Internet Economics and Financial Technology - Notes

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Contents

1 The Big Picture

Remark 1.1 - *History of Commercial Computing*

1950-60 Mainframes - slow; size of rooms.

1960-70 Minicomputers - slow; couple per rooms.

1970-80 PCs - faster; one per desk.

1980-90 LANs - distributed networks.

1990-10 Internet - world wide distributed network.

2010-20 Cloud Computing

Where does IT go next? Has it peaked as IT is almost fully diffused?

Remark 1.2 - *Economics in Computer Science*
Market Economics is a useful metaphor for new methods in computer science & engineering which deal with allocation of scare resources. This is field is known as *Market Based Control.* Algorithms in this field tend to model sellers & buyers, and are applicable across most problems in the field (from server allocation to automated stock traders).

2 Economic Principles

Definition 2.1 - *Externality*
The production or consumption of a good has an *externality* if it affects a third party who was not involved in the transaction. e.g. Pollution from production is a negative externality; education is a positive externality.

2.1 Micro-Economics

Definition 2.2 - *Microeconomics*
The study of the behaviour of individual economic actors (individuals & business) and how decisions are made based on the allocation of limited resources.

Definition 2.3 - *Production-Consumption Cycle*
Producers produce goods & services which consumers wish to buy. Consumers have a limited about of money so have to choose what to & to-not buy at given prices. Similarly, producers have a limited number of resources (raw, labour & capital) so need to decide what goods & services, at what price, to produce. These lead to the idea of supply & demand curves.

Definition 2.4 - *Supply and Demand Equilibrium*
The *Equilibrium* of a supply-and-demand curve is a *price* where the quantity demanded by all consumers is equal to the quantity supplied by all producers.
When there is *excess demand* prices will rise due to scarcity of supply. The increase in supply will reduce demand as some consumers will not be happy to pay the higher price, meaning a new (higher) *equilibrium price* will be reached.
If there is *excess supply* prices will decrease as producers try to encourage customers to buy their product over others, this will in turn attract new customers and cause some producers

out of business. A new lower *equilibrium price* will be reached.

Definition 2.5 - *Consumer Demand Curve*
A consumer's *Demand Curve* plots the quantity of a product a consumer is willing to buy for a given price-per-unit. These are typically downwards sloping as consumers prefer to pay lower prices. It is assumed a consumer will buy the quantity of units equal to the point where the *Demand Curve* intersects the market price.
The area under the curve, but above the *Market Price* is known as *Consumer Surplus*. This quantifies how much more a given consumer was willing to pay than the market price. The number of items a consumer is willing to buy at the *Market Price* multiplied by the *Market Price* gives the *Expenditure* for that consumer. Consumers want to maximise *Consumer Surplus*.
See `Figure 2`

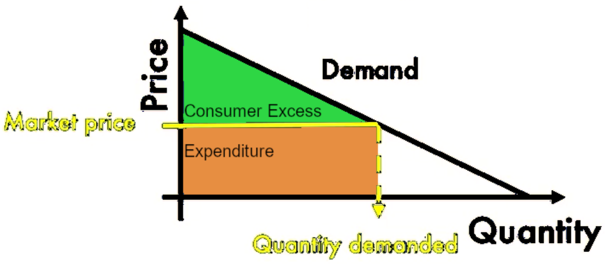


Figure 1: Consumer Surplus & Expenditure

Definition 2.6 - *Production Costs*
A producer will have costs they need to pay in order to stay in business. These costs can be categorised as

Fixed Costs A company must incur in order to operate, even before they start producing. (e.g. rent)

Variable Costs are costs which depend on the number of units produced. (e.g. equipment, raw materials)

Semi-Variable Costs Labour can be considered a variable cost as you can choose to pay overtime or to hire someone new in order to increase production.

The sum of these values will give you the *Total Cost* of production.

Definition 2.7 - *Marginal Cost Curve*
Marginal Cost is the cost of producing the last unit. It is equal to

$$\frac{\text{Change in Cost}}{\text{Change in Quantity Produced}}$$

We can plot a *Marginal Cost Curve* of marginal cost against quantity. Typically these are initially downwards sloping, then upwards sloping.

Definition 2.8 - *Economies of Scale*
When the *Marginal Cost Curve* is downwards sloping *Economies of Scale* are being experienced. *Economies of Scale* are the cost advantages a producer obtains by scaling their business. e.g. By hiring a new staff member existing staff are able to specialise better on their task and thus production per staff member increases.
When the *Marginal Cost Curve* is upwards sloping *Diminishing Marginal Returns* are being experienced. This is common as it is unlikely that hiring 10 new staff will increase marginal production by 10 times that of a single new staff member.

Economies of scale & diminishing marginal returns affect the *Cost Curve* for a producer.

Remark 2.1 - *Minimum Sale Price*
The *Marginal Cost* of a product is the minimum price a product must be sold at in order to make a profit.
A producer will go out of business if it cannot sell above its *Average Variable Cost* (per unit produced) in the short run; and if cannot cover its *Average Total Cost* (per unit produced) in the long run.
The point where these *AVC* & *ATC* curves intersect the *Marginal Cost Curve* define the minimum amount of units a business needs to sell to stay in business in the short and long term, respectively.

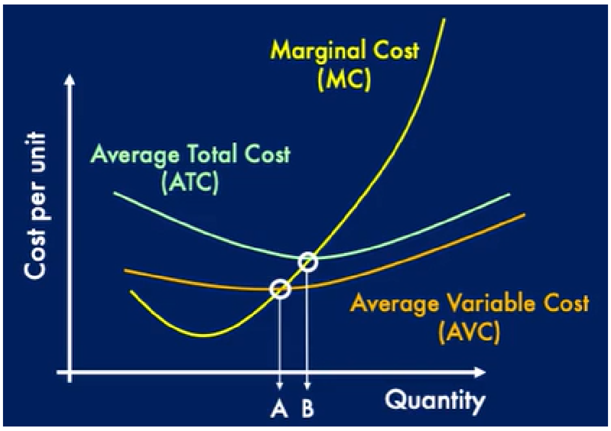


Figure 2: Cost Curve for a Product of a Physcial Retailor

Definition 2.9 - *Business Supply Curve*
A business's *Supply Curve* is the minimum price-per-unit it is willing to sell each quantity of product at. It tends to be upwards sloping as marginal cost increases with quantity. The *Supply Curve* will be truncated and not have a value for small quantities (in practice) as the business would fail if it sold too few products.

