STATISTICAL AND SOCIAL INQUIRY SOCIETY OF IRELAND.

THE DETERMINATION OF DEMAND CURVES IN RELATION TO WHEAT.

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1. The ultimate problem of economic analysis is the correlation of variations in associated series of events; the determination whether and to what degree a change in one series is associated with a change in another or others, so that from a known change in the latter a probable change in the former can be predicted; and the measurement of the likelihood of that prediction being correct in any particular case. Since the 1870's economic doctrine has been pervaded by the general acceptance of one such correlation, and the development of a structure of theory on it as a foundation : namely, in general terms, an inverse correlation between quantities and prices. By this is meant that, except in special circumstances, if a given quantity of anything is offered freely for sale, the whole of it can be cleared at a certain price per unit; if the quantity be increased, the price will fall and if the quantity be decreased the price will rise. The freedom of dealings in the market, the participants' opportunities of knowledge of market conditions, the ease of communication and transport between them—all the circumstances which economists collect under the topic of the perfection or imperfection of the market—will affect the rapidity and precision with which the clearance price is attained; its stability when reached, so long as the conditions which evoked it remain unchanged; and its ease and accuracy of readjustment to new conditions when they emerge. Alternatively, if we regard the price as the independent and the quantity as the dependent variable, we can read the correlation as signifying that for any price fixed beforehand a certain quantity can be sold, which increases if the price be lowered and decreases if the price be raised, so long as the original conditions remain approximately unaltered. So far as immediately consumable goods are concerned, the approximate truth of this general proposition is apparent from our own everyday experience, particularly if we are traders; to some the form of it which relates price variations to changes in the quantities offered or available for sale—the '' visible supply ''—will be more familiar ; to others, according to their business, the form which relates possible volumes of sales to a given schedule of prices. Such information, even if only a very rough-and-ready and perhaps not very consciously appreciated rule-of-thumb, is a part of the equipment of every farmer, manufacturer, trader and financier. But in economic theory the range of the notion is very much wider.

The conception of a declining demand curve, an inverse relationship between quantities and prices, is expanded to cover the price-determination of everything which has a price, including not only immediately consumable articles but also durable goods, capital goods, the generalised command over capital, and personal activity; it is applied equally to the determination of interest-rates, wage-rates and the volume of employment in each particular occupation and in the economy as a whole.

2. It is desirable that a notion which is thus used as a fundamental analytical device over a wide field of economic relationships should be capable of being clearly stated and should be reduced to concrete quantitative terms in as many cases as possible—*i.e.*, to the statement not only that *some* variation in price accompanies a variation in quantity, and *vice versa*, but also *how great* that variation is. But the attempt to '' quantify '' the rule is faced by great difficulties. The bare possibility of doing so depends on the conditions of demand remaining unchanged long enough to enable us to collect a number of instances large enough to negative the effects of chance errors—*i.e.*, in view of the defectiveness of much of our statistical information, to allow the law of large numbers to operate. But in the last analysis the '' conditions of demand '' are a purely psychological conception—the tastes, wishes, desires, wants, etc. ruling among a given population, or section thereof, at a given moment—and some '' demands '' are highly unstable, subject to all kinds of temporary and irrational influences or to sentimental exaggeration of real considerations—*e.g.*, the demand for the generalised command over capital, both long and short term. It is this which effectively obstructs quantitative precision in monetary theory, and leaves us quite in the dark with respect to the prediction of the most probable consequences of a given alteration in the monetary circulation, particularly if that alteration be in an upward direction. Again, some '' demands '' are composite—*i.e.* the article or service is used for two or more different purposes, each of which has its own conditions of demand—and others are derived—*i.e.* the article or service is demanded, not for its own sake, but for the sake of some further article or service which it assists in producing, so that a double computation is involved, of the relation between quantities and prices of the latter and that between certain quantities of the former and the corresponding quantities of the latter which they assist to produce. These are all intellectual difficulties obstructing the clear formulation of the relationship existing between the conditions of demand for the article or service in question and the factors whose variations control them; no amount of statistical data, however intelligently collected, will ever overcome them. They reduce our efforts in practice to the attempt to compute the conditions of demand for final consumable commodities. This is not, however, so great a sacrifice as might appear at first sight; for the demands for labour and capital are derived from those for the consumable articles which emerge from their utilisation, and if the conditions of demand for these can be quantitatively determined, enough will be known for practical use in any given case. As a last difficulty, applying equally to all demands whether final or derived, it must be mentioned that one of the influences causing instability in those very conditions whose stability must be assumed for the purpose of demand-curve computation is the variability in the amount and distribution of the community's

