

BASUDEV GODABARI DEGREE COLLEGE, KESAIBAHAL



BLENDED LEARNING STUDY MATERIALS

UNIT-II

DEPARTMENT :-ECONOMICS

SUBJECT :-Micro Economics-II

SEMESTER :-4th Semester

CONTENT

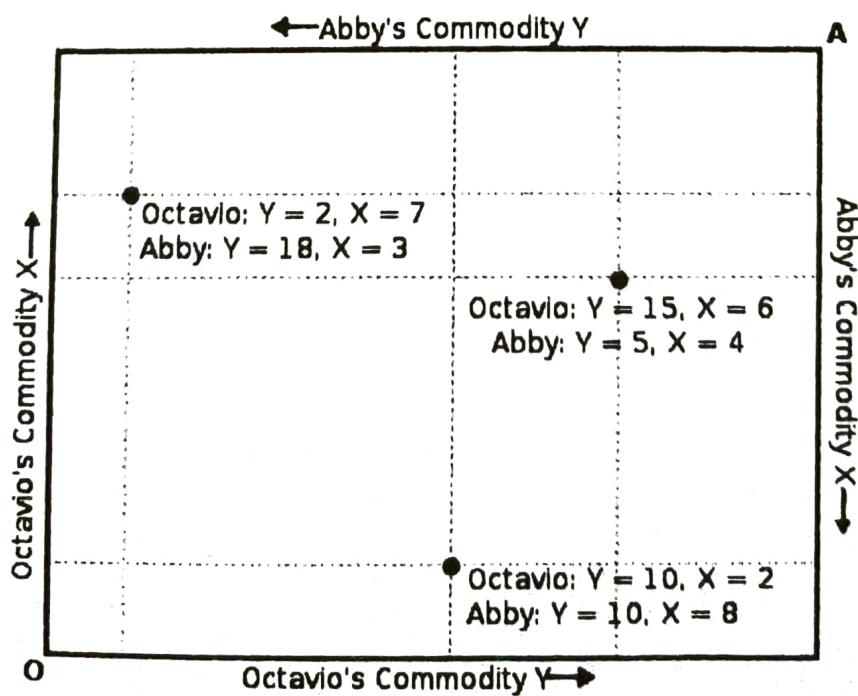
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Chapter 2

General Equilibrium, Efficiency and Welfare

The Edgeworth Box

In economics, an Edgeworth box, named after Francis Ysidro Edgeworth, is a way of representing various distributions of resources. Edgeworth made his presentation in his book *Mathematical Psychics: An Essay on the Application of Mathematics to the Moral Sciences*, 1881. Edgeworth's original two-axis depiction was developed into the now familiar box diagram by Pareto in his 1906 book "Manual of Political Economy" and was popularised in a later exposition by Bowley. The modern version of the diagram is commonly referred to as the Edgeworth–Bowley box.



Example of an Edgeworth Box with Total Quantity of X is 10, and Y is 20.

The Edgeworth box is used frequently in general equilibrium theory. It can aid in representing the competitive equilibrium of a simple system or a range of such outcomes that satisfy economic efficiency. It can also show the difficulty of moving to an efficient outcome in the presence of bilateral monopoly. In the latter case, it serves as a precursor to the bargaining problem of game theory that allows a unique numerical solution.

Example: Imagine two people (Octavio and Abby) with a fixed amount of resources between the two of them—say, 10 litres of water and 20 hamburgers. If Abby takes 4 litres of water and 5 hamburgers, then Octavio is left with 6 litres of water and 15 hamburgers. The Edgeworth box is a rectangular diagram with Octavio's origin on one corner (represented by the O) and Abby's origin on the opposite corner (represented by the A). The width of the box is the total amount of one good, and the height is the total amount of the other good. Thus, every possible division of the goods between the two people can be represented as a point in the box.

Indifference curves (derived from each consumer's utility function) can be drawn in the box for both Abby and Octavio. The points on each person's indifference curve represent equally liked combinations of quantities of the two goods for that person. Hence Abby is indifferent between one combination of goods and another on any one of her indifference curves, and the same is true for Octavio. For example, Abby might value 1 litre of water and 13 hamburgers the same as 5 litres of water and 4 hamburgers, or 3 litres and 10 hamburgers. There are an infinite number of such curves that could be drawn among the combinations of goods for each consumer (Octavio or Abby).

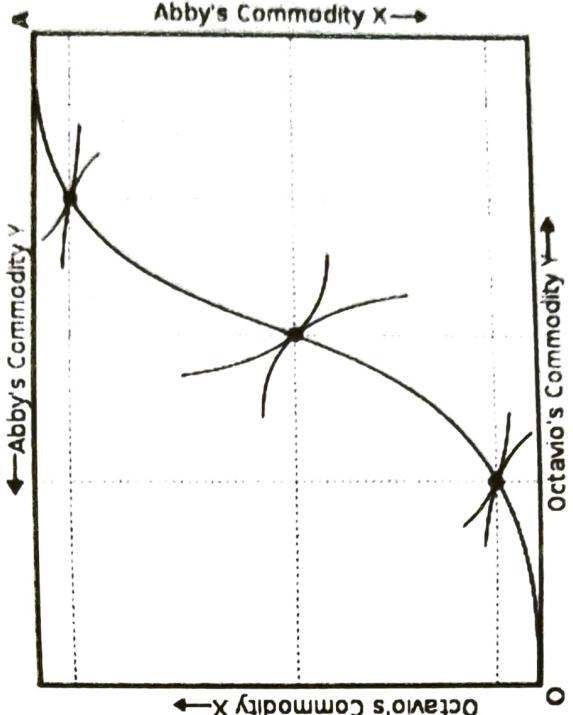
With Octavio's origin (the point representing zero of each good) at the lower left corner of the Edgeworth box and with Abby's origin at the upper right corner, typically Octavio's indifference curves would be convex to his origin and Abby's would be convex to her origin.

When an indifference curve for Abby crosses one of the indifference curves for Octavio at more than one point (so the two curves are not tangent to each other), a space in the shape of a lens is created by the crossing of the two curves; any point in the interior of this lens represents an allocation of the two goods between the two people such that both people would be better off, since the point is on an indifference curve farther from both of their respective origins, and thus, each individual achieves a higher utility.

Pareto Set

Wherever one of these curves for Abby happens to be tangent to a curve of Octavio's, a combination of the two goods is identified that yields both consumers a level of utility that could not be improved for one person by a reallocation without decreasing the utility of the other person. Such a combination of goods is said to be Pareto optimal.

The set of tangential points of contact between pairs of indifference curves, if all traced out, will form a trace connecting Octavio's origin (O) to Abby's (A). This curve connecting points O and A, which will not in general be a straight line, is called the Pareto set or the efficient locus, since each point on the curve is Pareto optimal.



Blue Pareto Set (Efficient locus) Showing Points of Tangency of Indifference Curves in an Edgeworth Box.

