The relation between wholesale and retail prices since the war

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The Relation between Wholesale and Retail Prices since the War

By Arthur L. Bowley,
Professor of Statistics, University of London.

It has been known for a long time in a general way that the movements of retail prices followed those of wholesale prices after an interval and that their oscillations were of a smaller amplitude, but there is not much published work on the subject. It has, in fact, been difficult to obtain data for such a study, since the more easily available statistics are on a yearly basis, while the interval between the movements is only a few months. Since July, 1914, the retail prices of food have been published monthly in the Labour Gazette, and it is, therefore, now possible to make a detailed analysis. This paper is limited to the period since the Armistice, and deals with index-numbers representing averages and not with prices of separate commodities.

The general nature of the problem is shown in the first figure of Diagram I. The index-numbers of wholesale and retail food prices were both approximately 230 at the beginning of 1919 (the period immediately before the war being represented by 100); after a brief fall both numbers rose to a maximum in 1920, and fell in 1921, and early in 1922 the fall was checked. The general movements are thus similar, but there is a difference in the dates of the maxima of the two numbers, and there are many differences in detail. The problem is to find a formula which relates the retail index-number at any date with the wholesale index-number of the same or of a preceding date, and there is a subsidiary problem to forecast the movements of the retail from those of the wholesale index-number.

Three methods are here applied to obtain a solution of the problem, which I may call Dr. Elsas's method, the correlation method, and the method of differences.

Dr. Elsas in connection with his bi-monthly analysis of prices in Germany desired to foretell by at least two months the movement of retail prices. He argued that retail prices in the near future are determined partly by the existing retail prices, which are related to the cost of the stocks of commodities already in the market, and partly by existing wholesale prices which determine the cost of the stock coming forward, and that, therefore, a future retail price index-number will be some function of the current wholesale and retail

1 For the war period, see Prices and Wages in the United Kingdom, 1914 to 1920, chs. iii and iv; and for a slight study of food prices in the years 1891 to 1913, see The Economic Journal, pp. 514-23, 1913.

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price numbers. He adopted the empirical formula, "Retail index-
number in any month equals the cube root of the product of the
wholesale index-number and the square of the retail index-number
two months earlier," and by this formula forecasted in May the
great fall of the internal value of the mark in the coming two months
with fair precision. 1 I have used a similar formula for the comparison
of wholesale and retail index-numbers for food in the United King-
dom, except that I have taken a weighted arithmetic instead of a
geometric average and have calculated the weights by the method of
least squares. For a two months’ forecast I use (approximately) the
formula, 2 "Three-fourths of the existing retail index plus one-fourth
of the wholesale index." The agreement of the formula and the re-
cords (shown in Table I) is fair, the mean error being 4 per cent.
(9 points).

Dr. Elsas’s formula is based on very short periods without explicit
reference to earlier movements. The correlation method, on the
other hand, depends on the average level of the numbers over the
whole period studied. Between the Statist wholesale food index and
the Labour Gazette retail food index in the 37 months to May, 1922,
I find that the correlation coefficient is the same (‘667 or ‘668) when
retail prices are compared with wholesale prices three and four
months earlier, and is greater than when the comparison is made for
two months (‘955) or five months (‘914) in advance. The coeffi-
cients are much smaller when retail prices are compared with retail,
being ‘622, ‘907 and ‘529 for one, two and three months earlier. The
closest relationship on this test is with retail prices two months and
wholesale prices three months before, and the result of the formula
is shown in the second figure of Diagram I. The mean difference
between formula and record is 6.1 points or 2.4 per cent. If, how-
ever, we take wholesale prices only the mean difference is only 6.2
points, and we have the advantage of forecasting three months ahead
instead of two.