income, and the dependence of these income-variations on the nature of the very demand-curve which is under calculation—*e.g.* granting for the moment that the conditions of demand for wheat existing at any given time could be accurately described by a curve and equation of a certain degree of inverse relationship between supply and price, and that the supply actually existing for any given year and the price actually realised can be accurately ascertained and plotted thereon, suppose that the supply actually becoming available in the immediately ensuing supply-period is ascertained to be greater than the previous by 10%, and that the conditions of demand ruling during the previous period entailed the association with this increased supply of a price lower by 8%; this would involve two consequences, first, that consumers of wheat would be spending on it an amount of money greater by 1.2% in the second than in the first period, so that their incomes available for the purchase of other things would be diminished, and secondly, that the incomes of persons engaged in the production, transport and sale of wheat would be increased by a corresponding amount, to increase their purchases of everything, including wheat; if it could be supposed that persons whose incomes increased spent the increase in purchasing the things left unbought by the persons whose incomes decreased, we would be justified in saying that, in the aggregate, conditions remained unchanged, but this is manifestly so improbable as to be impossible; of the diminished incomes some would otherwise have been spent on wheat, of the increased incomes some would be spent on wheat, but there is no reason whatever to suppose that these two magnitudes would be equal. That is, the inevitable consequence of the existence of a demand-curve for wheat and of concrete variations in the available supply is an alteration in the underlying conditions of that demand, whose stability is an assumption necessary to any computation whatever of demand functions. This conclusion might seem to render the labour involved in the attempt to compute demand curves wholly wasteful, but that would be too severe. When the annual variations involved are comparatively small, these inevitable derangements of the underlying conditions will not be quantitatively significant and can be neglected.

3. In addition to these intellectual difficulties, there are numerous merely operative ones to be surmounted. The problem is the establishment of two series of magnitudes, one of quantities and one of prices, whose periodical variations are to be compared. We require a series over a period of years long enough to blanket merely casual errors, and we must depend on published statistics for our data. The deficiencies of those will appear below. But the price series presents a more radical difficulty. The actual price of any commodity or service at any moment is the resultant of two quite different influences, one being the interaction of its own peculiar conditions of demand and supply and the other reaction of general monetary conditions: *e.g.* if we could say that as between one year and another the price of wheat changed by 10%, while prices in general changed by 20% (*i.e.*, the value of money increased by 25% or fell by 17⅔%), we could not possibly say that the real price of wheat, the price of wheat compared with the prices of all other saleable objects and services, had changed by 10%. The prices of wheat must be rewritten in terms of some standard unit of

money. Mathematically, this is a simple operation, but in fact there does not exist anywhere a satisfactory index of the purchasing power of money. Later on in this paper I use the general index published by the *Statist* weekly and also its " food " group, in default of anything better, but it inevitably introduces a degree of uncertainty into the results.

4. I selected wheat as the subject of this study because it is an object of comparatively simple demand, being used for little else than human food : the animal feeding-stuffs derived from it are mainly bye-products resulting from the process of its preparation as human food. Likewise statistics relating to it have been more or less intelligently kept by Governments over a considerable period, and can with some difficulty be adapted to scientific use. The local unit used for the investigation has been the United Kingdom of Great Britain and Ireland until 1923 and thereafter the United Kingdom of Great Britain and Northern Ireland. The information is drawn, unless otherwise stated, from the Statistical Abstracts of the United Kingdom, and consequently goes back to 1840.

5. For the quantity series, we have a continuous record of imports of wheat and flour, and their total equivalent in grain, since 1852. The estimated grain equivalent of a given weight of flour varies in the record, and the earlier series have been recalculated on the basis of 1 cwt. flour being equivalent to 1.389 cwt. wheat, which is the latest used. For 1840-52 no figures of re-exports are available, but it is assumed that during those years 99% of the wheat and 98.2% of the flour were retained, which are the averages for 1852-66; during the same years the records are in terms of quarters, which are converted at the official rate of 480 lb.

6. Official estimates of domestic production in Ireland commence in 1847 with records both of acreage and of gross produce. In Great Britain records of acreage begin with 1867 and estimates of gross produce with 1884. We must accept these figures without being able to express any opinion on their real reliability. Comparing the average yield per acre in the Irish Free State (whose records have been published in a very convenient and accessible form by the Department of Industry and Commerce [Agricultural Statistics of the Irish Free State, 1847-1926]), there is a very high degree of correspondence. From 1884 to 1902 the average difference is only 1-5 cwt. and there are only five occasions, 3 of which are trifling, on which their movements diverge. Thus applying the Free State yields to British acreage from 1867 to 1883 will give a close approximation to the produce of those years. For the years 1840-67 we must fall back on the records of sales in certain market towns in England and Wales : this is a series of monthly records, internally inconsistent, reports being collected from 150 towns till 29th April, 1842; from 290 till 31st December, 1864; again, from 150 till 31st December, 1882; from 187 till 12th April, 1890, and thereafter until 1902 from 196. In order to attempt to prolong the series of computed output for Great Britain backwards to 1840 by comparison with these figures, they must be regrouped on a " crop year " instead of a calendar year basis. Observation shows that in later years when the parallel figures of output show a marked change from one year to another, the break in the recorded monthly sales and in the