The vocabulary used to describe different objects which are part of the Edgeworth box diverges. The entire Pareto set is sometimes called the contract curve, while Mas-Colell, Winston, and Green (1995) restrict the definition of the contract curve to only those points on the Pareto set which make both Abby and Octavio at least as well off as they are at their initial endowment. Other authors who have a more game theoretical bent, such as Martin Osborne and Ariel Rubinstein (1994), use the term

core for the section of the Pareto set which is at least as good for each consumer as the initial endowment. In order to calculate the Pareto set, the slope of the indifference curves for both consumers must be calculated at each point. That slope is the negative of the marginal rate of substitution, so since the Pareto set is the set of points where both indifference curves are tangent, it is also the set of points where each consumer's marginal rate of substitution is equal to that of the other person.

Trade

The terms of trade is defined as the amount of one good that trades for another. It is typically presented as a ratio between the two goods. Thus, in the Edgeworth box example, if Smith and Jones were to trade 5 apples for 5 oranges and move from point E to point H in the diagram, the terms of trade would be 5 apples for 5 oranges, or to simplify, 1 apple/orange. This also corresponds to the slope of the line between points E and H from the perspective of both Smith and Jones. (Note that one could also express the terms of trade as oranges/apple in which case the value here would still be 1 orange/apple.) In contrast, if Smith were to exchange 8 oranges for 7 apples then the terms of trade would be $(7/8 = .875)$ apples/orange (or equivalently, $8/7 = 1.14$ oranges/apple).

There is one additional relationship we will need later. The terms of trade measured as apples per orange also corresponds to the ratio of dollar prices between oranges and apples. In other words we can write the terms of trade as P_o/P_A , where P_o is the price of oranges measured as \$/orange and P_A is the price of apples measured as \$/apple.

Pareto Efficient Allocations

Pareto efficiency or Pareto optimality is a state of allocation of resources from which it is impossible to reallocate so as to make any one individual or preference criterion better off without making at least one individual or preference criterion worse off. The concept is named after Vilfredo Pareto (1848-1923), Italian engineer and economist, who used the concept in his studies of economic efficiency and income distribution. The concept has been applied in academic fields such as economics, engineering, and the life sciences.

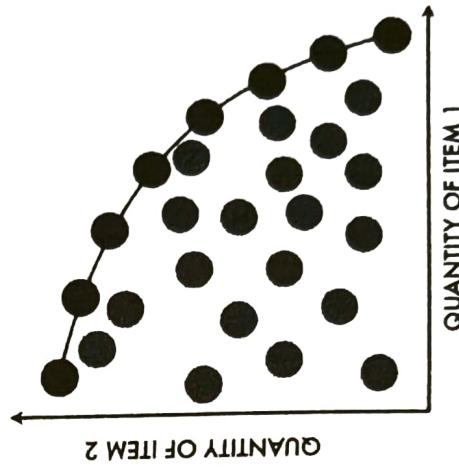
The Pareto frontier is the set of all Pareto efficient allocations, conventionally shown graphically. A Pareto improvement is a change to a different allocation that makes at least one individual or preference criterion better off without making any other individual or preference criterion worse off.

"Pareto efficiency" given a certain initial allocation of goods among a set of individuals. An allocation is defined as "Pareto efficient" or "Pareto optimal" when no further Pareto improvements can be made, in which case we are assumed to have reached Pareto optimality.

"Pareto efficiency" is considered as a minimal notion of efficiency that does not necessarily result in a socially desirable distribution of resources; it makes no statement about equality, or the overall well-being of a society. The notion of Pareto efficiency has been applied to the selection of alternatives in engineering and similar fields. Each option is first assessed, under multiple criteria, and then a subset of options is ostensibly identified with the property that no other option can categorically outperform any of its members.

Overview

"Pareto optimality" is a formally defined concept used to determine when an allocation is optimal. Simply put, an allocation is *not* Pareto optimal if there is an alternative allocation where improvements can be made to at least one participant's well-being without reducing any other participant's well-being. If there is a transfer that satisfies this condition, the reallocation is called a "Pareto improvement." When no further Pareto improvements are possible, the allocation is a "Pareto optimum."



QUANTITY OF ITEM 1

A Production-possibility frontier is an example of a Pareto-efficient frontier, where the frontier and the area left and below it is a continuous room of choices. The red points are examples of Pareto-optimal choices of production. Points off the frontier, such as N and K, are not Pareto-efficient.

The formal presentation of the concept in an economy is as follows: Consider an economy with i agents and j goods. Then an allocation $x \in \mathbb{R}^j$, where $x_n \in \mathbb{R}^i$, is *Pareto optimal* if there is no other feasible $\{x'_1, \dots, x'_n\}$, such that, for utility function u_n for each agent i , allocation $\{x'_1, \dots, x'_n\}$ such that, for utility function $u_n(x'_n) > u_n(x_n)$ for some n . Here, in this simple economy, "feasibility" refers to an allocation where the total amount of each good that is allocated sums to no more than the total amount of the good in the economy. In a more complex economy with production, an allocation would consist both of consumption vectors and production vectors, and feasibility would require that the total amount of each consumed good is no greater than the initial endowment plus the amount produced.

In principle, a change from a generally inefficient economic allocation to an efficient one is not necessarily considered to be a Pareto improvement. Even when there are overall gains in the economy, if a single agent is disadvantaged by the reallocation, the allocation is not Pareto optimal. For instance, if a change in economic policy eliminates a monopoly and that market subsequently becomes competitive, the gain to others may be large. However, since the monopolist is disadvantaged, this is not a Pareto improvement. In theory, if the gains to the economy are larger than the loss to the monopolist, the monopolist could be compensated for its loss while still leaving a net gain for others in the economy, allowing for a Pareto improvement. Thus, in practice, to ensure that nobody is disadvantaged by a change aimed at achieving Pareto efficiency, compensation of one or more parties may be required. It is acknowledged, in the real world, such compensations may have unintended consequences that can lead to incentive distortions over time, as agents supposedly anticipate such compensations and change their actions accordingly.

Under the idealised conditions of the first welfare theorem, a system of free markets, also called a "competitive equilibrium," leads to a Pareto-efficient outcome. It was first demonstrated mathematically by economists Kenneth Arrow and Gérard Debreu.

However, the result only holds under the restrictive assumptions necessary for the proof: Markets exist for all possible goods, so there are no externalities; all markets are in full equilibrium; markets are perfectly competitive; transaction costs are negligible; and market participants have perfect information.

In the absence of perfect information or complete markets, outcomes will generally be Pareto inefficient, per the Greenwald-Stiglitz theorem.

The second welfare theorem is essentially the reverse of the first welfare-theorem. It states that under similar, ideal assumptions, any Pareto optimum can be obtained by some competitive equilibrium, or free market system, although it may also require a lump-sum transfer of wealth.

Weak Pareto Efficiency

A "weak Pareto optimum" (WPO) is an allocation for which there are no possible alternative allocations whose realisation would cause every individual to gain. Thus, an alternative allocation is considered to be a Pareto improvement if and only if the alternative allocation is strictly preferred by all individuals. When contrasted with weak Pareto efficiency, a standard Pareto optimum as described above may be referred to as a "strong Pareto optimum" (SPO).

