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Input-Output Techniques and the Analysis of Inflation

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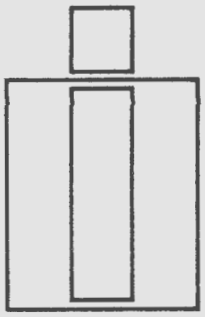

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INPUT-OUTPUT TECHNIQUES AND THE ANALYSIS OF INFLATION

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INPUT-OUTPUT TECHNIQUE AND THE ANALYSIS OF INFLATION

- An outline of a study in preparation in the Netherlands' Central Bureau of Statistics.

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In this paper a method is presented concerning the estimation of the contribution of primary inputs to the price changes of final demand categories. Using this method the contributions of the primary inputs used by each branch in the i/o-table can be estimated separately. It is proved that possible differences between the price change of final deliveries and that of intermediary deliveries per branche do not influence the results of this method as far as the price change of total final demand is concerned. For the analysis of separate final demand categories a check on the accuracy is part of this method.

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1. Introduction

In the Netherlands the most widely used indicator of inflation is the price index of household consumption (PHC). This index plays an important role in wage negotiations and income-tax rating and thus in the income distribution policy of the government.
The Netherlands' Central Bureau of Statistics (CBS) intends to rearrange available data and to complete a system of price indexes in order to use this material for an analysis of changes in the PHC in connection with changes in the income distribution. Elements of a similar analysis have been applied already by the CBS for purposes of separating the effects on the PHC of changes in the tariffs of indirect taxes. The thus corrected PHC is used by the Netherlands' Ministry of Finance for revising the (progressive) tariffs of income tax; in trade and industry it will be used in labour contracts in order to determine the so called "price compensation" (the additional wage increase which will be paid out, if prices appear to have been raised more than a certain percentage agreed on).
The CBS is now preparing a more general analysis of price movements of final consumption categories for the purpose of making a breakdown of price changes into changes of primary costs. In this paper a brief description will be given of some procedures to be followed in the analysis.

2. Available data and alternative analyses

Different kinds of analyses should be applied when different sets of data are available. In order to show some properties of the analysis discribed later, a bird's-eye view of various alternatives will be given below. The section concludes with some remarks about the available price data for The Netherlands.

2.1. Direct analysis of producer's prices

Changes in the producer's value per unit of output of an industry can be broken down into changes in the value of the inputs (including operating surplus) per unit of output, which in turn can be divided into changes in the input quantity used per unit of output and changes in the unit price per input category.
For an analysis of very recent price movements, in practice not all data needed, will be available. If e.g. only price indexes of output and input categories are given, assumptions have to be made about the relationship, in volume, between inputs and output. The character of the available price indexes partly determines the choice of those assumptions. If e.g. the price index of output is of the Laspeyres type it will be more appropriate to assume that the volume of each intermediate input per unit of output is constant than if a Paasche price index of production is used.
The volume of labour input per unit of output cannot be assumed to be constant, even in the short run. Data about changes of wage rates and data about productivity are needed unless data on changes in the value of wages and on the volume of production are available.

The same applies to capital input. The contribution of operating surplus to the change of the price index of output can then be estimated as a difference between the change of this price index and the part of it, which is estimated as the contribution of all other inputs.
If all data concerning quantities and prices of outputs and inputs are available, an analysis is possible in which the contribution of each input (excluding operating surplus) to the change in the price of output can be divided into changes in the quantity per unit of output and changes in the price per input category.
As well a Laspeyres version as a Paasche version of this refined analysis can be designed, while also versions based on other index formulas can be developed. We shall not elaborate further on this matter.