The formulæ based on correlation coefficients give only the answer
to the question, "What linear equation between the retail price-index
at one date and wholesale or retail price-indexes at earlier date gives
the closest approximation to the facts, under the test that the sum
of the squares of the residuals shall be least? " The formulæ are,
in fact, quite empirical, and the coefficients may depend on the period
taken in their calculation. There is little doubt that they will only
be applicable in the future over a small range of variation; under
formula (e) if wholesale prices returned to a pre-war level, retail
prices would be 36 per cent. above the pre-war level. The impor-
tance of the method (apart from short-period prediction) lies in the

---

1 Der Stand der Kosten der Lebenshaltung, May and July, 1922. In May the
purchasing power of the mark was reckoned at 3.19 and 1.52 pfennige, retail
and wholesale; the formula gives $\sqrt[3]{(3.19^2 \times 1.52)} = 2.49$. In July the
number actual was 2.38.

2 The formulæ and correlation coefficients are collected on pp. 199-201 below.
analysis of the time-lag between wholesale and retail prices (for which three or four months is here suggested), and in their relative oscillations. The coefficient of variation (the standard deviation expressed as a percentage of the average) is 19.0 for wholesale and 13.5 for retail; that is, by this measurement, the oscillations of retail food prices are seven-tenths of those of wholesale. The result agrees very closely with that found in the period 1896-1910 (loc. cit.).

A more direct method of approach is by the comparison of the change in the wholesale index-number with a subsequent change in the retail index-number. Thus from January 31st to February 28th, 1921, the wholesale index fell from 251 to 234, 17 points; from April 1st to May 1st, the retail index fell from 238 to 232, 6 points, and in the next month 14 points; either of these can be expressed as a ratio of the 17. The coefficients of correlation between these variables are relatively small; between the difference of successive retail prices and that of wholesale prices one, two, three and four months earlier they are 49, 505, 52 and 41. The correlation coefficients in the former method are larger, because they include the influence of the great movement up and down in the three years. We obtain as the relation for a three months' interval, "The number of points passed in a month by the retail index=three-eighths of the number passed three months earlier by the wholesale index." The mean deviation between the price-index given by this formula and the actual record is 5.2 points (2.4 per cent.), and is smaller than obtained by the previous methods. The advantage of the difference method is that it only depends on recent records, not involving a long period average; the disadvantage is that it can only be used for forecasting one month ahead, a two months' forecast proving to be untrustworthy. All these formulae have been used in the tables to forecast the retail index in June, July and August, 1922, months not involved in their computation. For June the forecasts varied from 171 to 178, the actual number being 170; for July the forecasts were from 171 to 183, the actual number being 180; for August the forecasts vary from 172 to 189 in sympathy with the irregular wholesale index-movements from April to June, and the actual number is 175. Formula \((f)\), depending on retail prices two months and wholesale prices three months before, comes best in this test, forecasting the numbers as 174, 178, 183, while 170, 180 and 175 were realized.

The retail and wholesale indices both include wheat (or bread), flour, potatoes, beef, mutton, bacon, butter, sugar and tea. The wholesale index includes also barley, oats, maize, rice, pork and coffee; the retail index includes also fish, milk, eggs and margarine. The allocations of weights also are different. A further test has been made by computing the retail index after the elimination of fish, milk, eggs and margarine, the first three of which are seasonal in their price variations. The results are shown in Section B of the formulae (p. 200 below) and in Table III. It is surprising to find
that there is, on the whole, no closer relationship found than in the unadjusted numbers.

For many purposes the study of the relationship between the more broadly based index-number of the cost of living and wholesale prices generally is more interesting than that which relates to food alone. For this study the usual Statist index-number for food and materials together is used. The relative weights in the Cost of Living index are: food 15, clothing, 3; fuel and light, 2; miscellaneous items, 1, and rent, 4; of these, rent, of course, is not represented in the wholesale index, while it has a steadying influence on the retail. The results are shown in Section C of the formulae (p. 200), Table IV and Diagram II. It is a curious fact that, with the wider basis and the less obvious connection, the correlation coefficients are nearly as great and the mean difference between the computed and recorded figures is actually less than before. The coefficients of correlation with wholesale prices two, three, four and five months before are 0.894, 0.938, 0.955 and 0.940, the greatest being that when the interval is four months. The mean difference when the four months’ formula is used is 5.9 points (2½ per cent.). Table IV shows that a great part of this difference is due to the movements in four months in the autumn of 1920, and in four months of the late summer and autumn of 1921; the causes of the excess retail prices at these periods have not been fully analysed, but the removal of the bread subsidy in 1920 and the effects of the drought on home produce in 1921 are certainly partly responsible. If the formula is reconstructed after the elimination of these 8 months (depending then on 29 months only) its agreement with observations over the 37 months is nearly as good as before, while in the 29 months the mean difference is only 3.6 (1½ to 2 per cent.). The correlation coefficient for the 29 months is no less than 0.901. This revised formula forecasts four months ahead, and gave 181, 180, and 181 for June, July and August this year, while, in fact, 180, 184, and 181 were recorded.