Weak Pareto-optimality is "weaker" than strong Pareto-optimality in the sense that any SPO also qualifies as a WPO, but a WPO allocation is not necessarily an SPO.

A market doesn't require local non-satiation to get to a weak Pareto-optimum.

Constrained Pareto-efficiency

The condition of constrained Pareto-optimality is a weaker version of the standard condition of Pareto optimality employed in economics, which ostensibly accounts for the fact that a potential planner (e.g., the government) may not be able to improve upon a decentralised market outcome, even if that outcome is inefficient. This will occur if it is limited by the same informational or institutional constraints as are individual agents.

The most commonly proffered example is of a setting where individuals have private information (for example, a labour market where the worker's own productivity is known to the worker but not to a potential employer, or a used-car market where the quality of a car is known to the seller but not to the buyer) which results in moral hazard or an adverse selection and a suboptimal outcome. In such a case, a planner who wishes to improve the situation is deemed unlikely to have access to any information that the participants in the markets do not have.

Hence, the planner cannot implement allocation rules which are based on the idiosyncratic characteristics of individuals; for example, "if a person is of type A, they pay price p_1 , but if of type B, they pay price p_2 ". Essentially, only anonymous rules are allowed (of the sort "Everyone pays price p^* ") or rules based on observable behaviour; "if any person chooses \mathbf{x} at price p_X then they get a subsidy of ten dollars, and nothing otherwise". If there exists no allowed rule that can successfully improve upon the market outcome, then that outcome is said to be "constrained Pareto-optimal".

Note that the concept of constrained Pareto optimality assumes benevolence on the part of the planner and hence it is distinct from the concept of government failure, which occurs when the policy-making politicians fail to achieve an optimal outcome simply because they are not necessarily acting in the public's best interest.

Use in Engineering and Economics

The notion of Pareto efficiency has been used in engineering. Given a set of choices and a way of valuing them, the Pareto frontier or Pareto set or Pareto front is the set of choices that are Pareto efficient. By restricting attention to the set of choices that are Pareto-efficient, a designer can make tradeoffs within this set, rather than considering the full range of every parameter.

Formal Representation

Pareto Frontier: For a given system, the Pareto frontier or Pareto set is the set of parameterisations (allocations) that are all Pareto efficient. Finding Pareto frontiers is particularly useful in engineering. By yielding all of the potentially optimal solutions, a designer can make focused tradeoffs within this constrained set of parameters, rather than needing to consider the full ranges of parameters.

The Pareto frontier, $P(Y)$, may be more formally described as follows. Consider a system with function $f : \mathbb{R}^m \rightarrow \mathbb{R}^n$, where X is a compact set of feasible decisions in the metric space \mathbb{R}^n , and Y is the feasible set of criterion vectors in \mathbb{R}^m , such that $Y = \{y \in \mathbb{R}^m : y = f(x), x \in X\}$.

We assume that the preferred directions of criteria values are known. A point $y'' \in \mathbb{R}^m$ is preferred to (strictly dominates) another point $y' \in \mathbb{R}^m$, written as $y'' \succ y'$. The Pareto frontier is thus written as:

$$P(Y) = \{y' \in Y : \{y'' \in Y : y'' \succ y', y'' \neq y'\} = \emptyset\}.$$

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Relationship to the Marginal Rate of Substitution: A significant aspect about the Pareto frontier in economics is that, at a Pareto-efficient allocation, the marginal rate of substitution is the same for all consumers.

A formal statement can be derived by considering a system with m consumers and n goods, and a utility function of each consumer as $z'_i = f(x')$ where $x' = (x'_1, x'_2, \dots, x'_n)$ is the vector of goods, both for all i .

The feasibility constraint is $\sum_{i=1}^m x'_i = b$, for $j = 1, \dots, n$. To find the Pareto optimal allocation, we maximise the Lagrangian:

$$L_i((x'_j)_{k,j}, (\lambda_k)_k, (\mu_j)_j) = f'(x') + \sum_{k=2}^m \lambda_k (z_k - f^*(x^*)) + \sum_{j=1}^n \mu_j \left(b_j - \sum_{i=1}^m x'_i \right)$$

where $(\lambda_k)_k$ and $(\mu_j)_j$ are the vectors of multipliers. Taking the partial derivative of the Lagrangian with respect to each good x'_j for $j = 1, \dots, n$ and $k = 1, \dots, m$ and gives the following system of first-order conditions:

$$\frac{\partial L_i}{\partial x'_j} = f^1_{x'_j} - \mu_j = 0 \text{ for } j = 1, \dots, n,$$

$$\frac{\partial L_i}{\partial x'_j} = -\lambda_k f'_{x'_j} - \mu_j = 0 \text{ for } k = 2, \dots, m \text{ and } j = 1, \dots, n,$$

where $f'_{x'_j}$ denotes the partial derivative of f with respect to x'_j . Now, fix any $k \neq i$ and $j, s \in \{1, \dots, n\}$. The above first-order condition imply that

$$\frac{f'_{x'_j}}{f'_{x'_s}} = \frac{\mu_j}{\mu_s} = \frac{f^k_{x'_j}}{f^k_{x'_s}}.$$

Thus, in a Pareto-optimal allocation, the marginal rate of substitution must be the same for all consumers.

Computation

Algorithms for computing the Pareto frontier of a finite set of alternatives have been studied in computer science and power engineering. They include:

- "The maximum vector problem" or the skyline query.
- "The scalarisation algorithm" or the method of weighted sums.

Existence of Equilibrium and Efficiency
 In economics, general equilibrium theory attempts to explain the behaviour of supply, demand, and prices in a whole economy with several or many interacting markets, by seeking to prove that the interaction of demand and supply will result in an overall general equilibrium. General equilibrium theory contrasts to the theory of *partial* equilibrium, which only analyses single markets.

General equilibrium theory both studies economies using the model of equilibrium pricing and seeks to determine in which circumstances the assumptions of general equilibrium will hold. The theory dates to the 1870s, particularly the work of French economist Léon Walras in his pioneering 1874 work *Elements of Pure Economics*.

When Arrow and Debreu published their famous proof of the existence of competitive equilibrium in 1954 their work was met with extraordinary praise. In fact, approbation was so intense that there was hardly any substantive criticism of the paper. Not a good omen. But then again, who needs to cast doubts when you want to have faith?

The existence question is not only a technical question (*i.e.*, finding out if a system of equations has a solution). In the grand narrative of market theory, the issue of existence of equilibrium is relevant because it concerns the reference point towards which disequilibrium prices (and allocations) are supposed to converge. The idea of market forces leading an economy to a point of equilibrium would be meaningless without certitude about the *existence* of the promised land. In macroeconomic theory, this is so important that in some extreme cases (*i.e.*, dynamic general equilibrium models), it is assumed that the economy is *always* in an equilibrium position.

The existence of a general competitive equilibrium haunted neoclassical economics since Walras. He knew that equality in the number of equations and unknowns was not enough to guarantee the existence of a solution. The problem was assumed away and the question of existence remained without an adequate answer for decades.