Definition 2.10 - *Market Supply Curve*
The *Market Supply Curve* is the total number of units available, for a given price, across all producers in a market.
The area above the *Market Supply Curve* and below the *Market Price* is the *Producer Surplus*. This is the total additional income a producer receives after costs (i.e. total profit). Producers want to maximise *Producer Surplus*

Definition 2.11 - *Competitive Equilibrium*
In a *Competitive Market* the *Market Equilibrium Price* will be that where the *Consumer Demand Curve* and *Market Supply Curve* intersect, as this is the price where quantity demanded and supplied are equal. The *Market Equilibrium Price* maximises total surplus for both consumers and producers.

Definition 2.12 - *Shifts*
Shifts can occur which move the whole of a supply or demand curve. These occur from non-price factors. e.g. a pandemic will cause a shift in the demand curve for face masks. These will cause a shift in *equilibrium price*.

Definition 2.13 - *Monopoly Market*
A market is considered a *Monopoly* if its structure is characterised by a single seller (The *Monopolist*). The *Monopolist* faces no competition and thus can be a price setter, rather than price taker. In the real world a firm with over 40% market share is considered to have a monopoly. Monopoly markets are not competitive.

Definition 2.14 - *Pareto Efficiency*
An allocation is *Pareto Efficient* if no-one can be made better-off without someone else being made worse-off. Pareto efficient allocations can arise from free markets, despite traders acting only to serve themselves (the *invisible hand* guides them).
Free markets are not *guaranteed* to achieve optimal allocations. Some conditions under which this fails are well known (e.g. monopolies).

2.2 Elasticity

Definition 2.15 - *Price Elasticity of Demand*
Price Elasticity is a measure of the how much the price of a product affects the quantity demanded. The more horizontal the demand curve, the greater the quantity demanded increases for a given decrease in price, (i.e. the more elastic the price is).

- A *Horizontal* demand curve has *Perfect Price Elasticity* as a change in quantity has no affect on price.
- A *Vertical* demand curve has *Perfect Price Inelasticity* as a fix quantity is demanded, at any price.
- A *45 degree* demand curve has *Unit Price Elasticity* as an $\Delta\%$ change in supply will produce an $\Delta\%$ change in demand.

Definition 2.16 - *Price Elasticity of Supply*
Supply Elasticity is a measure of how much a change in quantity supplied will affect the cost of production. The more horizontal the *Supply Curve* is the less the price of production increases for a given quantity.

- A *Horizontal* demand curve has *Perfect Price Elasticity* as a change in quantity has no affect on price.
- A *Vertical* demand curve has *Perfect Price Inelasticity* as a fix quantity is demanded, at any price.
- A *45 degree* demand curve has *Unit Price Elasticity* as an $\Delta\%$ change in supply will produce an $\Delta\%$ change in demand.

2.3 Price Discrimination

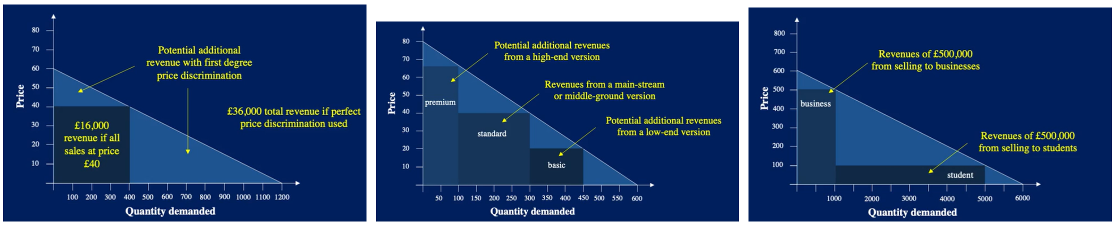
Definition 2.17 - *Price Discrimination*
Price Discrimination is the practice of charging different prices to different customers for the same product. There are three levels of price discrimination

1$^{\text{st}}$ Degree *Personalised* pricing. The business charges the maximum possible price for each unit sold (perfect price discrimination).

2$^{\text{nd}}$ Degree Product *versioning* or *menu pricing.* A company charges a different price for different quantities/qualities (ie bulk discount). Consumers have a choice over which version they buy, and thus the price. Here the discrimination depends on the product bought, rather than on characteristics of the customer, and encourages customers to self-select/

3rd Degree *Group* pricing. The business charges a different price to different customer groups (e.g. age,location). The consumer does not get to choose their group. The groupings try to separate customers by their *price elasticity* (The more price elastic charged less).

See `Figure 3`



(a) 1st Degree (b) 2nd Degree (c) 3rd Degree

Figure 3: Potential revenue increases for different pricing strategies

Proposition 2.1 - *Requirements for Price Discrimination*
For a seller to be able to effectively price discriminate they must fulfil the following

i). Be able to *distinguish between customers* so as to know what price to charge them.

ii). Have enough *market power* to be able to set prices above marginal costs.

iii). *Resale* must be impractical to prevent arbitrage.

It is generally easier for online business to meet these criteria.

Remark 2.2 - *Loyalty Schemes*
Loyalty schemes can be considered 2nd degree price discrimination. Loyalty schemes can be a useful way of profiling customers and thus contributes to other forms of price discrimination.

Definition 2.18 - *Price Steering*
Price Steering is when search results are personalised to place more/less expensive results at the top of the list. This encourages customers to spend at that price point due to placing an anchor, but the customer is still free to choose any product.

Definition 2.19 - *Net Utility*
The *Net Utility* of a product to a consumer is the difference between the price of the product and the consumer's perceived value of the product. (e.g. If a product is sold at £5 but a consumer values it at £7, the net utility is £7-£5=£2). It is assumed a customer will never by a product that has a *negative net utility* to them.

Example 2.1 - *Economics of Versioning*
Suppose we have a product priced at £10. Consider two customers: *addict* who values it at £20; and *casual* who values it at £8. The company will sell a single unit (to *addict*) at £10.
Now, suppose the company brought in a *cut-down* version at £5 which *addict* values at £8; and the casual user at £7. The company will now sell one full product (to *addict*) and one *cut-down* product (to *casual*) for a total of £15.
In fact, pricing the *cut-down* version at £7 and the *full* version at £19 would maximise profit (assuming customers go for the superior product when they have the same net utility for both) as this would be a perfect price for *casual* and the net utility is the same (£1) for *addict* for both products.

