Chapter 2
Supply and Demand

Abstract The law of demand and supply is the fundamental law of economic trade. It consists of the demand characteristics of the customer which describes the relationship between price and quantity of goods. For example, if the price of a good is low the customer will buy more goods and services than if the price is high. The relationship between price and the willingness of the customers to buy goods and services is called the demand curve. The other aspect of the demand and supply law is the supply curve which relates the relationship between the price and the quantity of goods suppliers are willing to produce. For example, the higher the price the more the goods and services the suppliers are willing to produce. Conversely, the lower the price the lesser the goods and services the suppliers are willing to produce. The point at which the suppliers are willing to supply a specified quantity of goods and services which are the same as those that the customers are willing to buy is called equilibrium. This chapter studies how the law of demand and supply is changed by the advent of artificial intelligence (AI). It is observed that the advent of AI allows the opportunity for individualized demand and supply curves to be produced. Furthermore, the use of an AI machine reduces the degree of arbitrage in the market and therefore brings a certain degree of fairness into the market which is good for the efficiency of the economy.

2.1 Introduction

The law of supply and demand has been studied by many thinkers. Some of the earliest studies of demand and supply were by a Muslim scholar Ibn Taymiyyah in the fourteenth century, English philosopher and physician John Locke in the seventeenth century and Scottish philosopher Adam Smith in the eighteenth century (Locke 1691; Hosseini 2003). The law of supply and demand has two aspects and these are the supply side as well as the demand side. On the supply side it states that the higher the price of goods and services is, the more the suppliers are willing to produce those goods and services. Conversely, the lower the price of goods and services, the fewer the suppliers are willing to produce those goods and services. On

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the demand side, the higher the price of goods and services is, the lesser the customers are willing to buy those goods and services. Conversely, the lower the price of goods and services, the more the customers are willing to buy those goods and services. The point where the demand matches the supply is called equilibrium. Every customer has his/her own demand curve and every supplier has his/her own supply curve. For a particular good, there is an aggregate demand curve which is a collection of the demand curves of all the customers whereas for the supply curve there is an aggregate supply curve for all suppliers of that particular good. The aggregate equilibrium is what most customers is used as a basis of pricing of goods that we find in stores and this is the price which suppliers are subjected to. With the advent of artificial intelligence (AI), online buying and big data analytics, it is now possible to create individualized pricing models because it is now possible to individualize the supply and demand curves and therefore have an individual equilibrium price.

There is a concept of price elasticity which was introduced by the English economist Alfred Marshall which is a measure of how much customers change their buying patterns given the change in price (Marshall 1920). With the advent of artificial intelligence, it is now possible to study individualized price elasticity. This chapter studies the law of supply and demand given the fact that a substantial amount of trades are now conducted online and that decisions are made by or with the help of computers which are capacitated by artificial intelligence technology.

2.2 Scarcity

The fundamental basis of supply and demand is the concept of scarcity (Montani 1987; Jeff et al. 2003; Mankiw and Taylor 2011). The concept which makes goods and services have economic value and therefore can be priced, according to neo-classical economics, is the notion of scarcity. Oxygen is valuable and without it there is no life but because it is not scarce it has no price. The trigger or the necessary condition for goods and services to have a price, i.e. economic value, is scarcity. Scarcity is a phenomenon which is a result of the fact that goods and services are limited and therefore cannot fulfil or be given to all human beings if they require them.

Suppose there is a farmer Peter who produces 200 apples per month. For this farmer to produce these apples he needs fertilizers, water, expertise and instruments. The 200 apples that he produces per month are not limitless as there are only 200 per month. Because of this situation, the apples are classified as being scarce. Suppose in this ideal world, Peter is the only person who produces apples. Then these apples will be classified as being scarce. Suppose we have another person, John, who is the only person who eats apples and eats one apple per day (30 apples per month). In this ideal world, there will be excess of 170 apples per month. In this case because the demand for apples by John are lower than the supply of apples by Peter, the price of apples will be low because the supply outstrips the demand.

Suppose 10 people now eat a total of 10 apples per day. Then the demand for apples will outstrip the supply because 300 apples are now needed per month. In this situation, the price of apples will be high. In this scenario of 10 people who eat an apple per day, the apples are scarcer than when only John is the only one who eats an apple per day. These ten people want these apples because somehow these apples fulfil their individual wants or have certain benefits such as the fact that they give them energy.