corresponding series of average prices occurs in September or October, and it is, moreover, plausible that wheat harvested in the late summer should be threshed and coming on the market from October onwards. Consequently, October-September is taken as the crop year and the figures regrouped thus. This series is reduced by a number of computations whose details it would be wearisome to enter here to a standard basis of 196 towns. Such a computation cannot fail to be highly speculative, but, except in the years during which changes in the basis of the records were made, it will faithfully reflect variations in the annual volume of transactions. From 1867 this series accords very closely with the parallel series of outputs. Carrying the comparison out until 1900 only, the annual variation corresponds in 24 cases, diverges in a trifling way in 4 and seriously in 6; the volume of sales averages 34.8% of the estimated gross outputs. It is suggested, therefore, that the gross produce series can be extended back to 1840 on this basis, and that, while the absolute figure may be in error (and, indeed, appears much too large), the annual variations will be fairly faithfully reflected; the error in the absolute amount is of the less moment in that the volume of imports which must be added to it is comparatively small. The gap in the Irish figures, 1840-7, is filled up on the fairly plausible assumption that the Irish proportion of the total remained fairly constant between those years, though the catastrophic change introduced into the Irish economy by the events of 1847 caused it to fall away rapidly afterwards. We have thus a series of figures of gross produce, as officially estimated from 1884, slightly speculatively 1867-84, and with a considerable degree of uncertainty 1840-67. The extension to cover these last 27 years was laborious, and not absolutely necessary, but it was desired to obtain as great a number of instances as possible and, as mentioned above, the annual variations are fairly reliable. Even so, a collection of 89 items is a lamentably small sample from which to attempt the deduction of a general relationship, but the inevitable paucity of data compels us to rely on such as we have, and to trust to luck that the sample approximates to a representative one.

7. This gives two series: (*a*) net imports, from which are also deducted exports of native wheat, flour, bread, biscuits, farinaceous products, etc. (as a rough approximation these latter are treated as equivalent weights of flour), recorded by calendar years; (*b*) estimated domestic gross produce, recorded or computed by crop-years. To make these susceptible of addition, they must be reduced to a comparable basis. The sales records suggest that 30% of the year's crop comes on the market in October-December and the output series can be reduced to a calendar year basis on this supposition. Alternatively, to reduce the imports series to a crop year basis, we can only suppose them to be imported evenly month by month. Neither of these estimates can be regarded as satisfactory, but an addition of calendar-year imports and crop-year domestic production would be deplorable. Again, one of the variable items in the underlying conditions of demand—changes in the population—can be more or less satisfactorily allowed for by working on the supply per head of the population (using the numbers as estimated by the Registrar-General for the middle of each year) instead of the aggregate supply.

8. A series of crude prices is easily obtained, for both crop and

calendar-years, from the monthly records of prices of British wheat. Average prices of imported wheat in each calendar year from 1854 onwards are easily obtained, where not directly provided by the Abstract, by dividing the quantity imported into its declared value. Where necessary for purposes of conversion, one quarter is taken as 480 lb. For the crop years an average price of imported wheat is obtained by means of a weighted arithmetic mean. Similarly, a weighted arithmetic mean is used to compute an average price of native and foreign wheat together in each calendar year since 1840, and each crop year since 1854. In calculating these weights, reference is made to the total grain equivalents of imports of wheat and flour together in each period. The three price series—native, foreign, average—agree very closely, and future reference is made to the first and last only. Finally, as mentioned above, an attempt is made to eliminate from these price series the effect of merely monetary phenomena by comparing each change with the corresponding change in the *Statist* general and food indices of wholesale prices.

9. This process of calculation provides a total of 16 series, as follows :—

A. Figures based on calendar years :

1. Aggregate supply available,

2. Supply available per head,

3. Crude price of native wheat,

4. Crude price of all wheat.

5. Price of native wheat corrected by " Statist " general index,

6. Price of all wheat corrected by " Statist " general index,

7. Price of native wheat corrected by " Statist " food index,

8. Price of all wheat corrected by " Statist " food index.

B. Figures based on crop-years :

1-8. Each identical with the corresponding number of A.