The formula is: "Cost of Living index for the rst day of a month =103.6+0.58P.4," where P.4 is the Statist index-month four months and a day before.

This formula does not express a law of nature or of economics, but is merely an empirical equation whose numerical constituents will be gradually modified, and it is liable to fail whenever there is any temporary disturbance in the retail price of a seasonal commodity. The closeness with which it represented the facts for three years is, however, very remarkable.

This paper should be regarded as an examination of methods, rather than as leading to definite and general conclusions. It is proposed in the near future to apply some of these methods to the relationship between wholesale and retail prices of particular commodities.

1 For September 1st, October 1st, and November 1st, 1922, the formula gives 182, 182, and 180.
WHOLESALE AND RETAIL PRICES SINCE THE WAR

NOTATION AND FORMULÆ.

\( \dot{p} \) is the retail (or Cost of Living) index-number in any month; \( \dot{p}_1, \dot{p}_2, \dot{p}_3 \) are the corresponding numbers one, two and three months previously; \( \ddot{p}_1, \ddot{p}_2, \ddot{p}_3 \), etc., are the corresponding wholesale index-numbers; e.g.:

\( \dot{p}, \) May 1st; \( \dot{p}_1, \) April 1st; \( \dot{p}_2, \) March 1st; \( \ddot{p}_1, \) March 31st; \( \ddot{p}_2, \) February 28th.

A.—See Tables I and II and Diagram I.

Statist wholesale food index-number and Labour Gazette retail food index-number.

Standard deviations and averages:

<table>
<thead>
<tr>
<th></th>
<th>Standard deviation</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wholesale, 37 mths. beginning Nov. 1918</td>
<td>42·26</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dec. 1918</td>
<td>249·6 P.5</td>
</tr>
<tr>
<td></td>
<td>44·63 P.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>247·6 P.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>245·6 P.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feb. 1919</td>
<td>243·7 P.2</td>
</tr>
<tr>
<td></td>
<td>1919</td>
<td>3·6 P.2</td>
</tr>
<tr>
<td></td>
<td>230·8 P.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>May 1919</td>
<td>228·4 P. p</td>
</tr>
<tr>
<td>Retail, 37 months beginning Mar. 1919</td>
<td>27·9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30·7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>228·4 P. p</td>
<td></td>
</tr>
</tbody>
</table>

Coefficients of correlation:

\( r_{\ddot{p}p-2} = .955, r_{\ddot{p}p-3} = .968, r_{\ddot{p}p-4} = .967, r_{\ddot{p}p-5} = .914; \)
\( r_{\ddot{p}p-1} = .622, r_{\ddot{p}p-2} = .907, r_{\ddot{p}p-3} = .529. \)

Formulae, and mean differences between results of formulæ and records:

1. Dr. Elsas's methods:

\[ \dot{p} = .877p_1 + .13p_2; \] mean difference \( 5·3 \) (a)
\[ \dot{p} = .74p_2 + .26p_2; \] \( 9·2 \) (b)
\[ \dot{p} = .63p_3 + .37p_3; \] \( 11·7 \) (c)
\[ \dot{p} = .56p_4 + .44p_4; \] \( 14·6 \) (d)

The coefficients are found, e.g., in (a) by choosing \( k \) and \( l \) so that the sum of the squares \( (\dot{p} - kp_1 - lp_2)^2 \) is a minimum.

See Table I.