2.2. Input-output analysis of producer's prices.

If price changes are studied within the framework of a macro-economic analysis, the contributions of intermediate inputs to price changes are not of primary interest. In this case a breakdown of the output price change into the contributions of (cumulative) primary cost categories will be interesting.
A "short-term analysis", analogous to the one mentioned in the previous paragraph, is possible if data, as described before, are available for all branches in the i/o-table. This procedure will be discussed in more detail below but it should be ascertained, that an implication of this method is that the volume of each intermediate input per unit of output is assumed to be constant.
A more refined analysis, analogous to the one mentioned at the end of the foregoing paragraph requires a great number of data. In principle complete i/o-tables in current as well as in constant prices are needed for the periods studied.
When different analyses according to different index number formulas are applied, several versions of the i/o-tables in constant prices are needed. In less refined versions more practical weighting procedures can be followed.

2.3. The analysis of the PHC

If the analysis of inflation is focused on the PHC the discrepancies between the PHC and the price indexes of producer's prices need to be investigated. These discrepancies become important if details of the PHC are analysed by means of an i/o-table valued at producer's prices since in such a table all trade margins appear in a separate row, a comparison of retail (based on the PHC) and producer's prices weighted together with import prices for separate products requires data about trade margins per product.
Particularly the breakdown of the changes in the margins into quantity and price changes gives rise to statistical problems. For an analysis of the total PHC only volume and price data for the total production of trade are needed; the same applies when the PHC is divided into a price index of all goods and one (or more) for total (or detailed categories of) services consumed because services are not sold via trade.
If goods or services are sold at other prices to households than to other sectors of the economy, the analysis of the PHC becomes very complicated. The identification of the cost differences connected with those price differences is problematic. If the goods or services are completely identical whether they are sold to households or to other sectors, the price differences are a pure reflection of the differences in profit margins.

Usually, however, technical differences will be the main cause of the price differences and this raises severe statistical problems. Whithin the framework of an i/o-analysis of inflation it has to be assumed, that the cost structure of a commodity (group) is the same for all consuming branches and sectors, but we shall return to this point later on.

2.4. Available data in the Netherlands.

The CBS yearly compiles i/o-tables in current prices. The tables are not available within 2 or 2½ years after the end of the year under review. The number of branches is usually 35 or in some cases 60. I/o-tables in constant prices are not available, also as a consequence of the incompleteness of the available price statistics.
For agricultural and industrial products the CBS now compiles index numbers of producer's prices for domestic sales, exports and imports (cif-prices). The first and second categories of indexnumbers are more complete than the last one. In addition to this material unit value data derived from the external trade statistics are available, for all commodities imported and exported.
For services the situation is less favourable. Inquiries on prices or on volumes and values are conducted for some service industries; for others some data are obtained from details of the PHC; only very roughly estimated price indexes are available for the rest of the service groups. In general the price statistics are available a few months after the period under review. Price data about value-added components can be estimated about half a year after the year under review. Then figures about wages paid by industry and about the volume of production are available and provisional figures about depreciation can be estimated within this period. For indirect taxes the estimates can be made even sooner.
A "short-term analysis" as mentioned in the previous paragraphs can thus be made with a delay of half a year. That seems to be useful since the complete i/o-tables become available with a delay of two years more.

3. Elements of an i/o-analysis of price changes.

In this section a brief description of an i/o-analysis of price changes of final demand categories will be given and some refinements will be discussed briefly. Special attention will be paid to some aspects of the assumption, that the cost structure of a commodity (group) is the same for all sales categories and that the price index of a commodity group is the same for all elements of a row in the i/o-table.

3.1. The simple i/o-analysis of price changes of final demand categories.

In a simple analysis of e.g. the PHC the contributions of elements of primary cost to the change of the PHC can be estimated as the product of the cumulative cost coëfficient and the price index (corrected for productivity changes) of each primary cost category, except operating surplus. The contribution of operating surplus to the PHC is obtained as the difference between the PHC and the contributions of all other primary cost categories.
This kind of analysis is applied in practice, but it appears to be a dangerous method for several reasons. Some of these reasons such as possible inaccuracy or inconsistency of the price data used apply to all kinds of analysis.