For the purposes of mathematical analysis these series are further distilled by writing for each number the appropriate logarithm, and secondly, by writing for each logarithm the difference between it and the preceding one. Thus, the table finally constructed shows the ratio of each year's supply and price to the preceding one's, a *plus* sign indicating a ratio greater than unity and a *minus* sign one less than unity. Considering the uncertainty of many of our data, and the great labour involved in the statistical manipulation of three-figure numbers, the demands of accuracy seemed sufficiently satisfied by carrying the logarithmic differences to the second place of decimals only : thus an entry -4 in a certain column, say the aggregate supply estimated to be available in the calendar year 1853, means that the logarithm of the quantity computed for 1853 was less by .04 than that of 1852, which means that the 1853 supply fell between 90.2% and 92.3% of that of 1852. If the figures support the general presumption of an inverse relationship between supply and price, a *plus* sign in a supply column ought to be accompanied by at least a *minus* sign in a relevant price column, and *vice versa*. The problem is to find which, if any, relevant pairs indicate the necessary agreement, and to what extent.

TABLE.

Comparison		gives			% Agreement
of	with	correspondences	doubtful[1]	disagreements	
A1	A3	31	17	41	34·8
	A4	25	13	37	33·3
	A5	29	17	44	32·2
	A6	28	13	34	37·3
	A7	26	12	41	29·2
	A8	26	13	36	34·7
A2	A3	32	13	43	36·4
	A4	27	11	37	36·0
	A5	32	12	44	36·4
	A6	30	12	33	40·0
	A7	30	9	40	38·0
	A8	28	12	35	37·3
B1	B3	44	12	33	49·4
	B4	30	18	27	40·0
	B5	51	15	24	56·7
	B6	38	17	20	50·7
	B7	41	17	21	51·9
	B8	40	14	21	53·3
B2	B3	44	11	33	50·0
	B4	30	17	28	40·0
	B5	50	14	25	56·2
	B6	39	14	22	52·0
	B7	42	14	23	53·2
	B8	41	11	23	54·7

[1]An item is entered in this column if either the quantity or the price member alone indicates no change.

10. It is evident from the above that not much can be derived from calendar year comparisons, as is only to be expected : it can be shown by example that a perfect correspondence based on crop-years can be completely masked by a regrouping of the data so as to refer to calendar years. The crop-year comparisons, considering the shakiness of many of the data, show a remarkably high degree of correspondence, the most remarkable thing being the extent to which even crude prices respond to quantity changes. The agreement is most decided in the cases where the aggregate and average available supplies are compared with the prices for native produce corrected by reference to a general index of the value of money. This is what theory would lead us to expect, since the transposing of imports and import prices, recorded for calendar years, to a crop-year basis would cause less disturbance to the quantity series than to the price series. The native price also is more relevant to further aspects of the problem not pursued in this paper, and to these aspects also the aggregate available supply is more relevant than the average, so that these two series are selected as the foundation of further computations and are appended hereto. These computations are made subject to the conventional assumption (which in this case is not susceptible of direct investigation) that the items are a fair sample of a normal distribution.

TABLE.

Changes in the Quantity of Wheat annually available to the population of the United Kingdom and of the associated changes in the Price of Wheat, corrected by reference to the " Statist " Index Number of General Prices, both being expressed logarithmically, correct to two places of decimals.

Year	Quantity	Price	Year	Quantity	Price	Year	Quantity	Price
1841	− 5	+ 1	1871	+ 4	− 2	1901	+ 2	+ 4
1842	+ 5	− 4	1872	+ 1	− 1	1902	+ 3	− 3
1843	+ 1	+ 3	1873	− 1	+ 4	1903	− 1	+ 1
1844	+ 9	− 5	1874	+10	−10	1904	− 3	+ 3
1845	− 3	+ 7	1875	− 4	+ 2	1905	+ 3	− 4
1846	+ 3	+ 6	**1876**	+ 3	+ 9	1906		− 1
1847	+ 3	− 8	1877	− 3	− 3	1907	− 2	+ 8
1848	− 8	+ 1	1878	+ 5	− 5	1908		+ 5
1849	+ 5	− 8	1879	− 6	+ 2	1909	+ 3	− 7
1850	− 4		1880	+ 5		1910	− 2	− 3
1851	+ 2	− 1	1881	+ .2	+ 2	**1911**	+ 4	+ 3
1852	+ 2	− 1	1882	+ 2	− 4	1912	− 1	− 4
1853	−14	+16	**1883**	− 7	− 1	1913	− 1	+ 1
1854	+12	− 1	1884	+ 5	− 4	1914	− 2	+10
1855	+ 2	− 2	1885	− 4	− 1	1915	+ 4	− 6
1856		− 7	1886	− 1	+ 4	1916	− 2	+ 3
1857	+ 1	− 6	1887	+ 4	− 3	**1917**	− 3	− 7
1858	− 1	− 2	1888	− 1	− 3	1918	+ 4	− 3
1859	+ 4	+ 3	1889	+ 1	+ 2	1919	+ 3	− 5
1860	− 8	+ 4	**1890**	+ 2	+ 6	1920	− 6	+15
1861	+ 6	+ 2	1891	+ 2	− 2	1921	+ 4	−10
1862	− 4	−12	**1892**	− 2	− 8.	1922	− 1	− 4
1863	+ 3	− 7	1893	− 1		1923	+ 1	+ 1
1864	− 3	+ 1	1894	+ 5	− 5	1924	− 6	+ 7
1865	− 4	+10	1895	− 5	+ 7	1925		+ 2
1866		+10	1896		+ 7	1926	+ 4	+ 1
1867	− 4	+ 5	1897		+ 7	1927		− 6
1868	+ 9	−16	1898	+ 5	−16	1928		+ 1
1869	− 7		1899	− 1	− 3	1929		+ 1
1870		+ 7	1900	− 2	+ 2			