2.3 Utilitarianism

Utilitarianism is another concept that is important for the understanding of the notion of demand and supply. It is a theory that prescribes what should be done given a set of conditions. It was developed by an English philosopher Jeremy Bentham and was extensively developed by the English philosopher John Stuart Mill (Bentham 1776; Bentham and Mill 2004). On defining utilitarianism, Jeremy Bentham advised that on choosing how to differentiate right from wrong a person should use the principle of "… the greatest happiness of the greatest number that is the measure of right and wrong". Utilitarianism emanates from the word utility which means how useful or beneficial goods and services are. For example, when John eats the apple he wants to ingest those aspects of the apple that makes him healthy and gives him enough energy to be able to pursue those aspects of life that are fulfilling to him.

Suppose Peter is a President of the Republic of Venda and wants to know what decision to take given a particular situation. If Peter is schooled in the philosophy of utilitarianism, he will take a decision that maximizes the aggregate happiness and minimizes the aggregate misery in his country, the Republic of Venda. This decision is summed and restated as Peter maximizing his utility.

In nature there are examples of biological objects that exhibit the principle of maximizing utility. For example, in Darwin's theory of evolution, species adapt to their environments through crossover, mutation and reproduction where the elements of the species that are not adapted to the environment die out (Darwin 1861). For example, those members of the population that are not adapted to the environment die and their gene pool is therefore not represented in the next generation. This mechanism can be viewed as a utilitarian problem where the species as a system undergoes evolution to maximize its utility i.e. survival. This concept of natural selection is so powerful that it explains many aspects of life in society, medical sciences and has been adapted in computer science to form an algorithm called genetic algorithm that has been successfully used to schedule optimal or shortest routes between multiple locations (Goldberg 1989).

Another example of populations maximizing their utility, is a swarm of pigeons in a park where when a person puts seeds at a particular location all the pigeons rush towards that location where the seeds were dropped. Each pigeon makes a move based on two factors and these are its own knowledge (individual

intelligence) and the knowledge of the swarm (group intelligence). It basically looks at what everyone is doing and what it knows in order to make its move. Each pigeon does this in order to maximize its utility which is measured by how many seeds it is able to find and then eat. There are many other examples that illustrate the concept of utility, such as the school of fish, ant colony, swarm of bees etc.

At the core of the principle of utilitarianism there is something valuable that individuals are pursuing to maximize such as survival in the theory of evolution as well as seeds in case of the swarm of pigeons we have described.

2.4 Supply and Demand

The demand and supply curve is an illustration of the relationship between the supplier and the customer which is shown in Fig. 2.1. The supplier produces goods and services with economic value and his intention is to maximize utility and in this case this is the return on his investment. The customer has money and he estimates the value of the goods and services he wants to procure, and he prices these goods and services to maximize utility. These transactions will go ahead if the supplier's perception of value of the price offered by the customer is at least equal to and preferably higher than the value he places on the good. Alternatively, the customer will procure the good if his perception of the value of the good is equal to or higher than the value of the money he will use. This is what is called the asymmetry of information with regards to perception of value and this will be discussed in detail in the chapters ahead. The concept of information asymmetry and its impact on the market won George Akerlof, Michael Spence, and Joseph E. Stiglitz a Nobel Prize (Akerlof 1970; Spence 1973).

