient quantity is produced, but producers receive the entire surplus.

Of course, in reality firms don't know the willingness to pay of their customers and can't necessarily prevent arbitrage. We call this idealisation *first degree discrimination*. Two other variants exist. *Second degree* price discrimination occurs where consumers don't have observable information, but they reveal information by selecting a product. In the third degree, consumers have some characteristic, such as age, which provide information on their willingness to pay.

Despite its unfeasability, first degree discrimination can be used to understand many real world systems. An example is why pharmaceutical firms pursue drugs over vaccines in the vast majority of cases. All of these products have massive upfront fixed costs and comparatively very minor variable costs. They have very high positive externalities, the existence of medical goods has positive social impacts. Thus to encourage development, governments offer patents to the developers of drugs. Incentives nonetheless skew developments; for example, firms are incentivised to develop drugs for wealthier groups, such as middle class people in first world countries, such as cholesterol drugs as opposed to drugs for poorer groups in third world countries, like drugs for tropical diseases.

For these poorer groups, vaccines tend to be much more effective than drugs. However, they are extremely under provided. This can be understood as the result of price discrimination. In the case of a drug, a firm can sell it at a high price to those who suffer a disease, while for a vaccine the firm must try to distribute it widely at a lower cost. The reason the firm chooses the drug is because all of its consumers are effectively the same in this case, meaning the firm need only determine the value of not having the ailment in order to allow it to use price discrimination, while for a vaccine, individual differences exist which are not apparent to the firm, precluding first degree discrimination.

Third degree price discrimination occurs in situations where characteristics of a consumer give the supplier information about a consumer. An example of this can be constructed as the market for movie tickets. If we take two different demand curves for adults and students we can solve each of them seperately to find the optimal price for each group

$$Q_A = 100 - P$$

$$Q_S = 160 - 2P$$

Assuming a constant price of 20 per unit sold we can find the optimal quantity for each of what is now effectively two monopoly markets.

$$\pi_A = Q(P)P - Q(P)20 \ = (100 - P)(P - 20)$$

$$\pi_A' = 0 \Rightarrow P = 60 \quad Q = 40$$

$$\pi_S = (160 - 2P)(P - 20)$$

$$\pi_A' = 0 \Rightarrow P = 50 \quad Q = 60$$

Thus, the firm should set a price for students of 50 and for adults of 60. We can compare this to a situation without discrimination by considering that the combined demand curve is simply the sum of the two. We know that the optimal overall price will be somewhere between 50 and 60, and calculating using the summed demand curve we find that $P^* = 53.3$ and $Q^* = 100$. In this case, surplus for consumers is higher than in the case of a price discriminated market; though most of this gain comes from the adult group who are less price sensitive, with the price sensitive student group actually losing surplus in the aggregate market. This is an echo of the general case; the price of a more inelastic market will increase while for an elastic market the price will decrease.

In the case that a group would not be served without price discrimination, total welfare actually increases under price discrimination, while if the total quantity decreases due to discrimination welfare decreases.

Second-degree price discrimination is the situation where the monopolist has no observable signals and thus must use the actions of consumers to use about them. It is a strategy that is often pursued by real world firms, who design their product offerings around the concept. They can offer specific goods in certain configurations to appeal to different groups, such as in different specifications on electronic devices or luxury offerings in cars like leather finishing. Through these different qualities, the producer can extract information from a consumer.

A consumer may desire to present themself as having lower willingness to pay by selecting a lower cost option, which incentivises sellers to discourage this behaviour. An example is in airline flights, where first class passengers are treated to short queues and luxurious settings while economy options suffer far worse conditions, in order for the airline to incentivise anyone who can afford such to select the first class option. In general terms, the firm needs to design a suite of options that incentivises customers to reveal their willingness to pay. The firm generally wants to reduce the quality of the lower end goods to make the higher end offerings more attractive. In doing so, they encourage consumers to give up their willingness to pay.

As an example, consider a situation where there exist regular passengers, who are willing to pay 2500 for an economy flight or 3000 for a first class flight, and wealthy passengers who are willing to pay 4000 for an economy flight or 8000 for a first class flight. Here, to encourage the passenger to purchase the product intended for them, the business needs to set pricest such that the surplus derived from an economy flight is greater than from a first class flight for a regular passenger, and vice versa for a wealthy passenger. This could be accomplished by pricing first class flights at 5000 and economy flights at 2500; here, regular consumers will purchase economy flights because $2500 - 2500 = 0$ is the greatest surplus they can obtain while for wealthy passengers $8000 - 5000 > 4000 - 2500$ so the first class flight is the greatest surplus they can generate. This process involves considering *incentive compatability* between the two groups. Optimally, the airline should set the prices at 2500 and 6500, as this sets the surplus for the two options equal for the wealthy passengers, who will naturally choose the nicer option.