These data are plotted on the accompanying diagram, data of the period 1867-1913 inclusive (with respect to which our quantity information is more reliable and during which changes in the value of money were less revolutionary) being marked by the sign x, those of the remaining years being marked (.) .   These give the following results :—

(a) 1841-1929 : Coefficient of correlation − .498 + .08, standard error 5.14, standard deviation 5.90, regression line y = − 0.05 − 0.71 x.

(b) 1867-1913 : Coefficient of correlation − .535 + .104, standard error 4.8, standard deviation 5.7, regression line y = − 0.07 − 0.7 x.

If we exclude the 13 most violently aberrant cases (ringed in the diagram and printed in heavy type in the table), on the supposition that that aberration is due either to exceptional defectiveness in our data (as the junction of two imperfectly correlated quantity series or a sharp fluctuation in the value of money) or to temporary influences (*e.g.* war) affecting sharply the conditions of demand; we get the following results :—

(c) 1841-1929, selected 76 years : Coefficient of correlation − .721 + .055, standard error 4.06 ; standard deviation 5.86, regression line y = − 0.034 − 1.074 x.

In these results the absolute figures of standard error, standard deviation and regression line coefficients are expressed in the same unit as that in which the table and diagram are constructed, *i.e.* 1 represents a change of 0.01 in the logarithm of the quantity concerned, 2 a change of 0.02, etc.
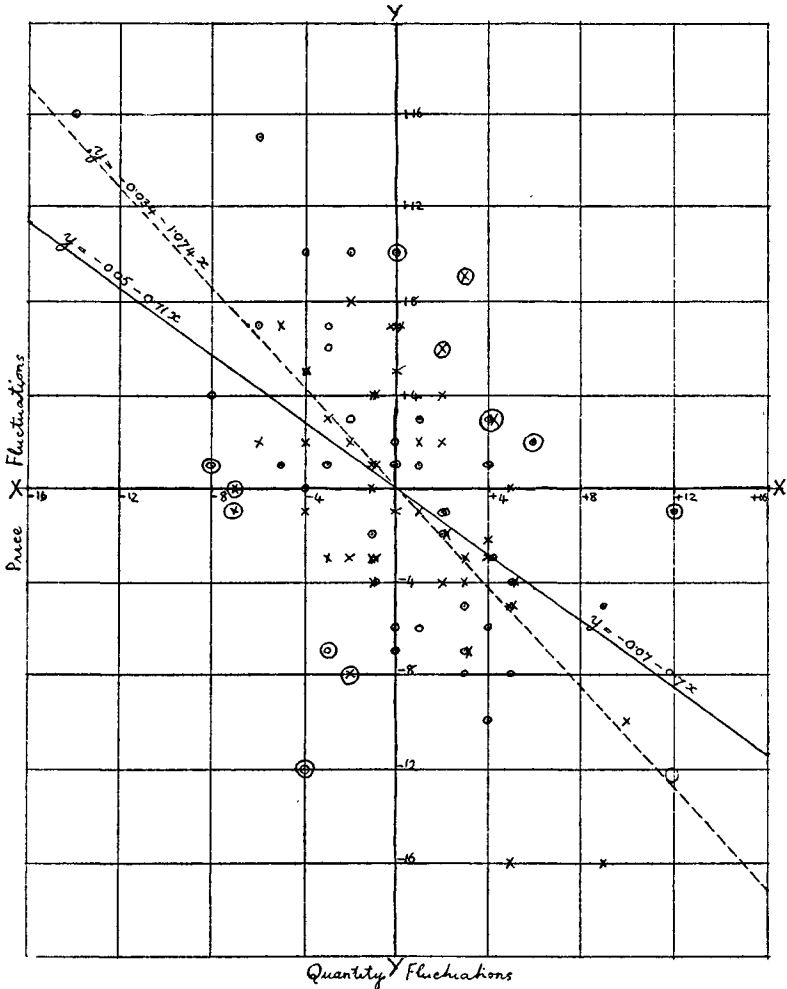