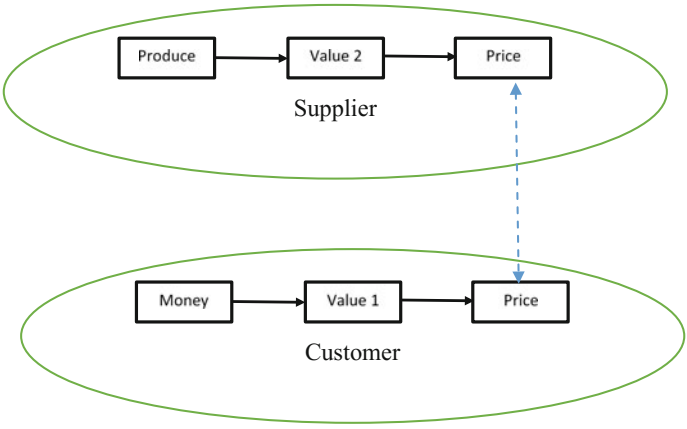

Fig. 2.1 An illustration of the relationship between the supplier and customer

Table 2.1 The demand data for Peter

Price	7	2
Quantity	1	8

Suppose a customer, Peter, is willing to buy 1 kg of rice for 7 cents and is willing to buy 8 kg of rice for 2 cents (see Table 2.1). Then Peter's demand curve is represented as in Fig. 2.2. Suppose a supplier George is willing to supply 1 kg of rice for 2 cents while he is willing to supply 8 kg of rice for 7 cents (see Table 2.2). Then George's supply curve is shown in Fig. 2.2. The point of equilibrium for this business transaction between Peter and George is 4.5 kg of rice for 4.5 cents and this is shown in Fig. 2.2. The point of equilibrium for the business transaction between Aiden and Isaac as per Tables 2.3 and 2.4 and further shown in Fig. 2.3 is 4.7 kg of rice for 5.69 cents. The aggregate point of equilibrium for this business transaction amongst all players is 9.12 kg of rice for 10.01 cents. This is shown in Fig. 2.4 (Tables 2.5 and 2.6).