2. Regression equations:

\[ \dot{p} = 81·0 + .605p_2; \] mean difference \( 7·4 \) ---
\[ \dot{p} = 72·2 + .636p_2; \] \( 6·2 \) (e)
\[ \dot{p} = 50·5 + .524p_3 + .213p_2; \] \( 6·1 \) (f)
\[ \dot{p} = 63·8 + .665p_4; \] \( 7·5 \) (g)

The coefficients are found, e.g., in (f), by choosing \( k, l \) and \( m \) so that the sum of the squares \( (\dot{p} - kp_1 - lp_2 - mp_2)^2 \) is a minimum.

See Table II and Diagram I.
3. Variate differences of the first order:
\[ p = p_1 + 0.35 (P_1 - P_2); \quad \text{mean difference} \quad 5.2 \quad \text{—} \]
\[ p = p_1 + 0.37 (P_2 - P_3); \quad \text{—} \quad 4.9 \quad \text{(h)} \]
\[ p = p_1 + 0.375 (P_3 - P_4); \quad \text{—} \quad 5.2 \quad \text{(i)} \]
\[ p = p_1 + 0.30 (P_4 - P_5); \quad \text{—} \quad 5.75 \quad \text{—} \]

The coefficients of correlation between \((p - p_1)\) and \((P_1 - P_2), \(P_2 - P_3), (P_3 - P_4), (P_4 - P_5)\) are \(0.49, 0.505, 0.52, 0.41\) respectively, and the standard deviations of \((p - p_1)\) and \((P_1 - P_2)\), etc., are approximately 8 and 11. The numerical factor in each equation is the correlation coefficient multiplied by the ratio of the standard deviations.

See Table II.

B.—See Table III.

Statist wholesale food index-number and Labour Gazette retail food index-number, fish, milk, margarine and eggs being excluded.

Standard deviation and average:

Retail, 37 months beginning May, 1919, standard deviation 32.12, average 222.46.

For wholesale, as under A.

Coefficients of correlation:
\[ r_{p_1-p_2} = 0.900, \quad r_{p_2-p_3} = 0.957, \quad r_{p_3-p_4} = 0.954, \quad r_{p_4-p_5} = 0.944, \quad r_{p_5-p_6} = 0.923; \]
\[ r_{p_1-p_2} = 0.963, \quad r_{p_2-p_3} = 0.898, \quad r_{p_3-p_4} = 0.818; \quad r_{(p_1-p_2) (p_2-p_3)} = 0.47; \]
\[ r_{(p_1-p_2) (p_3-p_4)} = 0.57. \]

Formula, and mean differences and mean squared differences between results of formulae and records:

<table>
<thead>
<tr>
<th>Formula</th>
<th>Mean difference</th>
<th>Mean squared difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p = 102.1 + 0.50P_1 )</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>( p = 80.4 + 0.585P_1 )</td>
<td>12.2</td>
<td>—</td>
</tr>
<tr>
<td>( p = 68 + 0.634P_2 )</td>
<td>8.6</td>
<td>11.0</td>
</tr>
<tr>
<td>( p = 61.4 + 0.656P_3 )</td>
<td>8.1</td>
<td>9.5</td>
</tr>
<tr>
<td>( p = 38 + 0.5P_3 + 0.28P_2 )</td>
<td>6.9</td>
<td>8.4</td>
</tr>
<tr>
<td>( p = 35 + 0.5P_3 + 0.283P_4 )</td>
<td>7.2</td>
<td>9.3</td>
</tr>
<tr>
<td>( p = 54.4 + 0.68P_4 )</td>
<td>8.1</td>
<td>10.5</td>
</tr>
<tr>
<td>( p = p_1 + 0.437(P_4 - P_3) )</td>
<td>4.3</td>
<td>—</td>
</tr>
<tr>
<td>( p = p_1 + 0.363(P_3 - P_4) )</td>
<td>4.1</td>
<td>—</td>
</tr>
</tbody>
</table>

No difference is made in (m), if \( p_3 \) is also included, since its coefficient is found to be zero.

C.—See Table IV and Diagram II.

