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Management of Energy Recourses, Marginal Input-Output Coefficients, and Layers of Techniques: A Case Study of US Chemical Industry

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The embodied technical change should reduce the cost of production of the commodity. However, price structure, wages and interest rates also will change over time. Thus if a commodity is following a fixed price regime, the adjustment of a historical input-output table to current price wage level will leaves less and less profit per unit of output. The extent of this reduction will indicate the extent of technological change. There are different approaches to the prediction of changes in input-output coefficients. The first approach, attributable to Leontief (1941) and Stone (1962), assumes that input-output matrices change over time in a "biproportional" way. The other approach is to estimate trends in individual coefficients using statistical data. Former approach is used by a number of experts, including Fontela, *et al.* (1970), Almon, *et al.* (1974) and Carter (1970). Arrow and Hoffenberg (1959), Henry (1974), Savaldson (1970, 1976), Ozaki (1976), Aujac (1972) and Buzunov (1970). These are examples of the application of the quantitative approach for forecasting input-output coefficients. Still another approach which could not get much attention for forecasting input-output coefficients, is constructing the marginal input-output coefficients [Tilanus (1967); Middelhoek (1970)]. Marginal coefficients for forecasting constructed by Tilanus and Middelhoek are based on average input-output tables, which shows that still new approach (marginal) is based on the old (average) one.

However, Professor Mathur (1977, 1986a, 1986b, 1989, 1990) was interested in both types of firms, i.e., best-practice and least efficient. According to him, in translating the extra final demand of macro-models, the best-practice coefficients will be more useful than the average ones, whereas in assessing the incidence of obsolescence, unemployment, etc., the least efficient coefficients will be the more appropriate ones. In the following sections the discussion will be based more on the Professor Mathur's work. His approach was also later on discussed theoretically and empirically by Azid (1993), Law and Azid (1993), Azid and Law (1994, 1995), Azid and Ghosh (1998) and Azid and Noor (2000), Azid (2002).

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When a new technical advance is embodied in the capital equipment, the old technique also remains producing for a certain time, though by the nature of things it will more likely be earning lesser returns. The very fact that the new technology requires an accumulation of the corresponding capital will allow for the old technology to be in use for some time, that is, until the time that the accumulated new capital becomes sufficient to meet the total demand of the product. Subsequently, investment of various techniques will work with different efficiencies, and hence with different requirements for inputs, labour and working stocks to produce a unit of output.

The afore-mentioned make clear that it is not necessary to assume, as Shumpeter (1934) and Galbraith (1952) do, that there must be monopoly power with the firm to prevent its capital equipment embodying old technology from becoming obsolete due to new innovations. Up until the time that sufficient equipment of new technology is not accumulated, the equipment of old technology will go on producing. Once sufficient new capital is accumulated, no amount of monopoly power can prevent the old capital equipment from being pushed out to the scrap heap, as the demand will be met cheaply by the processes employing the new capital equipment.

If the industry is under monopolistic control, the monopolist will not find it to his advantage to go on using the old capital which produces at a higher cost. As a matter of fact, new capacity will be installed when the cost advantage outweighs the loss of abandoning some old working capacity; or there is sufficient extra demand to justify it, and the extra revenues generated by increasing prices to equate this extra demand with supply are expected to be less than those achieved by increasing the capacity. Nevertheless, the monopolist may delay, purposely, the process of new capital accumulation thereby giving more time for the old capital goods to survive economically than would have been otherwise possible.

If the industry is working in a competitive environment, the firms possessing the technologically advanced outfit, which leads to the reduction of the production cost, would have to see that others with old capital equipment stop producing so that it can use its modern capital to the fullest capacity. This can be achieved by reducing the price of the product in such a way that production from the capital of old technology becomes loss making. The monopolist, however, needs not reduce the price to achieve this objective. He can switch off the machines of old techniques without reducing the price to such an extent as to make its use unprofitable.