If the airline could reduce the value of the economy class to the wealthy passengers through a method that didn't reduce the value as much for normal passengers, the airline can raise the price of first class tickets. Once again, an incentive exists for the airline to make economy *truly awful*. The firm wants to promote its higher end, higher margin products, and as a consequence hurts the lowest classes. The benefits gained for customers with higher willingness to pay are known as *information rents*. By reducing the value of lower class goods, firms can shrink these rents. For consumption goods like milk, higher volumes may be priced differently to lower volumes.

As consumer privacy erodes, information rents erode alongside them. If privacy continues to degrade in coming years, the economy will be highly efficient, but with extremely low consumer surplus.

Game Theory

Thus far, we have analysed economic agents make decisions without overarching strategy. They make decisions based on environments which they accept as givens. In reality, the actions of agents (or *players*) are dependent on each other. We call these effects *cross-effects*. Game theory is used to study these. Two main branches of game theory exist.

- *Cooperative Game Theory* is used to understand bargaining and matching.
- *Non-Cooperative Game Theory* is the primary theory used in this course, and addresses players aiming to better themselves with purely selfish decisions.

Game theory is important in many scenarios such as auctions, markets or politics. It helps us analyse inter-dependencies among actions taken by decision makers, and make the best choices in strategic situations.

Game theory models are described as "Shakespearean". This is because of the way we define a game theory problem by splitting it into three parts, in a way like the setting or stage and actors, the actions the characters can take and the interactions between the actors.

- The environment; who are the actors in this situation, what information do they have and what are their goals.
- Market mechanism; what are the rules of the game, what are the mechanics of the situation.
- Strategic action; how do individual decisions affect those of other actors.

Games are often categorised as *simultaneous* games and *sequential* games. Simultaneous, such as rock-paper-scissors involved players making decisions simultaneously, without information as to the other players' moves. In sequential games, like chess, players take turns interacting with the game, with full information about their opponents moves. A few other pieces of important vocabulary are strategy, which describes the overarching gameplan of a player, with decisions for every possible situation and equilibrium, a situation where each player chooses a strategy which represents the best response to the strategies of other players.

A strategy should be deep enough to perfectly describe the action that should be taken in every possible situation. These can be *pure*, where the action taken in every situation is deterministic, or *mixed*, where the strategy incorporates a random element. An action is a single decision, a small part of an overarching strategy. In a game like rock-paper-scissors, the action taken is the entire strategy.

A *Nash* equilibrium is a situation where each player knows the strategy of each other player and has chosen the optimal response to these strategies.

Prisoner's Dilemma

Consider a situation where if one player "rats out" the other, that player receives a one year prison sentence and the other receives a twenty-five year sentence, while if both confess they each receive a ten year sentence. If neither confesses, each will receive a three year sentence. We can examine this, effectively a simultaneous game, through a game table. Here a, b indicates the value of the outcome to player a, the player whose options are on the left and to player b, the player whose options are along the top.

	Confess	Not Confess
Confess	$-10, -10$	$-1, -25$
Not Confess	$-25, -1$	$-3, -3$

Here we can introduce a new term: a *strictly dominant* strategy is one for which the payoff is always higher than for all other strategies. If a rational player has access to a strictly dominant strategy, they will choose it. If all players have access to a strictly dominant strategy the Nash equilibrium will be all strictly dominant strategies. In this case, both players can choose the strictly dominant strategy of "confess", and so they will. If either player chooses to confess, then it is optimal for the other player to confess, as they will receive a ten year sentence rather than twenty- five. If either player chooses not to confess, then it is optimal for the other player to choose to confess, because then they will receive a one year sentence rather than three.

There are a few main techniques for finding Nash equilibria. These include

- Cell-by-cell inspection, the process of selecting a cell and checking whether the payoff can be improved for either player by changing strategy. This process can be repeated until no improvement can be made, indicating an equilibrium.

- Elimination of dominated strategies. For a player, we can consider whether all possible outcomes of a decision would be improved by selecting a different move; i.e. if that move is dominated. If the strategy is dominated it can be eliminated from consideration. Repeated application of the process can collapse the decision pool to equilibria.

- Best-response analysis involves determining the best action for a player in response to each possible move of their opponent. In situations where the best response for each player is the same cell a Nash equilibrium exists.

As an example of elimination of dominated strategies, we can consider the tables below. Starting from the top left and moving left to right, top to bottom, they show the process of elimination of dominated strategies to find the Nash equilibrium of 5, 4.