Statist general wholesale price index-number and Labour Gazette Cost of Living index.
WHOLESALE AND RETAIL PRICES SINCE THE WAR

Standard deviations and Averages:

<table>
<thead>
<tr>
<th></th>
<th>Standard deviation</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wholesale, 37 mths. beginning Dec. 1918</td>
<td>48.28</td>
<td>249.1 P.4</td>
</tr>
<tr>
<td></td>
<td>Jan. 1919</td>
<td>50.33</td>
</tr>
<tr>
<td>Cost of Living</td>
<td>May 1919</td>
<td>24.96</td>
</tr>
</tbody>
</table>

Coefficients of correlation.

$\alpha_{23} = 0.894, \alpha_{24} = 0.938, \alpha_{34} = 0.955, \alpha_{44} = 0.940.$

Regression equations and mean differences between results of formulae and records:

\[ p = 110.3 + 0.466P_3 \]
\[ p = 102.4 + 0.494P_4 \]
\[ 7.4 \] \[ (o) \]
\[ 5.9 \] \[ (f) \]

If the 8 months, October, 1920, to January, 1921, and August to November, 1921, are omitted in the calculation, the coefficient of correlation ($\alpha_{44}$) becomes 0.991 and the regression equation is

\[ p = 103.6 + 0.476P_4 \]
\[ 6.0 \] \[ (q) \]

the mean difference for the remaining 29 months is, however, only 3.6.

In the formulae under C, the Statist index is expressed as percentage of its average level, April to July, 1914, which on the Statist base was only 82. If $P_4$ stands for the Statist number as generally given, formula (q) becomes

\[ p = 103.6 + 0.58P_4. \]
<table>
<thead>
<tr>
<th>Wholesale</th>
<th>Retail</th>
<th>Dr. Eis's Method</th>
<th>Months in Advance</th>
<th>Formula (a)</th>
<th>Formula (b)</th>
<th>Formula (c)</th>
<th>Formula (d)</th>
<th>Formula (e)</th>
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<td>236</td>
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<td>One.</td>
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<td>207</td>
<td>214.</td>
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<td>+17</td>
<td>231</td>
<td>+24</td>
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<tr>
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<td>209.</td>
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<td>216</td>
<td>+12</td>
<td>226</td>
<td>+22</td>
<td>232</td>
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<td>211</td>
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<td>217</td>
<td>+8</td>
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<td>213</td>
<td>-4</td>
<td>217</td>
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<td>219.</td>
<td></td>
<td>214</td>
<td>-2</td>
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<td>-4</td>
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| 253       | 278    | 283.             | One.             |            |            |            |            |            |
| 251       | 263    | 275.             |                  | 294       | +16        | 284       | +6         | 290        | +12        |
| 254       | 249    | 261.             |                  | 284       | +21        | 295       | +32        | 287        | +24        |
| 232       | 238    | 247.             |                  | 272       | +23        | 285       | +36        | 296        | +47        |
| 225       | 232    | 237.             |                  | 260       | +22        | 269       | +31        | 286        | +48        |
| 211       | 218    | 231.             |                  | 236       | +18        | 243       | +25        | 258        | +40        |
| 207       | 220    | 217.             |                  | 230       | +10        | 236       | +16        | 242        | +22        |
| 206       | 226    | 218.             |                  | 216       | -10        | 229       | +3        | 235        | +9         |
| 207       | 223    | 223.             |                  | 217       | -8         | 215       | -10        | 219        | +4         |
| 190       | 210    | 223.             |                  | 221       | +11        | 215       | +5         | 215        | +5         |
| 168       | 200    | 207.             |                  | 220       | +20        | 219       | +19        | 214        | +14        |
| 168       | 193    | 196.             |                  | 205       | +10        | 218       | +23        | 217        | +22        |

Mean difference between formulae results & records: 5.3 9.2 11.7 14.6

The formulae are calculated on 37 months' records. Numbers in brackets are forecasts given by the formulae. The entries in the first line, first two columns, are for December 31st, 1918 (wholesale), and January 1st, 1919 (retail). For the first column: Average of 1913=100. Second column: July, 1914=100.