I am inclined to the opinion that for ordinary times this last is the most reliable guide. Statistically, this selection is quite unjustifiable. The excluded cases do not form an associated group or groups clearly demarcated from the rest, and only some of them (*e.g.* 1854, 1866, 1876, 1883, 1917) can be explained individually by reference to the causes enumerated generally above, while the same causes were certainly operating on some years also which are not excluded. Practically, perhaps, it can be justified by the need to show how unreliable, even under the most carefully selected circumstances, any concrete measurement of the relationship must be. That the relationship exists, and that our imperfect and imperfectly related data are more or less widely aberrant efforts to exhibit an

.association that would appear more perfectly if the data were more
exact, are plausible assumptions, but their intractability to exact
methods is one of the chief points of this paper. Translated into more
familiar language, it reads as follows : That, if the available supply
of wheat in any crop-year be known to have changed, in comparison
with the preceding crop-year, by the percentage shown in the first
line of the accompanying table, the most probable change in the real
relative price of wheat, variations in the value of money being dis-
counted, accompanying it is that shown in the third line of the table,
and the chances are 68 out of 100 that it will fall between the limits
set in the second and fourth lines, given a normal distribution.

Change in Supply. per cent. ..		−40·0	−30·0	−20·0	−10·0	0	+10·0	+20·0	+ 30·0	+40·0
Change in Relative Price. Per cent	Upper Limit	+89·9	+61·0	+39·4	+22·8	+9·7	−1·0	−9·8	−17·2	−23·6
	Most probable value	+73·0	+46·6	+27·0	+11·9	−0·1	−9·8	−17·9	−24·6	−30·4
	Lower Limit ..	+57·5	+33·5	+15·6	+1·0	−9·0	−17·9	−25·2	−31·3	−36·6

This series of relationships is exhibited in the second diagram.

Quantity *Y* Fluctuations
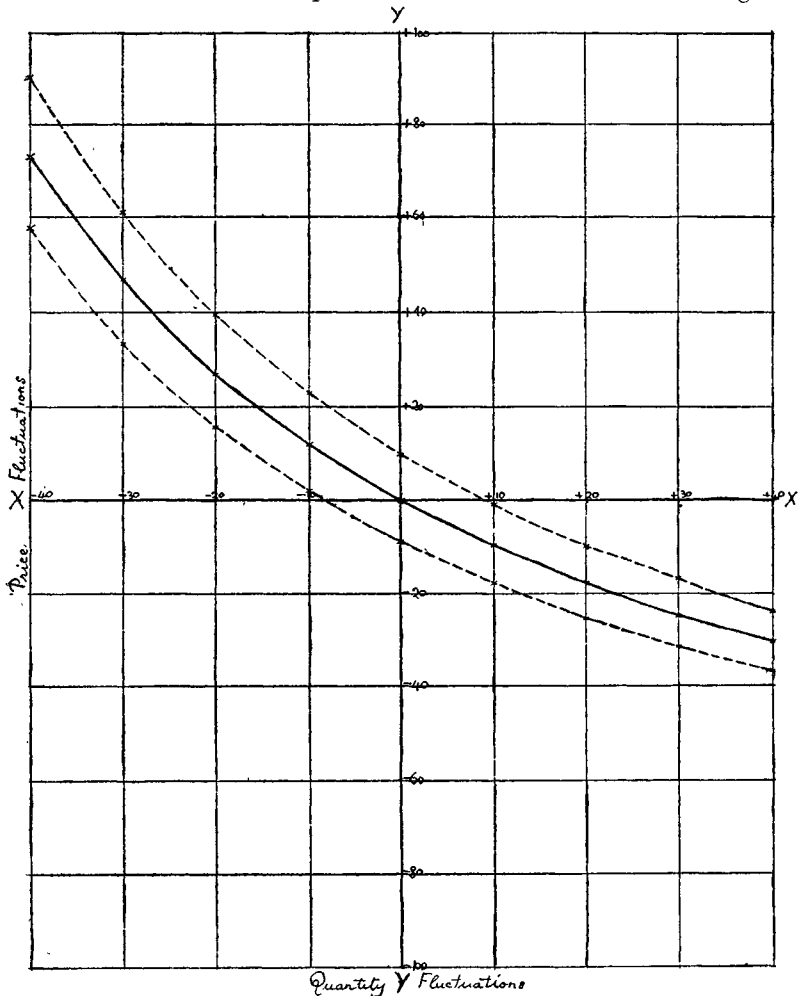
A similar equation can be constructed with the price data regarded as the independent and the quantity as the dependent variable, an interpretation which links the probable consumption to the price-level. The equation becomes $x = 0.14 - 0.47y$, and the table of most probable changes :—

Change in Relative Price, Per cent.	−40·0	−30·0	−20·0	−10·0	0	+10·0	+20·0	+30·0	+40·0
Change in Probable Consumption, Per cent.	+27·5	+18·6	+11·4	+5·4	0	−4·1	−7·9	−11·3	−14·4

The corresponding limits of the zone of estimate can be read off from the graph, and can be calculated in the same manner as before, namely by computing the standard error with respect to the x-data.