	A	B	C	D
A	3, 1	2, 3	10, 2	7, 2
B	4, 5	3, 1	6, 4	7, 2
C	2, 2	5, 4	12, 3	8, 2
D	5, 6	4, 5	9, 7	9, 2

	A	B	C	D
A	3, 1	2, 3	10, 2	7, 2
B				
C	2, 2	5, 4	12, 3	8, 2
D	5, 6	4, 5	9, 7	9, 2

	A	B	C	D
A		2, 3	10, 2	7, 2
B				
C		5, 4	12, 3	8, 2
D		4, 5	9, 7	9, 2

	A	B	C	D
A		2, 3	10, 2	
B				
C		5, 4	12, 3	
D		4, 5	9, 7	

	A	B	C	D
A				
B				
C		5, 4	12, 3	
D				

	A	B	C	D
A				
B				
C		5, 4		
D				

In words, these tables tell us that for the row player (player 1), strategy B is dominated by strategy D, and so will never be played. In this case, C dominates A for the column player (player 2), and can be eliminated. Now B dominates D for player 2, so D can be eliminated. For player 1, C dominates both A and D, so only C will be played. For player 2, B is the best response to C, dominating C, so the equilibrium outcome is C for player 1 and B for player 2.

Let us consider another game, where two players split a dollar between themselves, by each choosing a value between out of 25c, 50c and 75c. If the sum is less than a dollar, each receives their chosen share, otherwise neither receives anything.

	25c	50c	75c
25c	25, 25	25, 50	25, 75
50c	50, 25	50, 50	0, 0
75c	75, 25	0, 0	0, 0

Our strategies learnt thus far would tell us that there are three Nash equilibria in this situation. However, reality doesn't seem to align with this outcome. We need further tools to properly analyse simultaneous games. Ideally, we would be able to indentify the most likely outcome, or the probability of each possible outcome. In this case, human psychology dictates a bias towards fairness which skews results toward 50c. Sometimes, however, there isn't a simple explanation.

Oligopoly

Oligopolistic markets involve a few competing firms, as opposed to the single firm of a monopoly or the broad competition of a perfectly competitive market. It turns out that game theory has important implications for the optimal behaviour of a firm participating in an oligopoly.

While at first, it may seem optimal for firms to collude and create a monopoly structure in the market, it turns out that there are incentives for a firm to deviate from this agreement if possible, and overproduce to increase profits. To understand this, we can consider a situation known as a Cournot duopoly.

Say two firms A and B exist, with identical marginal cost curves of $MC = \$100 \cdot 10^6$. Here, $Q_S = Q_A + Q_B$. The inverse demand curve is $P = 800 - Q_D$. What is the monopoly outcome for this situation?

$$MC = MR \Rightarrow Q = 350, P = 450$$

If the two firms cooperated, each should produce half of this quantity and receive half of the profits. Let us now examine if this is the best possible outcome for each player. Say firm B decides to produce this quantity. Should the other player choose to match? In essence, the demand curve has been shifted downward by the quantity produced by firm B, and so for firm A it looks like

$$P = (800 - Q_B) - Q_A$$

$$R = (800 - Q_A - Q_B)Q_A$$

$$MR = 800 - Q_B - 2Q_A = MC \Rightarrow Q_A(Q_B) = 350 - \frac{Q_B}{2}$$

The optimal quantity for firm A to produce is dependent on the quantity produced by B. This *best-response function* tells us that it is optimal for A to produce *more* than the monopoly amount. Thus, both firms have an incentive to deviate from the agreement, and each must try to react optimally to the others behaviour. To find the Nash equilibrium of this situation, we can use the best response function we found earlier.

$$Q_A = 350 - \frac{Q_B}{2} \quad Q_B = 350 - \frac{Q_A}{2}$$

$$Q_A^* = \frac{700}{3} = Q_B^*$$

The Nash equilibrium has each firm producing the same quantity, which is greater than the monopoly quantities. We can extend this concept to a greater number of identical firms by simply considering player A playing against $(n-1)Q_B$.

$$R = P(Q)Q_A = (800 - Q_A - (n-1)Q_B)Q_A$$

$$MR = 800 - (n-1)Q_B - 2Q_A = MC = 100 \Rightarrow Q_A(Q_B) = 350 - \frac{(n-1)Q_B}{2}$$

We can set $Q_B = Q_A$ because we know that all of the firms are identical and so the optimal quantity will be the same.

$$Q_A = 350 - \frac{(n-1)Q_A}{2} \Rightarrow Q_A = \frac{700}{n+1}$$

This yields the same result for our duopoly situation, and generalises to higher numbers of firms. As n increases, the equilibrium quantity converges to marginal cost, as in a perfectly competitive market.

Game Theory and Market Failures

Externalities and Coase's Theorem

Externalities, as explored earlier, are costs or benefits incurred by an agent who is not party to a transaction. Externalities can cause market failure because they are not accounted for in the private marginal costs and benefits of individual agents. Earlier we examined how Pigouvian taxes and direct regulation can be used to manage subsidies, and now we have the tools to explore market based solutions, using property rights over the externality to manipulate the behaviour of market agents.