But, because the contribution of operating surplus to the PHC is obtained as a difference, no checks are part of the analysis. Another reason is the assumed constancy of input-coëfficients, but this assumption has to be made always in a short-term analysis for statistical reasons, except for labour- and capitalinput.
Some other reasons for raising objections to the analysis in question can be avoided more or less by refining the estimation procedures.
In the first place the heterogeneity of primary cost categories can be diminished, which makes possible to attribute more accurately price changes of primary costs to separate components of final demand. This refinement will be discussed briefly in the next paragraph.
Secondly, the assumption that the price index of a commodity group is the same for all elements of its row in the i/o-table seems to be unrealistic. This may be harmful to the results of the simple analysis, because price discrimination (e.g. between foreign and domestic market) occurs and because commodity groups in the i/o-table are not homogeneous. In paragraph 3.3. a method for testing the effects of the possible deviations from reality of this assumption will be described.

3.2. Heterogeneity of primary cost categories.

If in a simple analysis of e.g. the PHC, primary costs are subdivided into imports, indirect taxes, subsidies, depreciation, wages and salaries, contributions to social security schemes and operating surplus, the heterogeneity of these elements may be harmful to the results. It is possible e.g. that price changes of the imported commodities, which are used in the production of consumer goods differ from those, used in the production of capital goods. Using one general price index of imports leads to an inaccurate estimate of the contribution of import prices to the PHC in this case.
Better results can be expected when imports are subdivided into a number of more homogeneous groups so that for each group a separate cumulative coëfficient and a separate price index can be employed. The CBS intends to subdivide the row imports into as many rows as there are branches in the i/o-table with which the imports compete.
Similar procedures will be followed in respect of other primary costs. The row "wages" as well as the row "social security contributions". can be transformed into diagonal matrices. The indirect taxes can be broken down into separate tax categories and depreciation can be subdivided into e.g. depreciation of buildings, transport vehicles and machinery, and transformed to diagonal matrices as well. This kind of transformation is especially important when the price indicator of a primary input is estimated by dividing the change of the value of that input by the change of the volume of production of the branch, which consumes that input (e.g. depreciation per unit of production).

3.3. The treatment of operating surplus

If, analogous to the treatment of wages, the row "operating surplus" in the i/o-table is transformed into a diagonal matrix, for each branch a number of cumulative operating surplus coëfficients can be computed. Mathematically this can be shown as follows.

If b_{II}^{T} is the transposed vector of direct operating surplus coëfficients and we define $B_{II} = \hat{b}_{II}^{T}$ as the diagonal matrix mentioned, we can compute the cumulative operating surplus coëfficients by $B_{II}(I-A)^{-1}$ where A is the matrix of direct intermediate cost coëfficients.

We define B_{II} as the matrix of direct primary cost coëfficients, excluding operating surplus, p as the vector of producers's price indexes, k as the vector of "price indexes" of primary inputs (excluding operating surplus) and o as the vector of "price indexes" of operating sunplus.

Then $$p^T = k^T B_I (I-A)^{-1} + o^T B_{II} (I-A)^{-1} \qquad (1)$$

so that the unknown o^T can be computed as

$$o^T = p^T \left[B_{II}(I-A)^{-1}\right]^{-1} - k^T B_I (I-A)^{-1}\left[B_{II}(I-A)^{-1}\right]^{-1} \qquad (2)$$

This means, that the contribution of the operating surplus of each branch to the change of the producer's price of all branches separately can be estimated (eq.1) The change in the value of operating surplus per unit of product per branch can be estimated as well (eq.2)
If the system of price indexes is consistent, the price index of final demand (α) is equal to the weighted sum of the price indexes of producer's prices (p) and the price indexes of primary inputs, which are directly allocated to final demand (q). If f_I is defined as the vector of weights of final demand per branch in total final demand and f_{II} as the similar vector of weights for direct primary inputs of final demand we can write

$$\alpha = p^T f_I + q^T f_{II} \qquad (3)$$

From equations (1) and (3) we get

$$\alpha = k^T B_I (I-A)^{-1} f_I + o^T B_{II} (I-A)^{-1} f_I + q^T f_{II} \qquad (4)$$