The Arrow-Debreu model changed the name of the game. As Koopmans (1957) noted, “in this model the problem is no longer conceived as that of proving that a certain set of equations has a solution.” The idea was now to show there was a specific state of the economic system where

at some prices of goods the manifold individual price-taking maximisation behaviours are mutually consistent.

The Arrow-Debreu (A-D) model was acclaimed as the first rigorous solution to this problem. The essential idea of A-D is to build a model of an economy and to utilise tools developed in game theory by Nash (1950). The centre of attention here is a fixed-point theorem, considered today as the most important tool in mathematical economics (Geanakoplos 1989).

Arrow and Debreu's intuition was that because every equilibrium is a rest point, the fixed-point theorem lent itself beautifully for the proof of existence. The trick was to be able to interpret the fixed point as an (general) economic equilibrium.

In its simplest version, the procedure using this tool can be schematised as follows. Imagine you have a set P of price vectors each with the properties $\sum p_i = 1$ (*i.e.*, for each price vector in P the sum of its components is equal to 1). Now suppose you build a mapping f that transforms price vectors into new price vectors. This mapping transforms each price vector p in the set P to a point p' , that is, another price vector in P . The fixed point theorem tells us that under certain conditions, the mapping has a fixed point, *i.e.*, there is a p^* in P such that $f(p^*) = p^*$. The validity of the theorem depends on the properties of both the mapping and the set on which it is defined.

Suppose you build this mapping so that it represents the law of supply and demand, *i.e.*, if demand is greater than supply, the mapping ensures that the price of that commodity increases. If it is less, the price will decrease. If the excess demand equals zero (*i.e.*, supply equals demand) the price will remain unchanged. Now, under certain mathematical conditions, imagine you found that your mapping transformed one price vector into precisely the *same* vector. This is a fixed point at which the prices would remain unchanged. Suppose you also demonstrated that at this fixed point for every commodity with a strictly positive price, supply would be equal to demand and where a commodity's price was zero the excess demand would be negative (*i.e.*, positive excess supply). Your proof of existence would be complete.

But this is where one needs to look at the proof in more detail, especially at the structure of the mapping. In both Brouwer's and Kakutani's

The mapping must be defined on a convex, compact fixed point theorems, the mapping must be defined on a convex, compact set (i.e., a set that is closed and bounded). The unit price simplex P has this property. It is composed of all price vectors such that the addition of its components equals unity: $\sum p_i = 1$. This is strictly a mathematical necessity in order to be able to use the fixed-point theorem.

There are various mappings (transformational rules) that change price vectors into new price vectors and represent the law of supply and demand. But we need to guarantee that the new price vectors are elements of P : the simplex, for one simple reason: the fixed-point theorem requires that the mapping be defined on a compact set. Thus, the mapping must also involve a normalisation procedure in order to ensure that all of the new price vectors belong to the price simplex (i.e., they must have the desired property: $\sum p_i = 1$). And here is where things go awry: this normalisation destroys the interpretation of the mapping as a representation of the law of supply and demand.

In our paper "The law of supply and demand in the proof of existence of general competitive equilibrium" (by Carlo Benetti, Alejandro Nadal and Carlos Salas) we demonstrate that none of the mappings used in the various proofs of existence of a general equilibrium involving a fixed point theorem is a good representation of the law of supply and demand. In some cases, commodities where demand is greater (less) than supply may have their price reduced (increased).

The reason is straightforward: the normalisation process needed to ensure that the new price vectors belong to the price simplex destroys the possibility of interpreting the mapping as consistent with the law of supply and demand. With the normalisation procedure, price changes for one commodity not only depend on the sign of the excess demand of that specific commodity, but also on the sign of the excess demands of the other $n - 1$ commodities. This is not what the law of supply and demand indicates.

Our Conclusion: The proof of existence of a general competitive equilibrium using a fixed-point theorem fails to possess an economic meaning.

In 1994 I had a brief meeting with professor Kenneth Arrow. I showed him the abstract of our paper. As he read it, he smiled and said "You and your colleagues are mistaken, you are confusing stability with existence and this is of course the source of your error".

We had anticipated this type of reaction, so I replied: "No, we are clear on that. This has nothing to do with stability. We know the existence proof does not replicate a dynamic process. But you and professor Debreu claim that the mapping used in the proof of existence represents the law of supply and demand, and what we are saying is that the normalisation procedure you have to use to ensure that the new price vector is in the unit simplex contradicts your claim".

"Oh, it's about the simplex", exclaimed Professor Arrow. "Then you're right".

That simple comment confirmed our results: the mappings do not represent the law of supply and demand. As a consequence, the proof of existence of equilibrium using a fixed-point theorem is devoid of economic sense.

An Overview

It is often assumed that agents are price takers, and under that assumption two common notions of equilibrium exist: Walrasian, or competitive equilibrium, and its generalisation: a price equilibrium with transfers.

Broadly speaking, general equilibrium tries to give an understanding of the whole economy using a "bottom-up" approach, starting with individual markets and agents. (Macroeconomics, as developed by the Keynesian economists, focused on a "top-down" approach, where the analysis starts with larger aggregates, the "big picture".) Therefore, general equilibrium theory has traditionally been classified as part of microeconomics.

The difference is not as clear as it used to be, since much of modern macroeconomics has emphasised microeconomic foundations, and has constructed general equilibrium models of macroeconomic fluctuations. General equilibrium macroeconomic models usually have a simplified structure that only incorporates a few markets, like a "goods market" and a "financial market". In contrast, general equilibrium models in the microeconomic tradition typically involve a multitude of different goods markets. They are usually complex and require computers to help with numerical solutions.

In a market system the prices and production of all goods, including the price of money and interest, are interrelated. A change in the price

of one good, say bread, may affect another price, such as bakers' wages. If bakers don't differ in tastes from others, the demand for bread might be affected by a change in bakers' wages, with a consequent effect on the price of bread. Calculating the equilibrium price of just one good, in theory, requires an analysis that accounts for all of the millions of different goods that are available.

The first attempt in neoclassical economics to model prices for a whole economy was made by Léon Walras. Walras' *Elements of Pure Economics* provides a succession of models, each taking into account more aspects of a real economy (two commodities, many commodities, production, growth, money). Some think Walras was unsuccessful and that the later models in this series are inconsistent.

In particular, Walras's model was a long-run model in which prices of capital goods are the same whether they appear as inputs or outputs and in which the same rate of profits is earned in all lines of industry. This is inconsistent with the quantities of capital goods being taken as data. But when Walras introduced capital goods in his later models, he took their quantities as given, in arbitrary ratios. (In contrast, Kenneth Arrow and Gérard Debreu continued to take the initial quantities of capital goods as given, but adopted a short run model in which the prices of capital goods vary with time and the own rate of interest varies across capital goods.)

Walras was the first to lay down a research programme much followed by 20th-century economists. In particular, the Walrasian agenda included the investigation of when equilibria are unique and stable. (Walras' Lesson 7 shows neither uniqueness, nor stability, nor even existence of an equilibrium is guaranteed.)

Walras also proposed a dynamic process by which general equilibrium might be reached, that of the *tâtonnement* or groping process.