The next section makes a quick review of the work done in this field. Then we set up a mathematical model generalising the input-output analysis to take account of the situation, and examine how this model with the layers of techniques can be constructed. For the empirical analysis the data of US 3-digit chemical industry will be used.

1. LAYERS OF TECHNIQUES

The fixed capital embodies the technology of the time when it was newly installed. This embodied technology remains almost the same up to the time the equipment embodying it is scrapped. The technological progress comes about by the installation of new equipment, embodying more profitable techniques at the current price structure. At a particular time equipment installed at different past dates will be simultaneously working, having, of course, different productivities and profits. In understanding the working of the economy, we can neglect this embodiment of technological change in the equipment only at the cost of relevance. Thus in a growing economy there will be a layers of techniques of different technologies working simultaneously.

Let C^K_j represent the capacity of the fixed capital equipment of the *k*th technique for producing the jth commodity. Similarly, A^K_j and L^K_j stand for the column vectors of the commodity and labour inputs per unit of production of the *j*th commodity by the *k*th technique. Furthermore, let ${}^fB^K_j$ and ${}^wB^K_j$ give the column vectors of the fixed and working capital stock requirements respectively per unit of production of the *j*th commodity by the *k*th techniques. And finally, let there may be m_j techniques working to produce the *j*th commodity.

If all the capital equipments are working to the full capacity, then the total output of the *j*th commodity will be

$$X_j = \sum_{K=1}^{m_j} C_j^K \qquad \text{where } j = 1,2,3,\ldots.n \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (1)$$

the average input-output coefficients will be given by

$$a_{ij} = \left(\frac{\sum_{K=1}^{m_j} C_j^K a_{ij}^K}{X_j} \right) \quad i = 1,2,\ldots.,n \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (2)$$

whereas the price structure will be such that

$$P_j = P_1 a_{1j}^K + P_1 a_{2j}^K + \ldots\ldots\ldots + P_i a_{ij}^K + \ldots\ldots + P_n a_{nj}^K + w\left(l_{1j}^K + l_{2j}^K + \ldots\ldots\ldots + l_{nj}^K\right)$$
$$+ rP_1\, {}^wb_{1j}^K + rP_2\, {}^wb_{2j}^K + \ldots\ldots + rP_i\, {}^wb_{ij}^K + \ldots\ldots\ldots + rP_n\, {}^wb_{nj}^K + S_j^K \qquad \ldots \qquad \ldots \qquad (3)$$

for all *k* and in matrix algebra notation

$$P_j = PA_j^K + wL_j^K + rP\, {}^wB_j^K + S_j^K \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (4)$$

It is noted as while the row vector of prices (*p*), the wage rate (*w*) and the interest rate (*r*) are the same for all the techniques, the residual S^K_j are different for each one, which emphasises that the technical change comes about by the installation of new equipment embodying more profitable techniques at the current price structure. In fact it is on the value of this residual that the actions of units depend. When an investment is being done in an equipment pertaining to a new technology, the expected residual should be large as not only to cover the interest and depreciation charges of the fixed capital but also the risk as well as the profit expectations of the entrepreneur. It may be recalled that this residual is not like a fixed annuity over the physical life time of the equipment, as it is the case if there is no technical progress and, hence, no obsolescence. In the age of advancing technology, the value of this residual should be gradually declining and an investor should take this into account while making his investment.

However, the returns on the fixed capital are not essential for the firm to remain in production. Once the fixed capital is installed and if it is not economically worthwhile to produce with it, it can only fetch its scrap value. So its opportunity cost is almost zero. This, of course, does not imply that there must not be expectation of sufficient returns before it is installed at all. Therefore, in taking decisions whether to continue the production process, the unit will not take into consideration any returns on the fixed capital by continuing production. It should go on producing until it can cover the variable cost of production. In other words, a unit will remain in production until its residual is not negative. Thus the price of the *j*th commodity P_j will determine which techniques should be used in the production and which should not.