Proposition 2.2 - *Competing against Yourself*

A risk of versioning is that consumers who are willing to pay for the higher price, will choose to pay for the lower price one (due to greater net-utility). Thus choosing pricing points & functionalities is therefore critical to business success.

Proposition 2.3 - *Bundling*
Bundling is a form of *versioning* where several goods are sold together for a single price. (e.g. microsoft office). Bundling is used to sell customers products they would not otherwise buy. Bundling can create barries to entry for competitor producers as it requires competitors to produce a wider varity of product (e.g. a spreadsheet software & word processor rather than just one).

3 Economic Agents

Remark 3.1 - *CDA Curves in Practice*
The supply and demand curves for continuous-action double auctions are, in reality, stepped. This is due to the relatively few units for sale in the market

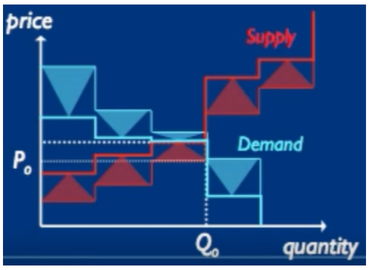


Figure 4: The arrows show the displacement from an agents hidden price and their quoted price

Proposition 3.1 - *No-one Trades their Marginal Price*
In practice sellers do not want to sell at their marginal price, nor do buyers want to buy at their maximum price. To avoid this both are advised to start a little away from these prices. These offered prices are known as *Quote Prices*. Quoted prices have their own *apparent* supply and demand curves which may be very different from the true curves. (See `Figure 4`).
The distance between the apparent and actual curves gives you the margin that agents are trying to achieve in the market. Agents should change their margin to reflect those of other people in the market. You would expect margins to decrease as the time since last transaction increases. Traders to the left of the equilibrium price can increase their margins to meet the equilibrium, while those on the right have to decrease.

Proposition 3.2 - *Dynamic Variation of Supply & Demand Curves*
In reality markets equilibriums are dynamic, as if the buyer and seller closest to the equilibrium perform a transaction they will drop out the market and a new equilibrium will need to be found. Also, new buyers and sellers may join the market. This is obvious in markets with very few units.

Definition 3.1 - *Experimental Economics*
Experimental Economics perform lab-style studies of human market-trading behaviours.

- A small number of human subjects are split into 'buyers' and 'sellers'.
- All traders are given a private-value/limit price which they cannot exceed.

- Traders interact within some market mechanism.

Experimental Economics has demonstrated rapid equilibration in CDAs with very small number of traders.

3.1 Metrics for Markets

Definition 3.2 - *Smith's α*
Smith's α is a measure of transaction price variation around the theoretical equilibrium price (as a percentage). Lower is better

$$\alpha := \frac{100}{P_0}\sqrt{\sum_{t\in T}\frac{(P_t-P_0)^2}{|T|}}$$

where P_0 is the equilibrium price and $\{P_t\}$ is the set of offered prices.

Definition 3.3 - *Allocative Efficiency*
Allocative Efficiency is a measure of how effecitve the market is at extracting *'gains through trade'*.

$$100 \times \frac{\text{Total utility earned by all traders}}{\text{Theoretical maximum possible total utility}}$$

Definition 3.4 - *Single Agent Efficiency*
Single Agent Efficiency measures how well an individual agent performs.

$$100 \times \frac{\text{Profit Earned}}{\text{Expected profit all all trades done at } P_0}$$

Proposition 3.3 - *Intelligence required for an allocative efficient CDA*
How much of the allocative efficiency of a CDA is due to the intelligence of the traders¿ And how much is due to the organisation of the market?
Experimental Economics demonstrated (in 1993) than a zero-intelligence trading agent (ZIC) which quoted random prices (but constrained not to trade at a loss) is surprisingly human-like. Suggesting most of the intelligence is in the market, not in the traders.

3.2 Trading Algorithms

Proposition 3.4 - *How ZIC Traders achieve an equilibrium*
ZI-C *sellers* generate offer prices at random in a range from the lowest seller limit price S_{min} and the maximum price allowed in the system P_{max}. This gives us a probability density function for offer prices which follows the supply curve.
ZI-C *buyers* generate offer prices at random in a range from the greatest buyer limit price D_{max} and the minimum price allowed in the system P_{min}. This gives us a probability density function for bid prices which follows the demand curve.
The intersection of these two distributions gives the distribution of prices at which transactions are done. See `Figure 5`. It is noteworthy that the expected values of these distributions are not equal as it means markets populated by ZIC traders achieve an equilibrium by chance (and will not reach an equilibrium in markets with assymetric supply and demand curves).

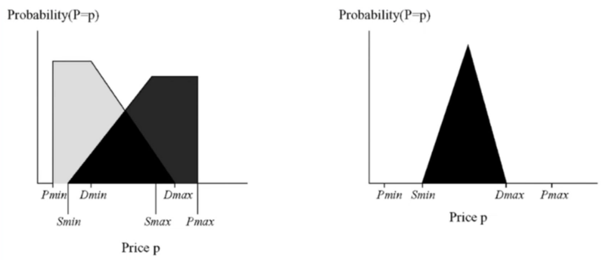


Figure 5: Distributions for offer, bid & transaction prices for ZIC Traders

Proposition 3.5 - *ZIP Traders (1997)*
ZI-Plus (ZIP) Traders are a more advanced form of *Zero-Intelligence Traders.* They still have a limit price which they cannot exceed, but also use machine learning in order to adapt. They have a *profit margin* which is the distance between the price they quote and their limit price, this margin is adjusted by the machine learning over time.
These have been shown to be much more human-like in CDA, than ZIC traders and achieves an equilibrium in cases where ZIC traders could not.

Proposition 3.6 - *ZIP Algorithm - Qualitative*
The algorithm a ZIP trader uses is as follows.
Consider a seller with limit price L. They will ask for a price $P := L(1+M)$ where M is some profit margin. If this price is *accepted* then increase M; otherwise, decrease M.
Buyers should do the inverse with their value of M.
The amount to change M by is determine by a *learning rule* (e.g. Widrow-Hoff with Momentum).