The *tâtonnement* process is a model for investigating stability of equilibria. Prices are announced (perhaps by an "auctioneer"), and agents state how much of each good they would like to offer (supply) or purchase (demand). No transactions and no production take place at disequilibrium prices. Instead, prices are lowered for goods with positive prices and excess supply. Prices are raised for goods with excess demand. The question for the mathematician is under what conditions such a process will terminate in equilibrium where demand equals to supply

for goods with positive prices and demand does not exceed supply for goods with a price of zero. Walras was not able to provide a definitive answer to this question.

In partial equilibrium analysis, the determination of the price of a good is simplified by just looking at the price of one good, and assuming that the prices of all other goods remain constant. The Marshallian theory of supply and demand is an example of partial equilibrium analysis. Partial equilibrium analysis is adequate when the first-order effects of a shift in the demand curve do not shift the supply curve. Anglo-American economists became more interested in general equilibrium in the late 1920s and 1930s after Piero Sraffa's demonstration that Marshallian economists cannot account for the forces thought to account for the upward-slope of the supply curve for a consumer good.

If an industry uses little of a factor of production, a small increase in the output of that industry will not bid the price of that factor up. To a first-order approximation, firms in the industry will experience constant costs, and the industry supply curves will not slope up. If an industry uses an appreciable amount of that factor of production, an increase in the output of that industry will exhibit increasing costs. But such a factor is likely to be used in substitutes for the industry's product, and an increased price of that factor will have effects on the supply of those substitutes. Consequently, Sraffa argued, the first-order effects of a shift in the demand curve of the original industry under these assumptions includes a shift in the supply curve of substitutes for that industry's product, and consequent shifts in the original industry's supply curve. General equilibrium is designed to investigate such interactions between markets.

Continental European economists made important advances in the 1930s. Walras' proofs of the existence of general equilibrium often were based on the counting of equations and variables. Such arguments are inadequate for non-linear systems of equations and do not imply that equilibrium prices and quantities cannot be negative, a meaningless solution for his models. The replacement of certain equations by inequalities and the use of more rigorous mathematics improved general equilibrium modelling.

Modern Concept of General Equilibrium in Economics: The modern conception of general equilibrium is provided by a model developed

jointly by Kenneth Arrow, Gérard Debreu, and Lionel W. McKenzie in the 1950s. Debreu presents this model in *Theory of Value* (1959) as an axiomatic model, following the style of mathematics promoted by Nicolas Bourbaki. In such an approach, the interpretation of the terms in the theory (e.g., goods, prices) are not fixed by the axioms.

Three important interpretations of the terms of the theory have been often cited. First, suppose commodities are distinguished by the location where they are delivered. Then the Arrow–Debreu model is a spatial model of, for example, international trade.

Second, suppose commodities are distinguished by when they are delivered. That is, suppose all markets equilibrate at some initial instant of time. Agents in the model purchase and sell contracts, where a contract specifies, for example, a good to be delivered and the date at which it is to be delivered. The Arrow–Debreu model of intertemporal equilibrium contains forward markets for all goods at all dates. No markets exist at any future dates.

Third, suppose contracts specify states of nature which affect whether a commodity is to be delivered: “A contract for the transfer of a commodity now specifies, in addition to its physical properties, its location and its date, an event on the occurrence of which the transfer is conditional. This new definition of a commodity allows one to obtain a theory of [risk] free from any probability concept...”

These interpretations can be combined. So the complete Arrow–Debreu model can be said to apply when goods are identified by when they are to be delivered, where they are to be delivered and under what circumstances they are to be delivered, as well as their intrinsic nature. So there would be a complete set of prices for contracts such as “1 ton of Winter red wheat, delivered on 3rd of January in Minneapolis, if there is a hurricane in Florida during December”. A general equilibrium model with complete markets of this sort seems to be a long way from describing the workings of real economies, however its proponents argue that it is still useful as a simplified guide as to how a real economies function.

Some of the recent work in general equilibrium has in fact explored the implications of incomplete markets, which is to say an intertemporal economy with uncertainty, where there do not exist sufficiently detailed contracts that would allow agents to fully allocate their consumption and

resources through time. While it has been shown that such economies will generally still have an equilibrium, the outcome may no longer be Pareto optimal. The basic intuition for this result is that if consumers lack adequate means to transfer their wealth from one time period to another and the future is risky, there is nothing to necessarily tie any price ratio down to the relevant marginal rate of substitution, which is the standard requirement for Pareto optimality. Under some conditions the economy may still be constrained Pareto optimal, meaning that a central authority limited to the same type and number of contracts as the individual agents may not be able to improve upon the outcome, what is needed is the introduction of a full set of possible contracts. Hence, one implication of the theory of incomplete markets is that inefficiency may be a result of underdeveloped financial institutions or credit constraints faced by some members of the public. Research still continues in this area.

Existence

Even though every equilibrium is efficient, neither of the above two theorems say anything about the equilibrium existing in the first place. To guarantee that an equilibrium exists, it suffices that consumer preferences be strictly convex. With enough consumers, the convexity assumption can be relaxed both for existence and the second welfare theorem. Similarly, but less plausibly, convex feasible production sets suffice for existence; convexity excludes economies of scale.

Proofs of the existence of equilibrium traditionally rely on fixed-point theorems such as Brouwer fixed-point theorem for functions (or, more generally, the Kakutani fixed-point theorem for set-valued functions). The proof was first due to Lionel McKenzie, and Kenneth Arrow and Gérard Debreu. In fact, the converse also holds, according to Uzawa's derivation of Brouwer's fixed point theorem from Walras's law. Following Uzawa's theorem, many mathematical economists consider proving existence a deeper result than proving the two Fundamental Theorems.

Another method of proof of existence, global analysis, uses Sard's lemma and the Baire category theorem; this method was pioneered by Gérard Debreu and Stephen Smale.

Welfare Theorems and their Implications

There are two fundamental theorems of welfare economics.

The First Theorem states that a market will tend towards a competitive equilibrium that is weakly Pareto optimal when the market maintains the following three attributes:

1. *Complete Markets*: No transaction costs and because of this each actor also has perfect information, and
2. *Price-taking Behaviour*: No monopolists and easy entry and exit from a market.

Furthermore, the First Theorem states that the equilibrium will be fully Pareto optimal with the additional condition of:

3. *Local Non-satiation of Preferences*: For any original bundle of goods, there is another bundle of goods arbitrarily close to the original bundle, but that is preferred.

The Second Theorem states that, out of all possible Pareto optimal outcomes, one can achieve any particular one by enacting a lump-sum wealth redistribution and then letting the market take over.

Implications of the First Theorem

The First Theorem is often taken to be an analytical confirmation of Adam Smith's "invisible hand" hypothesis, namely that *competitive markets tend towards an efficient allocation of resources*. The theorem supports a case for non-intervention in ideal conditions: let the markets do the work and the outcome will be Pareto efficient. However, Pareto efficiency is not necessarily the same thing as desirability; it merely indicates that no one can be made better off without someone being made worse off. There can be many possible Pareto efficient allocations of resources and not all of them may be equally desirable by society.