Let m_j be the least efficient technique required to be in production to meet with the demand. For that

$$Pj = PA_j^{mj} + wL_i^{mj} + rP\ {}^{w}B_j^{mj} + S_j^{mj} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

The above equation will be valid for one technique of each of the industries, namely for the marginal technique which is on the verge of obsolescence. The condition that the total output of each industry should be just sufficient to meet with the demand of its product will uniquely determine the number of techniques in use. Consequently the price structure will be such that all those techniques required to produce will be economically feasible. An increase in the demand might induce some obsolete techniques to be brought back into production by suitably adjusting the price structure and vice versa.

Collecting Equation (5) for each industry, viz. the marginal or zero residual units, we derive the price determining equation for the system as

$$P = P\overline{A} + w\overline{L} + rP\ {}^{w}\overline{B} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

where $\overline{A}$, $\overline{L}$ and ${}^{w}\overline{B}$ denote the sets of input, labour and working capital stock requirements respectively for the marginal techniques which are on the verge of obsolescence.

As we can see that the current price structure is related to the current wage and interest rates as well as to the least efficient technique and not to the average or the best practice technique. Besides, the profit rate and the value of fixed capital do not play any role in the determination of price structure.

If the production of the marginal technique units is represented by the vector *X*, then the net output available for use is given by

$$P\left(I - \overline{A}\right)\overline{X} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

out of this, $rP\ {}^{w}\overline{B}\,\overline{X}$ is the income of the interest receivers, and the rest the wage incomes of those working with the marginal units. Hence the wage rate is given by

$$P(I-\overline{A}-r\,{}^{w}\overline{B})\,\overline{X}/\overline{LX} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

which implies that given the interest rate, the marginal technique determines both the price structure and the real wage rate. Similarly given the real wage rate, the marginal technique determines the price structure as well as the interest rate. There is one degree of freedom. Either the interest rate or the wage rate can be determined.

The marginal technique itself will be determined in such a way that total savings in the economy are equal to the total investment and other autonomous demand. As less and less efficient techniques, in the sense of having lesser values of residual, are brought into production, both employment and savings will increase. The saving rate is likely to be higher from the residual income than that from the income from wages or interest. Therefore, such a redistribution of income in favor of the residual income earners will increase the total savings even from the old techniques. Over and above there will be some savings by the income receivers from the increased production. Thus bringing more and more marginal techniques into production will increase the total savings in the economy. In the opposite case of taking more and more marginal firms out of production will decrease the total savings. Therefore, the number of firms in operation depends on the savings out of their production matching the investment and other autonomous demand.

2. HIGH NOMINAL INTEREST RATES AND COST-PUSH INFLATION

From Equation 6 we have seen that price structure or fix price system is given by

$$P = P\overline{A} + w\overline{L} + rP\,{}^{w}\overline{B}$$

Let *W* be represented in terms of commodity or as a vector of commodities *C* then

$$P = PC\overline{L} + P\overline{A} + rP\,{}^{w}\overline{B} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

It may be noted that as *C* is a column vecter and $\overline{L}$ a row vector $C\overline{L}$ is a (*n* x *n*) matrix. So

$$P(I-\overline{A}-C\overline{L}-r\,{}^{w}\overline{B}) = 0 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

As shown elsewhere Mathur (1963) there will be only one value of *r* which will be associated with positive P vector and it will be given by the reciprocal of the largest Eigen value of the matrix ${}^{w}\overline{B}(I-\overline{A}-C\overline{L})^{-1}$. This shows that for every real wage, the equilibrium rate of interest is determined by the technology on the verge of obsolescence (no profit technology). It is obvious that as we move to more and more efficient technologies, the equilibrium rate of interest will be progressively higher and higher for a given wage rate. Alternatively, for a given interest rate real wage rate will be greater.