An example of a situation where this was applied can be found in radio bands in the United States. In the early years of radio broadcasting, licenses for certain frequencies were sold by the newly formed FCC, solving the externality of clashing broadcasts on the same frequencies. However, as time passed the inefficiencies in this system became clear as legacy incumbent broadcasters prevented new players from entering the scene as they possessed the all important licences. Ronald Coase introduced a solution where licenses could be bought and sold independently of the FCC, between broadcasters, arguing that this system would allow private individuals to solve the externality independently of regulation.

The foundation of the was what is known as the Coase Theorem, that if property rights for an externality are established, and private parties can trade the externality at a low transaction cost, bargaining will necessarily result in an efficient outcome.

Consider a situation where a chemical produces chemicals, releasing pollutants into a lake shared with a boat hire company as it does so. In a situation with no regulation, an obvious Nash equilibrium is reached on the following table.

	0	1	2
0	0, 0	0, 14	0, 15
1	10, 0	10, 10	10, 5
2	15, 0	15, 2	15, -3

Because the chemical plant (row player) has no incentive to limit its output, it will always produce 2 units, and the best response of the boat hire company (column player) is simply to produce 1 unit. This is not, however, the socially optimal outcome of a 20 unit surplus. To rectify this, property rights could be awarded to either party.

In the case that property rights are awarded to the boat hire firm, it could simply ban pollution, forcing a move of 0 from the chemical plant, and ensuring a surplus for itself of \$15. However, it could instead charge the chemical plant a fee of \$10 per unit to pollute the lack. The chemical plant would have a surplus of \$0, and thus would be indifferent as to the outcome, while the boat hire firm would gain a surplus of \$20, the socially maximal surplus. By awarding property rights, a situation was constructed which ensured an efficient outcome in spite of a negative externality.

It would also work for the rights to be awarded to the chemical firm. In this case, the chemical firm could of course simply produce 2 units, gaining a surplus of \$15. However, this is less than the possible maximum. If instead the chemical firm charged the boat hire firm \$8 per unit, the socially maximal surplus would once again be attained, though this time with the surplus on the side of the chemical firm.

This is obviously an idealisation; in reality transaction costs, and other costs such as monitoring pollution levels make it difficult for an efficient outcome to arise. For this reason, Coase argued that it was important to ensure that the initial allocation of property rights was efficient, because the secondary market may not be able to find this outcome.

Public Goods

For a public good, such as national defence, two important characteristics need to be considered for proper management to occur.

- Are these goods *excludeable*? Can others be prevented from utilising them?
- Are these goods *rivalrous*? If one person uses them, is the quantity available for others reduced?

Goods that satisfy either of these two properties are *not* public goods. All goods can be categorised according to the following table, with most goods being private goods.

	Rivalrous	Non-rivalrous
Excludeable	Private goods	Club goods
Non-Excludeable	Common resources	Public goods

In a competitive market, public goods are under-provided, because they generally entail a positive externality in production, and the fact of non-excludeability leads to what is known as a *free-rider problem*: where people receive the benefit of a good without paying for it.

An example could be a Jeweller and a Cafe considering hiring security guards. Obviously, the marginal benefit of the Jeweller is much higher, but if the Jeweller hires guards both firms will benefit. The social marginal benefit can be found by adding the two marginal benefit curve. If a constant marginal cost of security exists, the Jeweller will hire security at its own marginal benefit, with the cafe hiring none as the cost is well above its marginal benefit. However, the cafe will nonetheless benefit from the security, and the quantity of security hired will be below the socially optimal level, where $SMB = MC$. This is an example of a *free-rider problem*.

It is difficult to find a private solution for this, and so government intervention is often required, through e.g. public provision of security. Alternately, they can assign property rights to create excludeability in the market, a solution less applicable to the example of security.

Sequential Games

We can apply the concepts we have studied not only to games with players in simultaneous games, but additionally in sequential games where one player moves after another. Strategies in this case are slightly more complex; for a player responding to an action, they need to have an action for each possible outcome.

We can analyse these situations by using a table as we have previously, but rather than placing the possible moves of the second player on the table, we can place their possible strategies, to find the optimal strategy. However, this representation has some issues with identifying suboptimal strategies. Thus, the representation used for a sequential game is a game tree. We first track down to the bottom of the game tree, and find the optimal outcome in each case. These outcomes become the strategy for higher layers of the tree. More or less a mini-max approach.

A Nash equilibrium found in this way is a *subgame perfect Nash equilibrium*. The key difference from a simultaneous game is that it essentially restricts the possibilities; instead of each player considering their response to each other player, only one person gets to respond.