This appears to make the case that intervention has a legitimate place in policy – redistributions can allow us to select from all efficient outcomes for one that has other desired features, such as distributional equity. The shortcoming is that for the theorem to hold, the transfers have to be lump-sum and the government needs to have perfect information on individual consumers' tastes as well as the production possibilities of firms. An additional mathematical condition is that preferences and production technologies have to be convex.

Proof of the First Theorem

The first fundamental theorem was first demonstrated graphically by economist Abba Lerner and mathematically by economists Harold

Hotelling, Oskar Lange, Maurice Allais, Kenneth Arrow and Gérard Debreu. The theorem holds under general conditions.

The formal statement of the theorem is as follows: *If preferences are locally non-satiated, and if (X^*, Y^*, p) is a price equilibrium with transfers, then the allocation (X^*, Y^*) is Pareto optimal*. An equilibrium in this sense either relates to an exchange economy only or presupposes that firms are allocatively and productively efficient, which can be shown to follow from perfectly competitive factor and production markets.

Given a set G of types of goods we work in the real vector space over G , \mathbb{R}^G and use boldface for vector valued variables. For instance, if $G = \{\text{butter, cookies, milk}\}$ then \mathbb{R}^G would be a three dimensional vector space and the vector $\langle 1, 2, 3 \rangle$ would represent the bundle of goods containing one unit of butter, 2 units of cookies and 3 units of milk.

Suppose that consumer i has wealth w_i such that $\sum_j w_{ij} = p \cdot e + \sum_j p_j y_j$ where e is the aggregate endowment of goods (i.e., the sum of all consumer and producer endowments) and y_j is the production of firm j .

Preference maximisation (from the definition of price equilibrium with transfers) implies (using $>$, to denote the preference relation for consumer i):

$$\begin{aligned} &\text{if } x_i >_i x_i^* \text{ then } p \cdot x_i > w_i \\ &\text{if } x_i >_i x_i^* \text{ then } p \cdot x_i \geq w_i \end{aligned}$$

In other words, if a bundle of goods is strictly preferred to x_i^* it must be unaffordable at price p . Local non-satiation additionally implies:

To see why, imagine that $x_i \geq_i x_i^*$ but $p \cdot x_i < w_i$. Then by local non-satiation we could find x_i' arbitrarily close to x_i (and so still affordable) but which is strictly preferred to x_i^* . But x_i' is the result of preference maximisation, so this is a contradiction.

An allocation is a pair (X, Y) where $X \in \prod_{i \in I} \mathbb{R}^G$ and $Y \in \prod_{j \in J} \mathbb{R}^G$, i.e., X is the 'matrix' (allowing potentially infinite rows/columns) whose i th column is the bundle of goods allocated to consumer i and X is the 'matrix' whose j th column is the production of firm j . We restrict our attention to feasible allocations which are those allocations in which no consumer sells or producer consumes goods which they lack, i.e., for every good and every consumer that consumers initial endowment plus their net demand must be positive similarly for producers.

Now consider an allocation (X, Y) that Pareto dominates (X^*, Y^*) . This means that $x_i \geq x_i^*$ for all i and $x_i > x_i^*$ for some i . By the above, we know $p \cdot x_i \geq w_i$ for all i and $p \cdot x_i > w_i$ for some i . Summing, we find:

$$\sum_i p \cdot x_i > \sum_i w_i = \sum_i p \cdot y_i^*.$$

Because Y^* is profit maximising, we know $\sum_j p \cdot y_j^* \geq \sum_j p \cdot y_j$, so $\sum_i p \cdot x_i > \sum_i p \cdot y_j$. But goods must be conserved so $\sum_i x_i > \sum_j y_j$. Hence, (X, Y) is not feasible. Since all Pareto-dominating allocations are not feasible, (X^*, Y^*) must itself be Pareto optimal.

Note that while the fact that Y^* is profit maximising is simply assumed in the statement of the theorem the result is only useful/interesting to the extent such a profit maximising allocation of production is possible. Fortunately, for any restriction of the production allocation Y^* and price to a closed subset on which the marginal price is bounded away from 0, e.g., any reasonable choice of continuous functions to parameterise possible productions, such a maximum exists. This follows from the fact that the minimal marginal price and finite wealth limits the maximum feasible production (0 limits the minimum) and Tychonoff's theorem ensures the product of these compact spaces is compact ensuring us a maximum of whatever continuous function we desire exists.

Proof of the Second Fundamental Theorem

The Second Theorem formally states that, under the assumptions that every production set Y_j is convex and every preference relation \succeq_j is convex and locally non-satiated, any desired Pareto-efficient allocation can be supported as a price quasi-equilibrium with transfers. Further assumptions are needed to prove this statement for price equilibria with transfers.

The proof proceeds in two steps: first, we prove that any Pareto-efficient allocation can be supported as a price quasi-equilibrium with transfers; then, we give conditions under which a price quasi-equilibrium is also a price equilibrium.

Let us define a price quasi-equilibrium with transfers as an allocation (x^*, y^*) , a price vector p , and a vector of wealth levels w (achieved by lump-sum transfers) with $\sum_i w_i = p \cdot w + \sum_i p \cdot y_i^*$ (where w is the aggregate endowment of goods and y_i^* is the production of firm j) such that:

- i. $p \cdot y_j \leq p \cdot y_j^*$ for all $y_j \in Y_j$ (firms maximise profit by producing y_j^*)

- ii. For all i , if $x_i > x_i^*$, then $p \cdot x_i \geq w_i$ (if x_i is strictly preferred to x_i^* then it cannot cost less than x_i^*)

- iii. $\sum_i x_i^* = w + \sum_i y_i^*$ (budget constraint satisfied)

The only difference between this definition and the standard definition of a price equilibrium with transfers is in statement (ii). The inequality is weak here ($p \cdot x_i \geq w_i$) making it a price quasi-equilibrium. Later we will strengthen this to make a price equilibrium. Define V_j to be the set of all consumption bundles strictly preferred to x_i^* by consumer i , and let V be the sum of all V_j . V_j is convex due to the convexity of the preference relation \succeq_j . V is convex because every V_j is convex. Similarly $Y + \{\omega\}$, the union of all production sets Y_j plus the aggregate endowment, is convex because every Y_j is convex. We also know that the intersection of V and $Y + \{\omega\}$ must be empty, because if it were not it would imply there existed a bundle that is strictly preferred to (x^*, y^*) by everyone and is also affordable. This is ruled out by the Pareto-optimality of (x^*, y^*) .

These two convex, non-intersecting sets allow us to apply the separating hyperplane theorem. This theorem states that there exists a price vector $p \neq 0$ and a number r such that $p \cdot z \geq r$ for every $z \in V$ and $p \cdot z \leq r$ for every $z \in Y + \{\omega\}$. In other words, there exists a price vector that defines a hyperplane that perfectly separates the two convex sets.

Next we argue that if $x_i \succeq_j x_i^*$ for all i then $p \cdot (\sum_i x_i) \geq r$. This is due to local non-satiation: there must be a bundle x_i' arbitrarily close to x_i that is strictly preferred to x_i^* and hence part of V_j , so $p \cdot (\sum_i x_i') \geq r$. Taking the limit as $x_i' \rightarrow x_i$ does not change the weak inequality, so $p \cdot (\sum_i x_i) \geq r$ as well. In other words, x_i is in the closure of V .