If nominal interest rate ρ is greater than equilibrium interest rate *r*, Equation (9) becomes

$$P = P(C\overline{L} + \overline{A}) + \rho P\,{}^{w}\overline{B}$$

$$P = P(C\overline{L} + \overline{A}) + rP^{w}\overline{B} + (\rho - r)P^{w}\overline{B}$$

$$P = P + (\rho - r)\rho P^{w}\overline{B}$$

This is impossible since (ρ –*r*), *P*, as well as ${}^{w}\overline{B}$ are positive. The only way to have a feasible solution is for input prices to be different form output prices viz.

$$P^{t} = P^{t-1}(C\overline{L} + \overline{A}) + rP^{t-1\,w}\overline{B} + (\rho - r)P^{t-1\,w}\overline{B} \quad \dots \quad \dots \quad \dots \quad \dots \quad (11)$$

If we assume that in period *t*–1 the equilbrium interest rate prevails then

$$P^{t} = P^{t-1} + (\rho - r)P^{t-1\,w}\overline{B} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (12)$$

from the above equation it is clear that with fix price system a higher nimonal interst rate than the equilibrium one will lead to increases in prices. Not only that, the increases will be different for different conmmodities depending on their working capital requirements per unit of output. Thus we have a cost push inflation and inflation is not neutral.

In a flexible price monopolistic case also, the higher nominal interst rate will lead to higher marginal cost, and as marginal revenue would tend to be equal to this, the price of the commodity will increase. It may be noted that in this case the capital at change will be total capital rather than working capital only.

3. UNEMPLOYMENT OF THE RESOURCES AND OBSOLESCENCE

Let in matrix algebra notation, $\underline{A}$, $\underline{L}$, ${}^{f}\underline{B}$ and ${}^{w}\underline{B}$ stand for the input, labour, fixed and working capital stock requirements respectively per unit of production of the best practice technique in the economy, which is formed by collecting the technique with the largest residual for each industry, and let $\underline{F}$ denote the column vector of the extra final demand to be satisfied by the best practice technique, then the balanced capacity creation will be given by (13) becomes

$$\underline{C} = (I - \underline{A})^{-1}\underline{F} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (13)$$

the requirements of the extra capital goods and the extra working capital stocks to achieve $\underline{C}$ by

$${}^{f}\underline{B}\underline{C} = {}^{f}\underline{B}(I - \underline{A})^{-1}\underline{F} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (14)$$

and

$${}^{w}\underline{B}\underline{C} = {}^{w}\underline{B}(I - \underline{A})^{-1}\underline{F} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (15)$$

whereas the extra employment will be

$$\underline{L}\underline{C} = \underline{L}(I - \underline{A})^{-1}\underline{F} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (16)$$

If the increase in the final demand is lesser than the extra demand to be satisfied by the best practice technique, $\Delta F < \underline{F}$, then capacity of the least efficient technique will be unutilised. Using the notation of Equation (6), the unutilised capacity of the least efficient technique will be equal to

$$U = (I - \underline{A})^{-1}(\underline{F} - \Delta F) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (17)$$

and the newly created unemployment equal to

$$\overline{L}U = \overline{L}(I - \underline{A})^{-1}(\underline{F} - \Delta F) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (18)$$

Hence, the net employment will be given by the subtraction of Equation (16) from Equation (18)

$$\overline{L}U - \underline{L}\underline{C} = \overline{L}(I - \underline{A})^{-1}(\underline{F} - \Delta F) - \underline{L}(I - \underline{A})^{-1}\underline{F} \quad \ldots \quad \ldots \quad \ldots \quad (19)$$

or

$$\overline{L}U - \underline{L}\underline{C} = [\overline{L}(I - \underline{A})^{-1} - \underline{L}(I - \underline{A})^{-1}]\underline{F} - \overline{L}(I - \underline{A})^{-1}\overline{F} \quad \ldots \quad \ldots \quad \ldots \quad (20)$$

where the first term of the right hand side is positive, since the productivity of the best practice technique is greater than that of the least efficient technique.