12. The concept of a demand curve is at once one of the simplest and one of the most universal of the analytical devices necessary to any attempt to understand the interactions of economic quantities and to foresee the probable consequences of any given event or action. This paper has, I hope, indicated how laborious is the effort to reduce that general conception to concrete terms in any particular case, and how lacking in precision are the results yielded by even the most careful selection of statistical records. At best, a " demand zone " can be uncertainly calculated. The labour is due in large part to the Pickwickian nature of much of the statistics collected by Governments, but the imprecision is inherent in the data themselves, since elements which must be assumed to be stable, if any computation whatever is to be possible, are, in fact, unstable, and the best we can hope for is that over short periods of time this instability will not be so great as to vitiate entirely the calculated results. So far as concerns the subject matter of this paper, there is scarcely any doubt that the fundamental function which it set out to investigate—namely, the British population's demand for wheat, or, in concrete terms, the quantities of wheat which the British population, given its tastes, prejudices, likings and dislikes, would purchase at any given moment at each price in a schedule of real prices—has been changing through the period covered. In Ireland the alleviation of rural poverty brought by events subsequent to 1847 had some effect in substituting wheaten for potato products, while in Great Britain the steady rise in the standard of living which persisted, at any rate, until the last European war, probably had the opposite effect of weakening the demand for wheaten products by the partial substitution of animal and poultry products. Disturbances due to such secular changes I hoped to minimise by using the fluctuations from year to year as the basis of calculation.

DISCUSSION OF MR. DUNCAN'S PAPER.

Following are résumés of the observations of some of the speakers and of communications received with regard to the paper:—

Mr. R. C. Geary: On account of its subject matter Mr. Duncan's paper is scarcely likely to excite acute controversy unless the magic word " wheat " proves provocative and the President allows us latitude in the matter of digression. Nevertheless it is just the kind of paper which this Society wants. To me, perhaps the most interesting thing about Mr. Duncan's paper is not that he has shown there is a definite negative correlation between prices and supplies of wheat, but that the relationship is not more definite than he found it. There are hazards in the use of correlation in dealing with time series, but Mr. Duncan is on his guard against them. In correlating, not absolute wheat prices but the logarithm of the ratio between wheat prices (deflated by the "Statist" index figure) in consecutive years with corresponding year-to-year changes, in wheat supply per head, Mr. Duncan has, I think, amply protected himself, and his results seem significant. I am afraid that I cannot agree with Mr. Duncan's statement on page 35, that his table on the same page indicates a high degree of correspondence between the crop-year series. It certainly does show that the correspondence is more satisfactory for crop-year than for calendar-year series. It is curious to note so little evidence in this table of the relationship which the correlation co-efficient indicates. This can only mean that the extreme variations from the normal in both supplies and prices must have been favourable to his thesis. As Mr. Duncan I think recognises, the complexity of his problem is greatly aggravated by the fact that wheat is a non-perishable commodity, with regard to which the law of supply and demand cannot function in such a manner as to be readily indicated statistically. In this respect it appears to be in marked contrast with, for instance, pigs. Comparison of the trend of prices of baconers in the last ten years (even without making allowance for the general price trend) with the quantity of bacon purchased for curing in the Saorstát indicates only one exception to the rule " supplies up—prices down " between consecutive years, a result which is by no means obvious because, of course, Saorstát prices of pigs have hitherto been governed by English market prices. A further apparently causal relationship between pig prices and supplies suggests a question to Mr. Duncan with regard to wheat. What I would like to ask Mr. Duncan is : Has he found that year-to-year or short-term changes in wheat prices have influenced subsequent changes in area in Great Britain? We know, of course, that the long-term price trend has practically wiped out the Irish wheat crop. From the figures which are available for Ireland there is little evidence of the existence of demand curves for wheat. Statistics of imports of wheat and wheat-flour are only available from 1904—(of course for Ireland imports are practically identical with supply)—and indicate no less than 5 exceptions to the rule " prices up—supplies down " during the 10 years 1904 to 1914. The Saorstát statistics indicate 3 exceptions out of 9 in the years 1924 to 1933. I confess that at first I was rather shocked by Mr. Duncan's ruthless exclusion of 13 cases which did not suit his theory, for the purpose of computing his regression equation. The excluded points certainly do seem exceptional, and I think that on balance Mr. Duncan was justified. After all, the very fact of computing an equation connecting price and supply hypothecates the existence of a relationship, and why not make the relationship as strong as it can legitimately be made by improving the correlation?