Using this relation we see that for x_i^* itself $p \cdot (\sum_i x_i^*) \geq r$. We also know that $\sum_i x_i^* \in Y + \{\omega\}$, so $p \cdot (\sum_i x_i^*) \leq r$ as well. Combining these we find that $p \cdot (\sum_i x_i^*) = r$. We can use this equation to show that (x^*, y^*, p) fits the definition of a price quasi-equilibrium with transfers.

Because $p \cdot (\Sigma_i x_i^*) = r$ and $\Sigma_i x_i^* = w + \Sigma_j x_j^*$ we know that for any firm j :

$$p \cdot (w + \Sigma_i x_i^*) \leq r = p \cdot (w + \Sigma_j x_j^*) \text{ for } h \neq j$$

which implies $p \cdot y_j \leq p \cdot y_h^*$. Similarly we know:

$$p \cdot (x_j + \Sigma_k x_k^*) \geq r = p \cdot (x_i^* + \Sigma_k x_k^*) \text{ for } k \neq i$$

which implies $p \cdot x_j \geq p \cdot x_i^*$. These two statements, along with the feasibility of the allocation at the Pareto optimum, satisfy the three conditions for a price quasi-equilibrium with transfers supported by wealth levels $w_i = p \cdot x_i^*$ for all i .

We now turn to conditions under which a price quasi-equilibrium is also a price equilibrium, in other words, conditions under which the statement "if $x_i > x_i^*$ then $p \cdot x_i \geq w_i$ " implies "if $x_i > x_i^*$ then $p \cdot x_i > w_i$ ". For this to be true we need now to assume that the consumption set X_i is convex and the preference relation \geq_i is continuous. Then, if there exists a consumption vector x'_i such that $x'_i \in X_i$ and $p \cdot x'_i < w_i$, a price quasi-equilibrium is a price equilibrium.

To see why, assume to the contrary $x_i > x_i^*$ and $p \cdot x_i = w_i$, and x_i exists. Then by the convexity of X_i we have a bundle $x_i' = \alpha x_i + (1 - \alpha)x_i^* \in X_i$ with $p \cdot x_i' < w_i$. By the continuity of \geq_i for α close to 1 we have $\alpha x_i + (1 - \alpha)x_i^* > x_i'$. This is a contradiction, because this bundle is preferred to x_i' and costs less than w_i .

Hence, for price quasi-equilibria to be price equilibria it is sufficient that the consumption set be convex, the preference relation to be continuous, and for there always to exist a "cheaper" consumption bundle x_i' . One way to ensure the existence of such a bundle is to require wealth levels w_i to be strictly positive for all consumers i .

Related Theorems

Because of welfare economics' close ties to social choice theory, Arrow's impossibility theorem is sometimes listed as a third fundamental theorem.

The ideal conditions of the theorems, however are an abstraction. The Greenwald-Stiglitz theorem, for example, states that in the present

of either imperfect information, or incomplete markets, markets are not Pareto efficient. Thus, in real world economies, the degree of these variations from ideal conditions must factor into policy choices. Further, even if these ideal conditions hold, the First Welfare Theorem fails in an overlapping generations model.

The Firm; Production and Welfare Theorems

Theory of the Firm

Behaviour of a firm in pursuit of profit maximisation, analysed in terms of (1) what are its inputs, (2) what production techniques are employed, (3) what is the quantity produced, and (4) what prices it charges. The theory suggest that firms generate goods to a point where marginal cost equals marginal revenue, and use factors of production to the point where their marginal revenue product is equal to the costs incurred in employing the factors.

Welfare Theorems

Welfare economics are a part of normative economics which objective is to evaluate different situations of a given economic system, in order to choose the best one.

Its study can be traced back to Adam Smith, who related an increase of welfare with an increase on production, and to Jeremy Bentham, whose utilitarian views made him think that welfare was equal to the sum of individuals utilities or, in other words, to a "social" utility.

Traditional welfare economics is based on the work of three neoclassical economists. Alfred Marshall stated that consumer's welfare was the consumer's surplus, and therefore was measurable in monetary units. Vilfredo Pareto would criticise this cardinal view, and would be the economist who built a true theory of welfare economics in his book "Manual of Political Economy", 1906, based on the principles of unanimity and individualism, he designed what nowadays is known as the *Pareto Optimality*, which would become the core of welfare economics. Later, Pigou wrote "The Economics of Welfare", 1920, stating that a definition of social welfare must include both efficiency and equity.

During the XXth century, welfare economics developed quickly. Nicholas Kaldor and John Hicks' compensation criteria, and its following critics by Scitovsky, Little and Paul Samuelson, which aim was to find

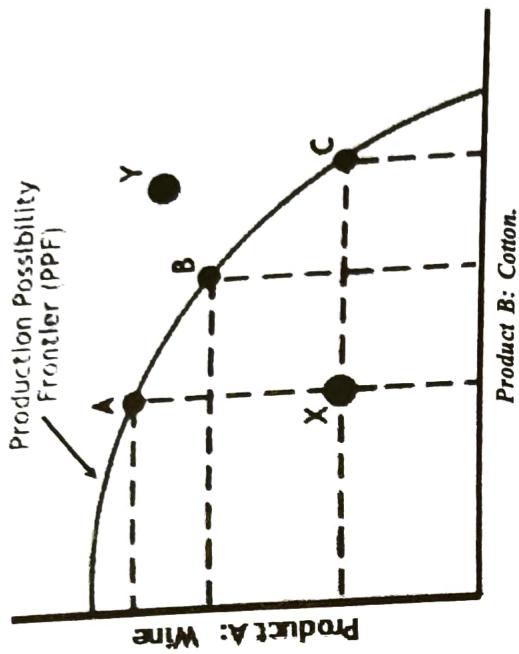
some way of classification of different optima. Also Bergson's social welfare function, and Kenneth Arrow's impossibility theorem, proving the former could not be identified. The theory of second best, developed by Lipsey and Lancaster, aimed at finding an optimum when Pareto optimality could not be found. Finally, the increasing use of cost-benefit analysis marks the validity of welfare economics nowadays.

Production Possibilities

In the field of macroeconomics, the production possibility frontier (PPF) represents the point at which a country's economy is most efficiently producing its goods and services and, therefore, allocating its resources in the best way possible. There are just enough apple orchards producing apples, just enough car factories making cars, and just enough accountants offering tax services. If the economy is not producing the quantities indicated by the PPF, resources are being managed inefficiently and the stability of the economy will dwindle. The production possibility frontier shows us that there are limits to production, so an economy, to achieve efficiency, must decide what combination of goods and services can and should be produced.

Let's turn to an example and consider the chart below. Imagine an economy that can produce only two things: wine and cotton. According to the PPF, points A, B and C – all appearing on the PPF curve – represent the most efficient use of resources by the economy. For instance, producing 5 units of wine and 5 units of cotton (point B) is just as desirable as producing 3 units of wine and 7 units of cotton. Point X represents an inefficient use of resources, while point Y represents the goals that the economy simply cannot attain with its present levels of resources.