The first two terms of the right-hand side of this equation represent a disaggregation of the contribution of total primary input used by enterprises to the price change of final demand. In a similar way each of these two terms can be disaggregated further so that the contribution of details of primary cost, e.g. wages paid by agriculture or operation surplus earned in agriculture, to the price change of final demand can be estimated separately.
The next stage of the analysis is the examination of separate final demand categories. If in equation (4) f_I and f_{II} are replaced by the weights of e.g. household consumption an estimated PHC is obtained which can be compared with the observed PHC. If the assumptions of the i/o-analysis are realistic these indexes are equal. But if price discrimination between final demand categories occurs or if rows within the matrix of final demand are not homogeneous a discrepancy between both indices appears.
This method thus provides a check on the assumption that the price index of a commodity group is the same for all elements of a row in the i/o-table.
But the question arises to what extend this method in itself produces results, which are influenced by possible heterogeneity of rows in the i/o-table. This question refers to heterogeneity in the sense, that within separate rows of the i/o-table the price index of intermediate deliveries differs from that of final deliveries. It will be demonstrated now that, if homogeneity is assumed though heterogeneity exists in reality, no discrepancy between the estimated and the observed price index of final consumption will appear, and that

the thus estimated contributions of separate primary cost categories to that price index are the correctly weighted averages of the contributions per primary input category, which could be estimated if the heterogeneous rows were subdivided into homogeneous rows with corresponding colomns.
It is assumed, that each branche of the i/o-table can be subdivided into a subbranch producing intermediate products (subscript 1) and a sub-branch producing final products (subscript 2).
Using the same notation as above and assuming that each sub-branch has its own cost structure and its own price indexes we can write, analogous to equation (1) above

$$p_1^T = k_1^T B_{1,I} (I - A_1)^{-1} + o_1^T B_{1,II} (I - A_1)^{-1} \qquad (5)$$

which leads to

$$o_1^T = p_1^T B_{1,II}^{-1} - p_1^T A_1 B_{1,II}^{-1} - k_1^T B_{1,I} B_{1,II}^{-1} \qquad (6)$$

and we can write

$$p_2^T = k_1^T B_{1,I} (I - A_1)^{-1} A_2 + o_1^T B_{1,II} (I - A_1)^{-1} A_2 + k_2^T B_{2,I} + o_2^T B_{2,II} \qquad (7)$$

which leads to, using (6)

$$o_2^T = p_2^T B_{2,II}^{-1} - p_1^T A_2 B_{2,II}^{-1} - k_2^T B_{2,I} B_{2,II}^{-1} \qquad (8)$$

Starting from equation (7) we can write

$$p_2^T f_I = k_1^T B_{1,I} (I - A_1)^{-1} A_2 f_I + o_1^T B_{1,II} (I - A_1)^{-1} A_2 f_I + k_2^T B_{2,I} f_I + o_2^T B_{2II} f_I \qquad (9)$$

so that it is proved, that no discrepancy will appear between the calculated and the observed price index of final consumption.