Proposition 3.7 - *ZIP Algorithm - Quantitative*
Let $_i$ denote the limit price of trader i; $p_i(t)$ denote the quote price of trader i at time t; and $\mu_i(t)$ denote the profit margin of trader i at time t. Then

$$p_i(t) = \lambda_1(1 +_i (t))$$

If $p_i(t)$ is accepted then $\mu_i(t+1) = \mu_i(t) + \textit{something}$; otherwise; $\mu_i(t+1) = \mu_i(t) - \textit{something}$ where the value of *something* is determined by a stochastically determined *Target price* and a learning rule aimed at achieving that price.

Proposition 3.8 - *ZIP Trader Target Price*
The target price τ_i should be slightly beyond the last quoted price in the market $q(t)$.

$$\tau_i(t) = A_i(t) + q(t)R_i(t)$$

where $R_i(\cdot)$ and $A_i(t)$ are stochastic functions for adjusting the last quoted price with $R_i(\cdot)$ being relative and $A_i(t)$ being absolute. These functions are defined by the learning rule.

Definition 3.5 - *Widrow-Hoff Learning Rule*
The *Widrow-Hoff* learning rule adjusts an observed value A towards a desired value D, at rate β. The rule is defined as

$$A(t+1) = A(t) + \Delta(t) \quad \text{where} \quad \Delta_i = \beta\big(D(t) - A(t)\big)$$

For ZIP a damping (momentum) factor $\gamma \in [0,1]$ is introduced

$$A(t+1) = \gamma A(t) + \Delta_i(t)(1-\gamma) \quad \text{where} \quad \Delta(t) := \beta\big(D(t) - A(t)\big)$$

In the context of ZIP this is defined as

$$\mu_i(t+1) = \frac{1}{\lambda_i}(p_i(t) + \Delta_i(t)) - 1 \quad \text{where} \quad \Delta_i(t) := \beta_i\big(\tau_i(t) - p_i(t)\big)$$

Giving

$$\mu_i(t+1) = \frac{1}{\lambda_i}\big(p_i(t) + \Gamma_i(t)\big) - 1 \quad \text{where} \quad \Gamma_i(0) := 0;\ \Gamma_i(t+1) := \gamma_i\Gamma_i(t) + \Delta_i(t)\big(1 - \gamma_i\big)$$

Proposition 3.9 - *Todd Kaplan's Sniper (1993)*
Kaplan's *Sniper Algorithm* is a robust and effective trading algorithm.
The trader does nothing until the bid-offer spread drops to a sufficiently small value <u>or</u> the offer is less than the smallest transaction price in the previous period <u>or</u> there is only a short time until the market closes. When one of these conditions is fulfilled the trader jumps in, as long as the deal makes the sniper a profit greater than some threshold, and *"snipes the deal"*.
Note that this algorithm does adapt to the market, nor does it help prices converge to an equilibrium. Moreover, it relies on there being other "more" intelligent traders in the market for it to leech off.

Proposition 3.10 - *GD Traders (1998)*
Gjerstad-Dickhaut (GD) Traders using an algorithm which is based on producing a estimate of the probability of a certain price being accepted. This is defined by the trader's *belief function* which uses data from the n most recent market activity.

$$f(p) = \frac{able(p) + ole(p)}{able(p) + ole(p) + rgbe(p)}$$

where p is the price being queried, $able(p)$ is the number of accepted bids at prices less than p in the last n; $ole(p)$ is the number of offers made below p in the last n; and, $rgbe(p)$ is the number of rejected bids priced above p, in the last n.

Proposition 3.11 - *MGD Traders (2001)*
MGD is a *Modified* version of *GD* with the follow considerations made:

- Use interpolation to smooth the function for prices which have not occurred in the market history.
- Choosing a quote-price which maximises the trader's expected gain (utility gain times probability of acceptance).
- Assign 0 probability for bids lower than previous lowest big, or offers above the previous greatest trade price.

Proposition 3.12 - *GDX Traders (2002)*
GDX is another extension of *GD* which uses real-time *dynamic programming* to formulate agent bidding strategies in a broad class of auctions characterised by sequential bidding and continuous clearing.

Proof 3.1 - *Adaptive-Aggressive Algorithm (2006)*
AA Traders uses past history to adjust it's *aggressiveness* (rather than profit margin) over time.
Aggressiveness quantifies how quickly it changes its pricing in response to market conditions.
AA Traders use an estimate of the current market equilibrium price P_0 (using past transactions) and *Smith's* α estimate of volatility to determine its level of aggression.

Proposition 3.13 - *Deciding which algorithm to use*
An analytical (game-theoretical) approach to choosing which trading algorithm is optimal is very hard and sometimes impossible. Some proofs require over simplifying assumptions which limit the end conclusion.
Instead *empirical studies* (simulation experiments) are used. This requires good *"Design of Experiments"* and appropriate statistical analysis of results.

Proposition 3.14 - *Design of Experiments*

- *Homogeneous Population Tests* assumes that all traders use the same algorithm. This is true in some cases (such as market-based resource allocation) but not many. This means only limited conclusions can be made.
- *One-in-Many Test* have all but one member of a trading population using the same algorithm. This explores the vulnerability of the dominant algorithm, and the ability of the alternative algorithm to exploit the market. IRL, if the alternative algorithm was better you would expect some other traders to defect.
- *Balanced-Group Test* have groups of equal size, each running a different algorithm but with matched limit prices. This is generally seen as the best test for comparing two different algorithms.

Simplex plots can be used to show the relationship between different ratio of traders.

Remark 3.2 - *The Best Algorithm*

- Balanced-Group Tests showed MGD to be superior to ZIC,ZIP & GD in all cases.
- Balanced-Group Tests AA was shown to out perform GDX & ZIP, in most cases. (Importantly AA is not dominant)

There are likely to be unpublished algorithms which out perform these.

4 The Economics of The Internet

Definition 4.1 - *Network Externalities*
A *Network Externality* is an *Externality* that occurs when the act of buying a product/serivce has an indirect cost or benefit to those who already own the same product/service. Products with <u>positive</u> network externalities are often known as *Network Goods*.
Owning a mobile phone has a positive network externality as you are increasing the number of contactable people. Owning a car has a negative network externality as you increase road traffic.
Positive network externalities can produce a *Positive Feedback Loop* where people by products which are compatible with their friends, rather than necessarily the best product. This is part of *Brand Value*.