As we can see, in order for this economy to produce more wine, it must give up some of the resources it is currently using to produce cotton (point A). If the economy starts producing more cotton (represented by points B and C), it would need to divert resources from making wine and, consequently, it will produce less wine than it is producing at point A. As the figure shows, by moving production from point A to B, the economy must decrease wine production by a small amount in comparison to the increase in cotton output. However, if the economy moves from point B to C, wine output will be significantly reduced while the increase in cotton will be quite small.

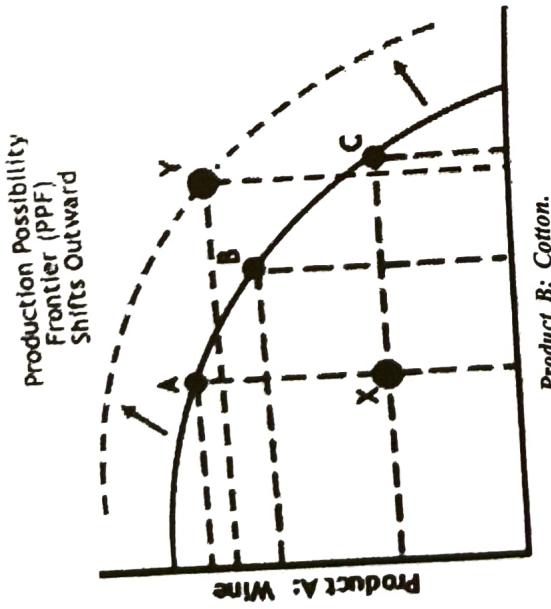


Product B: Cotton

Keep in mind that A, B, and C all represent the most efficient allocation of resources for the economy; the nation must decide how to achieve the PPF and which combination to use. If more wine is in demand, the cost of increasing its output is proportional to the cost of decreasing cotton production. Markets play an important role in telling the economy what the PPF ought to look like.

Consider point X on the figure above. Being at point X means that the country's resources are not being used efficiently or, more specifically, that the country is not producing enough cotton or wine given the potential of its resources. On the other hand, point Y, as we mentioned above, represents an output level that is currently unattainable by this economy. But, if there were a change in technology while the level of land, labour and capital remained the same, the time required to pick cotton and grapes would be reduced. Output would increase, and the PPF would be pushed outwards. A new curve, represented in the figure below on which Y would fall, would then represent the new efficient allocation of resources.

When the PPF shifts outwards, we can imply that there has been growth in an economy. Alternatively, when the PPF shifts inwards it indicates that the economy is shrinking due to a failure in its allocation of resources and optimal production capability. A shrinking economy could be a result of a decrease in supplies or a deficiency in technology.

*Product B: Cotton.*

An economy can only be producing on the PPF curve in theory; in reality, economies constantly struggle to reach an optimal production capacity. And because scarcity forces an economy to forgo some choice in favour of others, the slope of the PPF will always be negative; if production of product A increases then production of product B will have to decrease accordingly.

Comparative Advantage Trade, Comparative Advantage and Absolute Advantage

An economy may be able to produce for itself all of the goods and services it needs to function using the PPF as a guide, but this may actually lead to an overall inefficient allocation of resources and hinder future growth – when considering the benefits of trade. Through specialisation, a country can concentrate on the production of just a few things that it can do best, rather than dividing up its resources among everything.

Let us consider a hypothetical world that has just two countries (Country A and Country B) and only two products (cars and cotton). Each country can make cars and/or cotton. Suppose that Country A has very little fertile land and an abundance of steel available for car production. Country B, on the other hand, has an abundance of fertile land but very little steel. If Country A were to try to produce both cars and cotton, it

would need to divide up its resources, and since it requires a great deal of effort to produce cotton by irrigating its land, Country A would have to sacrifice producing cars – which it is much more capable of doing. The opportunity cost of producing both cars and cotton is high for Country A, as it will have to give up a lot of capital in order to produce both. Similarly, for Country B, the opportunity cost of producing both products is high because the effort required to produce cars is far greater than that of producing cotton.

Each country in our example can produce one of these products more efficiently (at a lower cost) than the other. We can say that Country A has a comparative advantage over Country B in the production of cars, and Country B has a comparative advantage over Country A in the production of cotton.

Now let's say that both countries (A and B) decide to specialise in producing the goods with which they have a comparative advantage. If they then trade the goods that they produce for other goods in which they don't have a comparative advantage, both countries will be able to enjoy both products at a lower cost. Furthermore, each country will be exchanging the best product it can make for another good or service that is the best that the other country can produce so quality improves. Specialisation and trade also works when several different countries are involved. For example, if Country C specialises in the production of corn, it can trade its corn for cars from Country A and cotton from Country B.

Determining how countries exchange goods produced by a comparative advantage (the best for the best) is the backbone of international trade theory. This method of exchange via trade is considered an optimal allocation of resources, whereby national economies, in theory, will no longer be lacking anything that they need. Like opportunity cost, specialisation and comparative advantage also apply to the way in which individuals interact within an economy.

Absolute Advantage

Sometimes a country or an individual can produce more than another country, even though countries both have the same amount of inputs. For example, Country A may have a technological advantage that, with the same amount of inputs (good land, steel, labour), enables the country to easily manufacture more of both cars and cotton than Country B. A country that can produce more of both goods is said to have an absolute

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advantage. Better access to quality resources can give a country an absolute advantage as can a higher level of education, skilled labour, and overall technological advancement. It is not possible, however, for a country to have an absolute advantage in everything that it produces, so it will always be able to benefit from trade.

Pareto Efficiency

Pareto efficiency, also known as "Pareto optimality," is an economic state where resources are allocated in the most efficient manner, and it is obtained when a distribution strategy exists where one party's situation cannot be improved without making another party's situation worse. Pareto efficiency does not imply equality or fairness. Pareto efficiency has broad implications in economics, particularly in game theory. Unlike the predicted logical outcome of a prisoner's dilemma (participants choose selfishly and do not achieve the best possible outcome), if an economic state is Pareto efficient, individuals are maximising their utility. The final allocation decision cannot be improved upon, given a limited amount of resources, without causing harm to one of the participants.

Pareto efficiency does allow for a party to experience improvement, a process known as Pareto improvement, but it must not come at the expense of any other party. For example, if a company produces three products as part of its normal business operations, the addition of an employee on one production line may result in higher outputs of that product without any negative impact on the other two.

In contrast, if the company move one employee from one production line to another, there may be an increase in productivity in one line. This may be offset by the decrease in the other and, therefore, is not an example of Pareto efficiency since a negative outcome occurred.

Question

- 01- what is Edgeworth Box? Discuss the use of it in Trade
- 02- what do you mean by Resoumn Allocating? Discuss how it allocates of Resources on the plane?
- 03 what do you mean by welfare Theorems? Discuss their implications.
- 04- what is the relationship between Production and the welfare Theorems?
- 05- Write short notes on

 - a- Production possibilities
 - b- Comparative advantage
 - c- Pareto efficiency.