APPLICATION OF DIFFERENTIAL EQUATIONS IN ECONOMICS

Muydinov Khusniddin Nuriddin ugli
Assistant professor of the Department of social, humanitarian and special sciences,
Andijan faculty of Tashkent Institute of Finance, Andijan, Uzbekistan
Khusanova Raykhona Khasanboy kizi
Student of Andijan faculty of Tashkent Institute of Finance,
Andijan, Uzbekistan

Abstract: A differential equation is an equation that connects the desired function of one or more variables, these variables and derivatives of various orders of this function. The relevance of the article is to consider the use of differential equations in economics.

Key words: integral, differential equations, several variables, geometric control constraint, derivative, linear equation.

Differential equations are widely used in models of economic dynamics, which investigate not only the dependence of variables on time, but also on their relationship over time.

Let us consider the questions of the theory of differential equations on the example of first-order equations resolved with respect to the derivative, i.e. those that admit representation in the form:

a. where f is some function of several variables.

The theorem of the existence and uniqueness of the solution of a differential equation.

Let in differential equation (a) the function and its partial derivative be continuous on an open set R of the coordinate plane *Oxy*.

Then:

For every point of the set G, there is a solution y=y (x) of equation (a) satisfying the condition y ();

If two solutions y = (x) and y= (x) of equation (a) coincide for at least one value of x=, i.e. if these solutions coincide for all those values of the variable x for which they are defined. A first-order differential equation is called an equation with separable variables if it can be represented as

g(y).

or as

$M(x)\,N(y)\,dx+P(x)\,Q(y)\,dy=0,$

where, M(x), P (x) are some functions of the variable x, g(y), N(y), Q(y) are functions of the variable y.

Equation of the form:

b. where p(x) and q(x) are continuous functions, it is called a linear differential equation of the first order.

The unknown function and its derivative enter the specified equation in the first degree - linearly, which explains the name of the equation.

If q(x) is 0, then equation is called a linear homogeneous equation; if the function q(x) is not identically zero, then equation is called a linear inhomogeneous equation.

For a linear equation of the first order, a general solution can be written using the method of variation of the constant. Here this solution is given without a conclusion:

It should be noted that some nonlinear equations are reduced to linear equations by corresponding substitutions of an unknown function y (x). These include the Bernoulli equation:

where p and q are continuous functions, and n is some constant number. For n = 0 we have a linear inhomogeneous equation, and for n = 1 - a linear homogeneous equation Let n ? 0, n ? 1.

Multiplying both parts of this equation by (1 - n), taking into account the expressions for the new function z and its derivative, we obtain a linear differential inhomogeneous equation with respect to an unknown function z (x):

In this equation, the method of solving which we know, the function z (x) is related to the desired function y (x) by relation.

Task 1. About the effectiveness of advertising.

Suppose a trading company sells some products, about which at time t = 0 x0 people out of a total of N potential buyers received information from advertising. Further, this information is distributed through people's communication, and at time t > 0, the number of people who know about the products is x (t). Let's assume that the growth rate of the number of people who know about the products is proportional to both the number of currently aware buyers and the number of uninformed buyers.

From the equation we obtain the equality of the differentials of the two functions of the argument t:

- Integrating the left and right parts, we find the general solution of the differential equation:
- The general solution includes an indefinite constant C. Assuming NC = D, we obtain the equality:
- from which we define the function x (t):

- Here E = . This kind of function is called a logistic function, and its graph is called a logistic curve.

If we now take into account that x (0) = x0 and put x0 = N/a, where a > 0, then we can find the value of the constant E. The logistic function will take the form:

The integral of a function is analogous to the sum of a sequence. Informally speaking, the (definite) integral is the area of a part of the graph of the function (within the integration), that is, the area of a curved trapezoid. The process of finding the integral is called integration.

A definite integral is an additive monotone normalized functional defined on a set of pairs, the first component of which is an integrable function or functional, and the second is a domain in the set of the assignment of this function (functional).

The definition of the integral given above, with all its apparent generality, eventually leads to the usual understanding of a certain integral as the area of a subgraph of a function on a segment.

a - lower limit;

b - upper limit;

f(x) - integrand;

lR - the length of the partial segment;

yR is the integral sum of the function f(x) by [a; b] corresponding to the partition R;

Traditionally, the practical application of the integral is illustrated by calculating the areas of various figures, finding the volumes of geometric bodies and some applications in physics and engineering. However, the role of the integral in modeling economic processes is not considered. Often the economic applications of the integral are out of the question in the classes of the economic direction. At the same time, integral calculus provides a rich mathematical apparatus for modeling and studying the processes occurring in the economy.