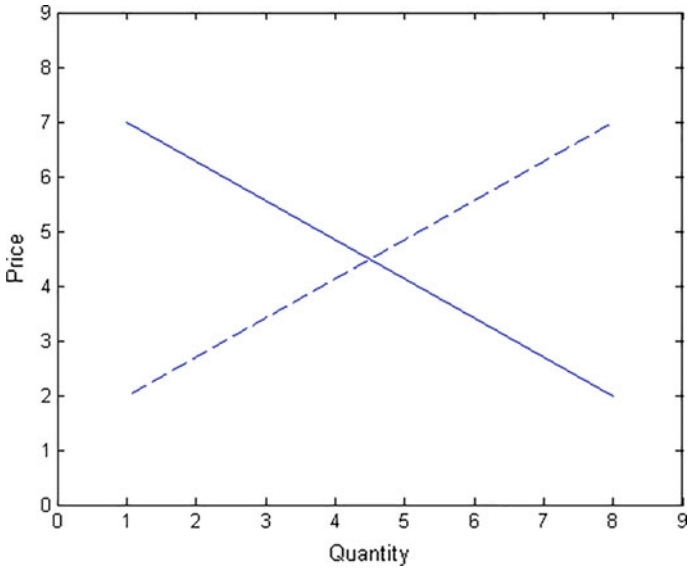

Fig. 2.2 The supply and demand curves for Peter and George

Table 2.2 The supply data for George

Price	2	7
Quantity	1	8

Table 2.3 The demand data for Aiden

Price	8	2
Quantity	2	9

Table 2.4 The supply data for Isaac

Price	3	9
Quantity	2	8

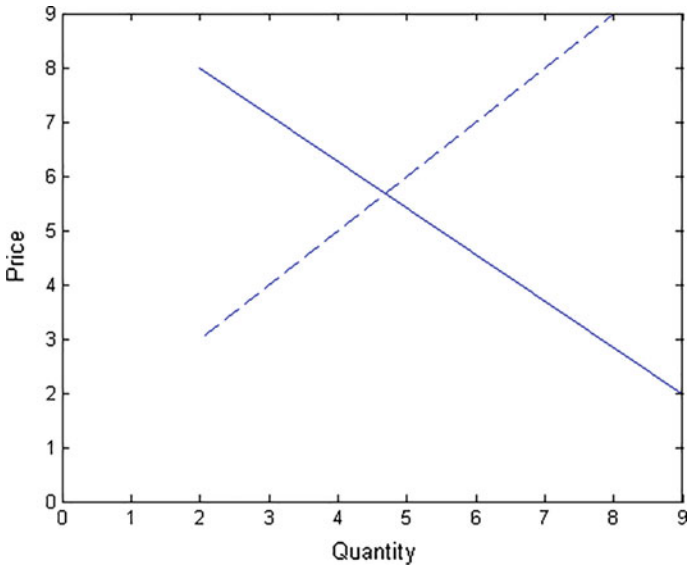

Fig. 2.3 The supply and demand curves for Aiden and Isaac

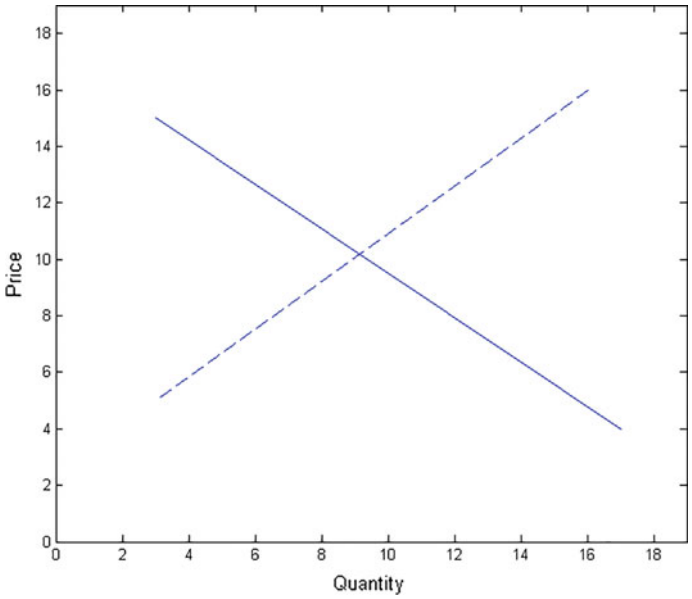

Fig. 2.4 The aggregate supply and demand curves

Table 2.5 The aggregate demand

Price	7 + 8 = 15	2 + 2 = 4
Quantity	1 + 2 = 3	8 + 9 = 17

Table 2.6 The aggregate supply data

Price	2 + 3 = 5	7 + 9 = 16
Quantity	1 + 2 = 3	8 + 8 = 16

What do we learn from this picture? That individual customers and suppliers have their own demand and supply curves and these differ from the aggregate demand and supply curves. If a customer goes to a market in Delhi in India and wants to buy a shirt and approaches five different suppliers selling the same shirt then he will get five different prices. Then there are 6 sets of equilibriums and these are from the five suppliers and the aggregate for all of them. Of course the customer will buy from the supplier with the lowest price to maximise his utility. The normal way of handling this Indian market is to negotiate a better deal rather than subject yourself to the aggregate equilibrium, forces we see often in Western markets.

2.5 Factors Influencing Demand and Supply

The demand curve is an expression of a measure of the willingness of the customers to buy a particular quantity of a good or service at a particular price. What are some of the factors that make customers buy a desired good or service? Do we buy a good or service because it will maximize utility? Does a common individual even know how to maximize utility?

One of the factors that influences the demand is the amount of capital one has because without any money, then customer is not willing or perhaps able to buy a particular amount of a good at a specified price. That is why sellers want to get into markets that have capital. For example, China prefers to sell its goods and services in the USA as opposed to the Democratic Republic of Congo because the demand for goods and services is higher in the USA than in the Democratic Republic of Congo. No money, no demand, square and simple!

The second is the taste of the customers and the need for that good. So it will not make any sense for a beef farmer in Botswana to try to enter the Indian market because people there are largely vegetarian. When a customer for a used car goes to look for a red Toyota Corolla, then he is willing to pay for it at a given price which is a point in his demand curve. The other factor is the comparative price for other goods. For example, the customer might prefer a red Toyota because a BMW is too expensive. He might prefer to buy the car now because the future price of cars is going to go up considerably. The fact of the matter is that a human being has his own demand and supply curve. If these are not in line with the market, then the

supplier will get out of business, whereas, the customer for goods and services will not find anyone that is willing to sell him goods and services.

In a practical situation, suppose we introduce an artificial intelligent agent that is meant to buy goods and services on his behalf. This artificial intelligent agent is able to look for all cars in the market including the internet and look at his needs such as what are his average daily travels, the nature of the roads he travels and other factors to find a best match for the car he desires. This artificial intelligent agent maximizes the utility of their human owner far much better than the human being himself. This agent is known as a recommender system and organizations such as Amazon are full of these agents that study the characteristics of their human owners and then make recommendations on what book to buy. Now given that the customers will more and more no longer be making purchases directly and that artificial intelligent agents are well suited for such tasks, what does this configuration do to the nature of the demand curve?

On the supply side, the producers are willing to produce a good and service at a particular price provided that they are able to maximize their utilities (i.e. profits). The factors that influence the supply curve include the production costs that are more and more being automated with artificial intelligence capabilities. The fourth industrial revolution will see more and more intelligent automation and thus resulting in the dramatic decrease in the cost of labour. This will result in the dramatic reduction in the cost of production.