Mr. G. S. Philipotts: An enormous amount of work must have been done to get all the figures, and the resulting correlations are quite as good as could be hoped for, considering what an influence differences in stocks at the beginning and at the end of the year would have in measuring the quantities and also that there must be a considerable lag between the changes in price and in consumption. I would like to ask one or two questions about the figures in the paper. Why, for instance, logarithmic figures were taken for the quantities and prices, as the use of these appeared (on page 38) to give curves and not straight lines, but the basis for these was very doubtful. The variations in quantity actually observed were not much more than 10 per cent. each way, yet the table gave the effects of variations up to 40 per cent. each way, which appeared to be an extrapolation which could hardly be justified, especially as, for instance, a decrease of 40 per cent. in the price involved an increase of 27 per cent. in the consumption. In a country like England, such a change was most unlikely; in fact, if these curves were correct, there should in recent years have been an increase in consumption of considerably more than this, as the price of wheat between 1929 and 1931

diminished by more than this, while he wondered whether the consumption had increased by even 10 per cent. It was remarkable that the correlation between quantity and price was not much better when the price was corrected by the " Statist " Index. Possibly, the cause was that the quantity consumed depended on the prosperity in the country. In the early years, when the working man was actually underfed, greater prosperity would enable him to consume more bread; in the later years, greater prosperity would enable him to change from bread to a more highly-priced food, which he preferred. It would be interesting to see whether partial correlations would elucidate this point. As regards the 13 excluded cases, it seemed hardly justifiable to exclude certain years because they were found not to fit into the diagram. A correlation was only supposed to show how far one factor varied with another during periods when the latter was being influenced by a large number of other factors, and so one would naturally expect there would be a considerable number of exceptions. An opponent to this paper might exclude the 13 cases which were most negatively correlated and then say that the relationship was so small as to be negligible.

Professor George O'Brien: It has always struck me as curious that the two commodities, wheat and gold, seem incapable of rational discussion. They have become atavistic symbols. In mythology they were the symbols of life and immortality. It was a relief to take part in a cold, rational discussion on the subject of wheat. I rather doubt if it were a good commodity to choose for the purpose of establishing demand curves. In certain circumstances there might be a possibility of a *positive* correlation between price and demand on account of concentration on so cheap a food. With regard to a previous speaker's observations about the " apriorist," his view was that if the conclusions of economic deductive reasoning appeared to be in conflict with statistical inductions the latter would frequently be found to be fallacious on more detailed investigation.

Lt.-Col. K. E. Edgeworth (in a letter): In the discussion on the paper several of the speakers expressed surprise that the relationship between the price level and supply was not more marked, and were disposed to take the view that either the theoretical principle or the statistics must be erroneous. The author of the paper himself drew attention to the extreme complexity of economic problems in general, and it seems clear that the correct explanation of his results is that the effect which is being looked for is masked by other factors whose influence it has not been possible to estimate. One important factor which affects prices, for example, is the bargaining power of the various parties to any transaction. In the case of wheat the consumer's bargaining power is considerably influenced by his ability to purchase alternative supplies such as potatoes, so that the price of wheat probably depends not only on the supply of wheat but also on the supply of other foodstuffs of a similar character. The bargaining power of the producer and the trader, on the other hand, may be influenced by views as to future prospects and by facilities for storage. It must also be noted that the statistics apply to great Britain, whereas wheat is in fact an international commodity. An abundant crop in America would affect prices in Great Britain even if the wheat itself is never shipped. Some work on which I am now engaged has led me to the view that economic phenomena are so complex that they are not amenable to treatment by means of mathematical analysis of any kind with which we are at present familiar. Mr. Duncan's paper seems to support this conclusion.

Mr. E. G. Peake (in a letter): The subject of the variation in prices, due to variations in the supply, is, of course, no new question, and it was investigated by a man named Gregory King about the year 1700. The following is his statement:—" You are perhaps acquainted with Gregory King's law of prices. one of the most important generalisations in statistics, and applicable to all values whatever. King applies it to the harvest only, and states that a defect in produce raises prices in a different ratio from that which characterises the dearth. Thus, a defect of

1/10th raises	the price	above	the common rate	3/10ths.
2/10ths ,,	,,	,,	,,	8/10ths.
3/10ths ,,	,,	,,	,,	1.6/10ths.
4/10ths ,,	,,	,,	,,	2.8/10ths.
5/10ths ,,	,,	,,	,,	4.5/10ths.

" This rules operates in depressing as well as in exalting prices, and is not thought of in times of high and low prices as it should be. It applies to all articles in demand, but the depression is more marked in the case of oversupply in articles of voluntary use, and the exaltation more marked in the case of undersupply in articles of necessary use."