Let's start with the concept of consumer surplus, which is widely used in the market economy (the difference between the price that a consumer is willing to pay for a product and the one that he actually pays when buying). The supply of an individual product is graphically depicted as a curve with a positive slope, reflecting the relationship between the unit price of this product P and the quantity of product Q that consumers are willing to sell at each price.

Note that economists found it convenient to depict the argument (price) on the ordinate axis, and the dependent variable (quantity of goods) on the

abscissa axis. Therefore, the graphs of the supply and demand functions look as follows.

Let's introduce a concept that plays an important role in modeling economic processes - market equilibrium. The equilibrium state is characterized by such price and quantity at which the volume of demand coincides with the value of supply, and graphically the market equilibrium is represented by the intersection point of the supply and demand curves, E* (p*; q*) is the equilibrium point 2.

Let us now turn to the consideration of applications of integral analysis for determining consumer surplus. To do this, we will plot the inverse demand function P = f (Q) on the graph. But now let's assume that the product in quantity Q * is not sold by sellers immediately, but enters the market in small batches of Q. Note that this assumption is quite justified, because such a scheme for the sale of goods is quite common in practice and follows from the seller's goal to maintain the price of the goods as high as possible.

Then we get that first the product is offered in quantity Q1 = D Q (Fig.5), which is sold at the price P1 = f (Q1). Since, according to the assumption, the value of Q is small, it can be assumed that the entire first batch of goods is sold at the price of P1, while the buyer's costs for the purchase of such a quantity of goods will amount to P1D Q, which corresponds to the area of the shaded rectangle S1.

Next, the second batch of goods arrives on the market in the same quantity, which is sold at the price P2 = f (Q2), where Q2 = Q1 + D Q is the total number of products sold, and the buyer's costs for the purchase of the second batch will be P2D Q, which corresponds to the area of the rectangle S2.

We will continue the process until we reach the equilibrium quantity of the product Q* = Qn. Then it becomes clear what the value of D Q should be in order for the process of selling the goods to end at point Q*:

As a result, we get that the price of the nth batch of goods Pn = f (Qn) = f (Q*) = P*, and the cost of consumers to purchase this last batch of goods will be PnD Q, or the area of the rectangle Sn.

Thus, we get that the total costs of consumers when buying goods in small batches D Q are equal.

Since the value of D Q is very small, and the function f (Q) is continuous, we conclude that it is approximately equal to the area of figure B, which, as is known, for small increments of the argument D Q is equal to a certain integral of the inverse demand function when the argument changes from 0 to Q*, i.e. as a result, we get that

Remembering that each point on the demand curve Pi = f (Qi) (i = 1, 2,., k) shows how much the consumer is willing to pay for the purchase of an additional unit of product, we get that the area of figure B corresponds to the total amount of money that the consumer is willing to spend on the purchase of Q* units of goods. The difference between the area of figure B and the area of rectangle A is the consumer surplus when buying this product - the excess of the total cost that the consumer is willing to pay for all units of the product.

Thus, the consumer surplus can be calculated using the following formula:

Task 2.

It is known that the demand for a certain product is described by a function and the supply of this product is characterized by a function q = 500p. Find the amount of the consumer's surplus when buying this product.

Decision. To calculate the consumer surplus, we first determine the parameters of market equilibrium (p*; q*). To do this, we will solve a system of equations

Thus, p* = 2, q* = 1000.

Let's write down the formula for calculating the consumer surplus (1), where f(q) is the inverse function of

From here

Determine the stock of goods in the store formed in three days if the receipt of goods is characterized by the function f (t) = 2t + 5.

Mathematics has now ceased to be the subject of studies only of the scientific elite; now mathematics classes attract an increasing number of gifted people. The field of mathematical research and the application of mathematical apparatus has significantly expanded. Applications of mathematical methods penetrate far beyond the limits of mathematics proper: into physics, new branches of technology, biology, economics and other social sciences; without strict mathematical logic, the work of a lawyer or manager is impossible. Information and computer technologies have contributed to the emergence of new areas of scientific research, which are undoubtedly of extremely great importance both for mathematics itself and for all sciences directly related to it.

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