The other factor influencing the supply curve is the expected future prices and profits, a feat that is more and more becoming easier to manage because of the advent of artificial intelligence which makes forecasting easier to handle. The other factor that influences the supply curve is competition. Today it is far easier to understand competition than before because of the availability of information in the internet due to dramatic increase in data analytics capabilities, as well as the availability of techniques such as deep learning that make sense of information from big data.

2.6 Artificial Intelligence (AI) and Demand and Supply

AI is a computational procedure that is able to mimic high level skills that are observed in natural and biological systems (Marwala 2007, Marwala and Hurwitz 2015). For example, neural networks mimics the functioning of the human brain and have been used to solve complex problems in medical sciences (Marwala 2009), mechanical engineering (Marwala 2010), modelling interstate conflict (Marwala and Lagazio 2011, Marwala 2015), electrical engineering (Marwala 2012), economics (Marwala 2013), automated rational decision making (Marwala 2014) and aeronautical engineering (Marwala et. al. 2017). How does AI impact the demand and supply theory? Firstly on the demand side, AI is acting as a DNA of agents that act on behalf of their human owners. For example, on buying a book on the Amazon online system, the computer learns the buying behaviour of the

customer. How does this happen? There are two ways of teaching a neural network to learn and these are supervised learning and unsupervised learning.

The supervised learning technique learns labelled data with inputs and outputs. A practical illustration of this is on teaching a child pictures and their names. The first picture is of a dog and a child is told that this is a dog. Then a second picture of a cat is presented and the child is told that this is a cat. The third picture is of a lion and the child is told that this is a lion. This scenario has input to the neural network which is the picture and the output of the neural network which is the corresponding name of the animal. This is called supervised learning. Neural networks maps the input i.e. pictures of animals to the output i.e. their corresponding identity using network weights which are akin to the neurons of the brain and activations functions which are akin to the mechanism in which these neurons are handled.

This works very well for structured environment like in a classroom. The other way of learning the same information is for a child to operate in the environment and by observing and listening to people in their normal conversations, gets to learn what a cat, a dog and a lion are. This is unstructured learning and in artificial intelligence terminology is unsupervised learning. Again, unsupervised learning occurs in many forms including through grouping similar data together e.g. cats are grouped together.

The introduction of artificial intelligence agents does not change the income of the person it is acting for nor does it change his tastes and preferences. However, it recommends based on historical knowledge of the preferences of the human being it is acting on behalf of and therefore it does influence his future decisions. Because it is able to search much more extensively than its human owner, it gets better products at better prices. By so doing, it reduces the probability of the customer to over pay for the products he buys and therefore reduces the degree of arbitrage i.e. exploiting the flow of information resulting in suboptimal pricing. People generally buy goods and services because they need the goods but also because they are getting a better price. If the artificial intelligence agent improves the flow and accuracy of the information of the goods and services the customer is buying, the result is that the volume of trades will decrease.

On the supply side, artificial intelligence is changing the mode of production of goods and services. Goods and services that normally required large number of people to produce are now produced using AI enabled robots. The consequence of intelligently automating production is that the cost of producing goods decreases. The production facilities self-repair thereby decreasing the amount of downtime. Artificial intelligence predicts equipment failures due to advances in condition monitoring and signal processing. All these factors make production more efficient and therefore contribute towards the reduction of the cost of production.

What do these do to the supply curve? It increases the willingness of suppliers to produce goods and services. What happens to the expected price of goods and services? Because machines do not get tired, the price of goods and services decreases. What does it do to the barrier of entry into the supply chain by new entrants? Capital becomes the major barrier to entry to by new entrants. What does AI do to the flexibility of the production lines? Evolutionary based procedures, such

as genetic algorithm, become part of the production process and thereby make production facilities be autonomously adaptive. Genetic algorithm is an artificial intelligence procedure that is inspired by the way evolution operates and which is driven by crossover i.e. mixing of different production configurations, mutation i.e. adapting production process, and reproduction i.e. synthesizing best production configurations.

2.7 Conclusion

This chapter studied the impact of artificial intelligence on the law of demand and supply. The demand curve is a measure of how much quantity of goods and services customers are willing to buy given the price. The supply curve is a measure of how much quantity of goods suppliers are willing to produce given the price. Equilibrium is a measure of the position where the quantity of goods customers are willing to buy at a certain price is the same as what the suppliers are willing to produce. AI through learning and evolution is able to ensure that the demand and supply curves are better modelled. The use of an AI machine reduces the degree of arbitrage in the market and therefore brings a certain degree of fairness into the market which is good for the efficiency of the economy.

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