Transforming the terms of equation (6) into diagonal matrices and bearing in mind that $B_{1,II}$ is already a diagonal matrix we can write

$$\hat{o}_1 = \hat{p}_1 B_{1,II}^{-1} - \widehat{p_1^T A_1} B_{1,II}^{-1} - \widehat{k^T B_{1,I}} B_{1,II} \qquad (10)$$

and, defining x as the vector of total production per branch

$$\hat{o}_1 B_{1,II} (x - f_I) = \hat{p}_1 (x - f_I) - \widehat{p_1^T A_1} (x - f_I) - \widehat{k_1^T B_{1,I}} (x - f_I) \qquad (11)$$

Similarly we can write, starting from equation (8)

$$\hat{o}_2 B_{2,II} f_I = \hat{p}_2 f_I - \widehat{p_1^T A_2} f_I - \widehat{k_2^T B_{2,I}} f_I \qquad (12)$$

and from equation (2)

$$\hat{o} B_{II} x = \hat{p} x - \widehat{p^T A} x - \widehat{k^T B_I} x \qquad (13)$$

Now:

$$\hat{p}_1 (x - f_I) + \hat{p}_2 f_I = \hat{p} x \qquad (14)$$

since $\hat{p}$ is the average of $\hat{p}_1$ and $\hat{p}_2$ weighted by their respective share in the output.

$$\widehat{p_1^T A_1} (x - f_I) + \widehat{p_1^T A_2} f_I = \widehat{p^T A} x \qquad (15)$$

since $\widehat{p^T A}$ is the change of intermediate cost per unit of production which is the average of $\widehat{p_1^T A_1}$ and $\widehat{p_1^T A_2}$ weighted with their respective share in the output.

$$\widehat{k^T B_{1,I}}\,(x - f_I) + \widehat{k_2^T B_{2,I}}\, f_I = \widehat{k^T B_I}\, x \qquad (16)$$

since $\widehat{k^T B_I}$ is the change in the primary cost (excluding operating surplus) per unit of production which is the average of $\widehat{k_1^T B_{1,I}}$ and $\widehat{k_2 B_{2,I}}$ weighted by their respective share in the output.

It follows from equations (11) through (16) that

$$\hat{o}_1 B_{1,II}\,(x - f_I) + \hat{o}_2 B_{2,II} f_I = \hat{o} B_{II} x \qquad (17)$$

This means that vector o is the average of the o_1 and o_2 weighted with their respective shares in total production per branch. This had to be proved.

3.4. Conclusions and final remarks.

The analysis described in paragraphs 3.2. and 3.3 seems to be less risky than the well-known simple i/o-analysis of price changes of final demand categories. This is partly due to the diminished heterogeneity of primary inputs distinguished in the analysis. But it seems to be more important, that a check is built in on the assumption of homogeneity with respect to price changes per commodity group(branche) in the analysis of separate final demand categories.
The discrepancy between the estimated price index of e.g. household consumption and the PHC can be an indication of the accuracy of the analysis. The evaluation of this accuracy should take place within a broader framework, because several considerations will be important. The opinion on the quality of the PHC is one of them, the opinion on the homogeneity of branches in the i/o-table and on the price indexes of production is another. More interesting from a theoretical point of view is the possibility that e.g. a shift in profits from the export market to the domestic market may have appeared as a result of a revaluation of the currency.
If the accuracy can be considered satisfactory, the analysis described provides very detailed information on the contribution to price changes of separate primary inputs per branche, which seems to be interesting information for a price and income policy.
The analysis can be worked out in this detail for separate product groups, but only for totals of final demand categories the check, described in paragraph 3.3, is valid. Furthermore, a confrontation of the results by product group with details of the PHC requires the solution of the problems of comparing producer's prices and retail prices, as mentioned in paragraph 2.3. If the i/o-table is a commodity-table instead of an industry-table this kind of analysis by product group seems to be more convenient, but within the framework of a price and income policy the analysis based on an industry-table seems to be more useful.

Several ways of entering into further details are possible especially with respect to the price indicators of primary inputs. Wages per unit of production can be subdivided into productivity changes, changes of wage rates (from labour-contracts) and so called incidental wage changes (wage drift); changes of depreciation per unit of production can be subdivided into productivity changes and changes of prices of capital goods; etc.
It seems to be possible to link this analysis to a productivity and income-distribution analysis by branch but this goes beyond the scope of this paper.