Definition 4.2 - *Network Effect Demand Curve*
We can plot a *Network Effect Demand Curve* (`Figure 3`) of the price customers are willing to pay against network size. This is slope upwards initially as the marginal value of each extra user is higher; eventually it will slope downwards as these marginal gains diminish.
For any given price there are three equilibrium points q_0, q_1, q_2 for network size. q_1 is deemed unstable, the *'tipping point'*, as once the network is larger than q_1 it will naturally grow to q_2

(as there is a consumer excess) but whilst it is smaller it will shrink to q_0 (as there is a consumer deficit). This means q_1 is the *Critical Mass* for the network to be sustainable.

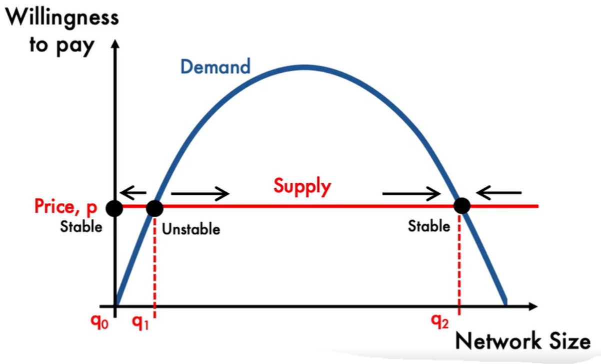


Figure 6: Network Effect Demand Curve

Proposition 4.1 - *The Long Tail*
Sales business typically sell either: high volume, low margin goods (e.g. burgers); Or, low volume, high margin goods (e.g. cars). Physcial sales businesses are constrained by the physical shelf space they have and thus avoid low volume, low margin goods. This means that the sales distribution for products in a physical store will be a truncated *Pareto Distribution.*

Internet businesses have unlimited shelf space to advertise products, and since warehouse space is much cheaper (per sq ft) they can store a lot more products for the same cost, effectively increasing the margin of each product. Meaning their are more products which are profitable to stock and the sales distribution for products of an internet business will have a much longer tail. (See `Figure 1`).

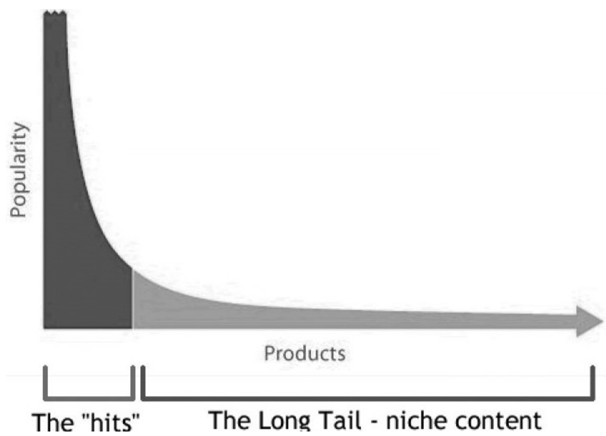


Figure 7: The Long Tail

Remark 4.1 - *How to take advantage of 'The Long Tail'*

i). Make everything available.

ii). Reduce prices (due to economies of scale & reduced costs).

iii). Help customers find new products.

Remark 4.2 - *Sustaining v. Disruptive Innovations*

Sustaining Innovations are those that incrementally improve existing products on traditional performance metrics. Eventually these will superceed customer requirements.
Disruptive Innovations perform less well on traditional performance metrics but sufficiently better along other metrics in order to generate new markets.

Proposition 4.2 - *Disruptive Technology*
Established companies are often late to invest in new *disruptive* technologies. Typically this is due to the *disruptive* tech not reaching the requirements of their customers. However, the *disruptive* tech maybe better in other ways (lighter, more durable etc.) and so can establish a sufficient market for startups to invest in it. Once the *disruptive* tech does reach the requirements of mainstream customers, they are likely to jump to the new tech for these bonus features (lighter, more durable etc.) and the established company may fail.
The new tech may still be less powerful than the established tech, but it is sufficient for customers so it doesn't matter. The traditional performance metric for performance will vary by industry (e.g. mb/£ for hard drives).

Proposition 4.3 - *Timeline of Disruptive Technology*

i). *Disruptive Technology* is invent. Often by an established company.

ii). The *disruptive technology* does not meet established the established company's requirements and so not focused on.

iii). New companies form to pursue the *disruptive technology.* Often by ex employees of the established company.

iv). *Disruptive Technology* improves & meets traditional performance metric requirements. The established company will likely try to enter the new market at this point but will be too late.

v). *Disruptive Technology* becomes the main stream.

Proposition 4.4 - *How to spot Disruptive Technology*

i). *Determine whether the technology is disruptive or sustaining*

4.1 Properties of Online Businesses

Remark 4.3 - *Economic Laws*
The *Economic Laws* are not fundamentally different between online & irl businesses, but the characteristics of online business activities can result in different markets.

Definition 4.3 - *Combinatorial Innovation*
Combinatorial Innovation describes a technology who's components can be combined & recombined to create new products and services. The Internet is a *Combinatorial Innovation* due to its standardised and open-source nature.

Proposition 4.5 - *Economic Differences between Digital & Physical Goods*

- Digital goods tend to be costly to produce; but *cheap to reproduce.* (i.e. Fixed costs are high but variable costs are low).

- Production costs for digital goods are <u>sunk</u> costs. (e.g. You can sell a building you don't need, but cannot get money back from a software developer).

- There are *no capacity constraints* limiting the number of times something can be reproduced.
- Digital goods are often *Experience Goods*. (i.e. a customer will no know whether they will like it before they try it, and thus cannot assign a value to it).
- *Serach Costs* for a consumer are very low. It is easy for consumer to compare products are go with the best. IRL this is harder as it requires going to different stores.
- Digital goods have *strong positive network externalities*

Remark 4.4 - *Switching Costs*
A customer may incur a cost (inc. non-monetary) to switch services. This is more common (and costly) in the digital space than the physical. When switching costs are too high, consumers are *locked in*. Possible switching costs include:

- Training cost.
- Network effects.
- Setup costs.
- Reduced service quality due to new provider not having all your information (consider switching from Netflix).

Proposition 4.6 - *Cost Curve for Digital Goods*
Since digital goods have high fixed cost but low variable costs their *cost curves* are very different. The *Marginal Cost Curve* is effectively zero for all quantities; Average Variable Costs are effectively zero for all quantities; and, average total costs tend asymptotically towards zero. This means it is easy for an online business to survive in the short term and the minimum price they are willing to sell a product at is zero (due to v. low variable costs). Eventually the company will need to pay off its fixed costs.

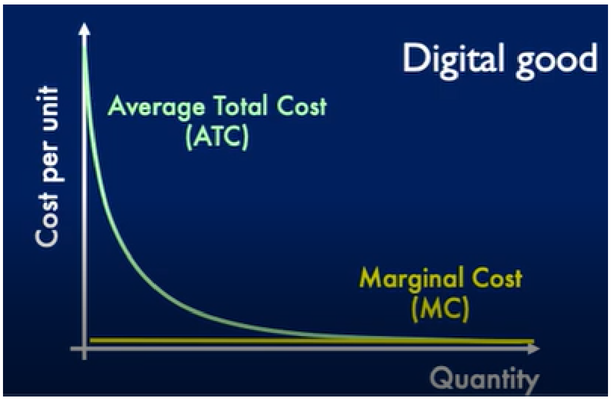


Figure 8: Consumer Surplus & Expenditure

Remark 4.5 - *Competition between Digital Companies*

- Due to low variable costs, companies with identical digital products will very quickly move prices to near-zero.
- New companies will struggle as fixed costs are high.
- Network effects & switching costs make it hard for new companies.

Due to these *barriers to entry* monopolies are common among digital companies. To succeed, a company needs to focus on product differentiation (i.e. innovation).

Remark 4.6 - *Formats*
Companies can make their software use *Proprietary Formats*, meaning the files cannot be used by other software. This increases switching costs for customers.
Using *Industry-Wide Standards* allow a user's files to be shared between providers. This can increase the network effect, potentially attracting new customers. Here companies have a trade-off between having a large part of a small pie, or a small part of a large pie.

Remark 4.7 - *How Standards Develop*
Industry-Wide Standards general develop in one of two ways

i). A *single (major) player* sets a standard by opening up their proprietary format (e.g. PDF).

ii). A *war* occurs between multiple standard setters. Generally detrimental to everyone involved.

iii). A *negotiation* occurs between multiple standard setters. There is a risk that one party may pull out of the deal and use their own proprietary format.

4.2 Price Discrimination Online

Remark 4.8 - *Personalised Pricing Online*

- Consumers tend perceive personalised pricing as *unfair*.
- Consumers like *transparency* (i.e. how a price is decided).
- European data protection laws *require* companies inform people about the specific purpose of processing their personal data.

Proposition 4.7 - *Digital Product Versioning*

- Digital versions are used extensively and creatively as they are easy to prepare and near-zero cost to duplicate.
- Buyers have a choice over which version to buy, so do not find the practice controversial.
- *Personalisation of Product* is an extreme typr of product versioning (becoming closer to 1^{st} degree price discrimination) as it allows user to specify many properties (e.g. screen quality, amount of ram & storage for a pc).
- People tend to *upsell* towards an "almost top option" when given a choice (the 2nd most expensive bottle of wine is often the most popular).
- Product versioning can cause you to *compete with yourself* as some people who would have payed the higher price, will go for the lower price.

Remark 4.9 - *Unbundling*
Bundling is common with physical software but there is also a practice of *unbundling.* Since there is no physical substrate online there is less commercial pressure to bundle. (e.g. publishers can sell individual articles rather than a full magazine).

Remark 4.10 - *'Free' Digital Versions*

As the duplication cost of digital goods is almost zero, many are given away for free. In these cases there are still several ways for producers to make money: cut-down versions encourage you to buy a full version; Artificial delay (e.g. stock feeds); Ads (or pay for no adds).
'Free' versions allow a customer to build a truer valuation of a product, particularly useful for *experience goods.*
Even if a user is on the free model they are building the *network effect* of the product and likely increasing the *swapping costs* they will experience if they want to change product.

Proposition 4.8 - *Freemium Model*
The *'Freemium'* business model is to offer different versions at different prices, *including a free one.* The hope is a consumer will *upgrade* to a paid version because they like the service.

5 Auction Theory

Remark 5.1 - *Why Use Auctions?*
Auctions allow an item to be sold for a price which is wholely decided by a consumer's willingness to spend. *Auctions* are a mechanism for first-degree *price discrimination*, this makes them particulary popular online.
Auctions are used when sellers are *uncertain* about the value consumers place on an object (common with one off items). In this case auctions are good as they allow for *price discovery.*
Auctions are easy to automate and a form of differential pricing.

Proposition 5.1 - *Auctions vs Posted Prices*
When a seller chooses to run either an auction or use posted prices, they are choosing whether between *price discovery* and *convenience.* Auctions are often favoured by unexperienced sellers and unique items. Auctions sell for less than a posted price listing (otherwise consumers would pay the posted price listing).

Definition 5.1 - *Private Value*
An object's *Private Value* is the value each consumer places on the object. Each bidder knows their private value for an object, but do not know the private value of others nor does knowledge of other bidders' private values affect your private value. This situation is common for consumable goods, less so with investments.

Definition 5.2 - *Interdependence*
Interdependence occurs when a bidder does know have a fixed value for an object and use other bids to improve their estimate of an objects value. This is common when other bidders may have more information.

Definition 5.3 - *Open Auction*
In an *Open Auction* all bids are known to all particpants.

Remark 5.2 - *Assumptions in Auction Theory*
In Auction theory several assumptions are made:

- All auctions are equally attractive (ie there are no auctions where no one turns up);
- There is no collusion between bidders;

These assumptions means auction theory often does not work well in practice.

Remark 5.3 - *Attendance at Auctions*
Entering an auction can be quite involved, so often bidders will skip auctions they don't think they can win.

Definition 5.4 - *Signalling*
During an auction a bidder may place a *'weird'* bid which signals their intent for the rest of the auction to other bidders. This is a form of collusion without any prior agreement necessary. (Consider the T-Mobile - Mannesbane auction for parts of the german telephone network).

Definition 5.5 - *Reverse Auction*
Reverse Auctions are when multiple suppliers bid for a contract with a single consumer. This is commonly used for construction & suppliment contracts, (inc. by governments).
Often suppliers must be *qualified* in order to *offer* a price.

Definition 5.6 - *Double Auction*
In a *Double Auction* multiple buyers and multiple sellers take part. The sellers offer descending prices, and buyers bid ascending prices. When two prices meet a sale is made between those two parties.
Continuous Double Auctions all buyers and sellers to place bids at any time, and not necessarily in order. This is used in stock exchanges.
Double Auctions are very efficient for price discovery.

Proposition 5.2 - *Trading in the Dark*
Sometimes you do not want to give away your private information (e.g. You dont want to list a large stock sale on a public order book as this would affect the stock price).
Dark Pools are designed to keep your trading intensions secret so that it does not impact price. WARNING it is common for dark pool owners to use this information against their users.

Definition 5.7 - *Posted Auction*
A *Posted Auction* is one where the seller posts a price and then buyers have an option to buy at that price (and that price alone). This is how most shops work.

5.1 Open Auctions

Definition 5.8 - *English Auction*
AKA *Open Ascending-Price Auction.* Used in *Homes under the Hammer.*

i). The auctioneer announces a (low) price to everyone.

ii). If a bidder is happy to pay that price they raise their hand. (Price is reduced if no one bids).

iii). Auctioneer will announce that that bidder is currently winning and will announce a new, higher price.

iv). ii)-iii) repeat until no-one accepts the new higher price (ie no hands are raised)

v). The item is sold to the person who bid last, at the price of that last bid.

Bidders can infer information from when others drop out of an auction. However, with *Private Values* this will not change their strategy (it would for *Interdependence*).

Proposition 5.3 - *English Auction - Optimal Strategy*
Let v be the private value a bidder assigns to an object

- It is not optimal for a bidder to bid a price p if $p > v$ as the bidder makes a loss.
- It is not optimal for a bidder to drop out at a price $p < v$ as the bidder still has surplus demand.

Therefore, the optimal strategy is to bid on any price p that does not exceed v.

Remark 5.4 - *Weak Bidders*
It is harder for a weak bidder to win an English auction as stronger bidders can just accept the next price.

Definition 5.9 - *Dutch Auction*
AKA *Open Descending-Price Auction.* Used in *Dutch Flower Markets.*

i). The auctioneer announces a (high) price to every.

ii). The auctioneer keep reducing the price until someone bids (raises their hand).

iii). The item is sold to this (first) bidder, at the price the auction was stopped.

Proposition 5.4 - *Dutch Auction - Optimal Strategy*
Shade you bid. i.e. bid $p < v$ where v is your private value.

Remark 5.5 - *Robustness*
Collusion is much easier in an open auction, meaning the auction is less robust.

5.2 Sealed Auctions

Definition 5.10 - *Sealed Auction*
In a *Sealed Auction* bidding is done in private. Participants do not know what others have bid.

Definition 5.11 - *First-Price Sealed Bid Auction*
Used to buy *Houses in Scotland.*

i). Auctioneer announces the auction is open and how long it is open for.

ii). Each participant makes a single secret bit.

iii). The highest bid will win, and will pay that price. (ie pay *First-Price*)

Proposition 5.5 - *FPSB - Optimal Strategy*
Shade you bid. i.e. bid $p < v$ where v is your private value.

Definition 5.12 - *Second-Price Sealed Bid*
AKA a *Vickery Auction*

i). Auctioneer announces the auction is open and how long it is open for.

ii). Each participant makes a single secret bit.

iii). The highest bid will win, and will pay the price of the second highest bid. (ie pay *Second-Price*)

Proof 5.1 - *SPSB Auction - Optimal Strategy*
Let v be the private value a bidder assigns to an object, p be the value they bid and c be the greatest value of a competitor bid.
If $p = v$ then

- Bidder wins if $c < p = v$ for a profit of $(v - c)$.
- Does not win if $v = p < c$.

If $p < v$ then

- if $v > p > c$ then the bidder *still* wins with profit $v - c$.
- if $c > v > p$ then the bidder *still* loses.
- if $v > c > p$ then the bidder now loses (making less profit), where they wouldn't have with the previous strategy.

Therefore, bidding $p < v$ never increases a bidders profit. A similar argument can be made for not bidding $p > v$.
The optimal strategy is to bid $p = v$ (same as an *English Auction*)

Remark 5.6 - *Auctions for Sellers*
If buyers are risk averse (ie don't want to lose the opportunity of buying) then FPSB can increase revenues over SPSB auctions.

Remark 5.7 - *Robustness*
Sealed auctions are more robust as you cannot observe other bidders actions, and thus cannot punish a colluder who defects.

Remark 5.8 - *Weak Bidders*
Weak Bidders have a better chance of winning a sealed auction as other bidders may over-shade their bid.

5.3 Equivalent Auctions

Definition 5.13 - *Incentive Compatible*
Auctions are *Incentive Compatible* if they encourage bidders to bid their true value for an item. Incentive compatible auctions stop game playing between bidders as there is no advantage to second guess other users' values. This makes *Incentive Compatible* auctions more predictable and thus favourable for auctioneers.
English & SPSB auctions are incentive compatible.

Remark 5.9 - *Equivalence of English & Second-Price Sealed Bid Auctions*
English & SPSB auctions are weakly equivalent as the optimal strategies are only the same if values are *private* (i.e. there is no *interdependence*).

Remark 5.10 - *Strategic Equivalence of Dutch & First-Price Sealed Bid Auctions*
Bidding a certain amount in a FPSB auction is equivalent to offering to buy at that amount in a Dutch auction. Thus they are *Straegically Equivalent* (for all strategies in one game there is a strategy in the other which will produce the same outcome).

Theorem 5.1 - *Revenue Equivalence Theorem*
If private values are iid and all bidders are risk neutral, then any standard auction yields the same expected revenue to the seller.

Remark 5.11 - *Revenue Equivalence Theorem*

In practice the *Revenue Equivalence Theorem* does not hold since bidders are not risk neutral (they do have an emotional attachment to goods) and interdependence exists.

5.4 Online Auctions

Remark 5.12 - *Auctions Online*
Due to the algorithmic nature of auction rules & no need for a physical auctioneer or room, the internet enables auctions to be run quickly and cheaply.
Bidding can be automated too, and more complex auction rules can be implemented.
The only limit to online auctions is server capacity and bandwidth.

Remark 5.13 - *Intermediates*
In the beginning of the Internet it was believed that small businesses (e.g. farmer) would be able to sell to customers directly, without the need of an intermediary (e.g. supermarket). This has not been realised as it is much harder to get customers attention online. So *Online Marketplaces* (e.g. amazon, ebay) sprung up to act as intermediaries.
Online marketplaces not host listings but also ease payments and improve trustworthiness of both sellers & buyers.

Remark 5.14 - *eBay*
eBay is one of the most famous online auctioneers. Mainly does consumer-to-consumer and business-to-consumer auctions, but also some business-to-business.
Reviews of sellers act as a lock-in mechanism and part of why *eBay* has an effective monopoly.
eBay auctions are open-ascending auctions with a deadline set before the auction begins (similar to an english auction, but with a time line).

Remark 5.15 - *Snipping*
The timelimit on eBay auctions has lead to phenomena of *snipping*, where bidders wait to place their bid till near the end of an auction in the hope it is too late for anyone else to join (and so as not to give away information about their value).
eBay don't like this as there is hidden information.
To combat this eBay introduced a 'proxy' bidding functionality (if everyone uses this then it is similar to a SPS auction). Alternatively, they could have extended the time limit each time someone bid (similar to a true english auction)

Proposition 5.6 - *Estimating Demand for Dynamic Pricing in Electronic Markets*

i). Track bidders and *'recover'* missing bidders (who could not bid as the price was too high when they first entered). Use this data to estimate a demand curve.

ii). Build a demand and supply curve.

iii). Calculate supplier costs and estimate revenues.

iv). Determine optimal sales quantity/strategy using the revenue and cost curves.

Remark 5.16 - *Google Ad Auctions*
Google understands their customer very well as they know exactly what they are looking for.
Adverts for webpages are highly idiosyncratic and thus hard to compare.
Google uses auctions on its ad-space in order to perform price discovery. Multiple auctions are done for each user search (60k auctions per second). Google considers both the *bid price* and

the *advert quality* when choosing the winner of an auction, as they don't want their users to get loads of shit adds.
Advert quality is assessed using: Historic click-through-rate; relevancy; and landing page quality (inc. load speed).
This type of auction works best for the seller when there is lots of competition in the auction. To encourage this Google relax the strictness of their keyword matching.
Originally, Google used FPSB auctions but this lead to their servers being overloaded with advertisers checking the results of auctions (to see if they could lower their price). Google then switch to SPSB auctions, solving the server overload problem, as this is *incentive compatible*.

6 Financial Technology

6.1 Financial Technology Firms

Proposition 6.1 - *Key Player - Traditional Banking and Finance*
Traditional Banking and Finance are using technology to automate/improve their traditional business functions (e.g. online banking), this is *digitisation*. Their aim is to increase productivity, efficiency, profit maximization and overlay new services. This is a form of *incremental innovation*.

Proposition 6.2 - *Key Player - Start-Up Technology Companies (FinTechs)*
Start-Up Tech Firms are using technology to introduce new kinds of financial services models. They redesign finance from the ground-up in order to use the technology. Their aim is to disrupt traditional finance through new technology.

Proposition 6.3 - *Key Player - Big Tech (TechFins)*
Big Tech Firms are using their technology dominance to move into financial services. Their aim is to streamline technology processes and lock-in customers. They are leveraging their positive network externalities and customer data.

Remark 6.1 - *Public Perception*
Changes in public perception of who is capable/should provide financial services (partly due to 2008 crash) has allowed for greater competition in the market.

Remark 6.2 - *Underbanked*
Studies have shown that *in the western world* fintech users tend to be young (under 35) and that the more someone earns the more likely it is they will use a fintech product.
But, around 70% of the world do not have access to basic banking facilities. These people of prime customers for certain fintechs. It is important to note that the products these people need are not necessarily the same as richer people. They generally want easy-to-use, simple products (savings accounts and short-term loans are generally inappropriate).
Mobile phones are common, even among low income communities. Thus, fintechs which use mobiles phones have a good chance to reach these customers.

Definition 6.1 - *Financial Regulation*
Financial services have long-since been regulated by government & regulatory bodies. These institutions define rules and directives to control and manage the financial services. The goal of these regulations are to: *protect* actors; improve *competitive efficiency* (ie antitrust lasts & prevention of monopolies); reduce *risk*; and build *trust*.

Remark 6.3 - *Regulation & FinTechs*
Financial Technology is subject to regulation but due to its often novel nature it may require new regulation. Some regulators are much more welcoming to new technologies than others. Some regulators take a *"watch and see"* approach where they allow a new technology to enter a market and then work with the firm to implement regulations (This is known as *Sandboxing*). Regulators tend to only get involved once a product reaches a certain size.

Proposition 6.4 - *LASIC Principles*
Less & Teo proposed set of principles for a FinTech to succeed:

- *Low Margin.* Allows the business to service whilst offering very low prices to encourage customers.
- *Asset Light.* Reduce fixed costs. Can be done by utilising exists infrastructure (such as mobile phones).
- *Scalable.* The technology and business model must be able to scale (without affect efficiency or costs) in order to reap positive network effects.
- *Innovative.* Encourage adoption.
- *Compliance Easy.* Otherwise model may not be scalable.

6.2 National Banking Maturity

Proposition 6.5 - *National Banking Maturity*
The viability for new financial technologies will vary by country. If we consider the prevalence of banking in a country and the amount of venture capital investment in that country (as a ration of GDP) we can derive four categories which partition countries:

i). *Bank Dominant* - High prevalence, low investment. (e.g. Eastern Europe).
Traditional banking is well established and likely to continue to dominate. Most competition is likely to occur between existing businesses (and not from new FinTechs)

ii). *Partnering* - High prevalence, High investment. (e.g. Western Europe).
Traditional banking is well established, but there is also a strong technology ecosystem. This means it is possible for competition to come from outside traditional banks. It is possible for FinTechs to do well in this environment, although it is likely easier for them to partner with established banks.

iii). *Tech Dominance* - Low prevalence, High investment. (e.g. India & China).
A well-developed tech eco-system exists, while banks underserve the population. This is ideal for FinTechs as there are few established players in the market. Technology and Financial firms may partner in the future so they can utilise each other.

iv). *Race to the Finish* - low prevalence, low investment. (e.g. Sub-Saharan Africa).
Due to under-development technolgy and banking prevelance, telecom companies are often the most significant tech firms in these countries. Meaning, mobile phones are the key technology to utilise to gain a foothold in these markets.

Remark 6.4 - *China*
China uses a *Development-led* approach where it allows technologies to develop first and then adds regulation later (once it is clear where it is needed).

Remark 6.5 - *India*

India uses a *Devlopment-Lagged* approach where regulators largely restrict financial technologies until it it well understood.