Therefore, it is evident that in translating the extra final demand of macro-models, the best practice coefficients will be more useful than the average ones, while in assessing the incidence of obsolescence, unemployment, etc. the least efficient coefficients will be the more appropriate ones. Moreover, if the extra final demand to be satisfied by the best practice technique is larger than the change in the final demand of the economy, there will be a rise in the unemployment. The net employment will take its highest value when there is no change in the final demand of the economy. Thus the present level of employment will be maintained when the change in the final demand of the economy is such that Equation (20) will become equal to zero.

4. DATA REQUIREMENT

The preceding analysis points out that the knowledge of both best practice and least efficient coefficient is more essential than the knowledge of average coefficients for disaggregating planning and forecasting as well as for exercising a suitable economic policy. Therefore, the analysis underlines the need for compiling input-output tables referring to the best practice and the least efficient techniques, rather than to the average technique, in order to improve the reliability of input-output estimates.

The data were tabulated by the US Census Bureau from its Longitudinal Research Database (LRD). This research is based on data from the 1982[1] Census of Manufacturers. Individual establishment data in the LRD file were sorted at three digit level according to the following scheme. First the cost per unit of output for every establishment in every industry was computed. Output was defined as shipment plus the changes in the finished goods and half of goods-in-progress inventories between 1981 and 1982. Total variable cost was defined as the sum of the purchased

[1]However, it is not a recent data, but for the understanding of the problem, detailed data of any other year is not available. We are also thankful to US National Science Foundation for the provision of this data.

materials, fuels, electricity, communication services, and building and machinery repairs plus worker payroll and supplementary labour cost. Thus the information gathered at this stage pertained to the average variable cost (AVC) of each establishment. Disclosure rules prevent the Census of Bureau from releasing information on any single establishment. Therefore, the unit of observation had to be changed from an establishment to a group of establishments. This was done by first arranging all establishments in order of rising unit variable cost within each three digit industry as a whole. Then groups of establishments were formed in such a way that unit cost of each establishment within a group was less than that of any establishments in the subsequent group. The number of establishments that fell within a group was determined in such a way that this number be equal for all groups within an industry.

Once these groups were formed information was collected for variables like output, employment, material and energy inputs, wages, etc. In fact most of the data available on the short file of the Census were collected. We did not collect the data regarding individual material input as that would have led to tabulating data from the comprehensive files themselves. This would have been not only very time-consuming but also quite costly in term of resources. Further, it would have been much beyond our aim to have a preliminary understanding of the dimensions and hence practical importance of the problem of layers of techniques in US manufacturing industry.

For empirical testing we select the following eight US three digit chemical industries to measure the effects of technological change under the state of flux. These three digit industries areas: Industrial Inorganic Chemicals (SIC 281), Plastics Materials and Synthetics (SIC 282), Drugs (SIC 283), Soap, Cleaners and Toilet Goods (SIC 284), Paints and Allied Products (SIC 285), Industrial Organic Chemicals (SIC 286), Agricultural Chemicals (SIC 287) and Miscellaneous Chemicals (SIC 289). Among the eight US three-digit chemical industries, Industrial Chemicals (SIC 281), Drugs (SIC 283), and Agricultural Chemicals (SIC 287) have 25 groups of establishments and the other five industries consist of 50 groups. List of variables used in this analysis is as below:

Variable	Description
AVC	Variable Cost Per Dollar Worth of Output
EF	Fuel Cost Per Dollar Worth of Output
EE	Electricity Purchased Per Dollar Worth of Output
Energy	Total Energy Cost Per Dollar Worth of Output

5. MARGINAL INPUT-OUTPUT COEFFICIENTS OF U. S. 3-DIGIT CHEMICAL INDUSTRY

For the empirical analysis the required data (as mentioned above) for the U.S. 3-digit chemical industry is available and also fulfill the requirement for the construction of best-practice and least efficient coefficients.

Table 1 shows the marginal input-output coefficients at different level of capacity of 3-digit US chemical industry. Five levels of capacity are assumed, i.e., 10 percent, 25 percent, 50 percent, 75 percent and 90 percent, which implies that five layers of techniques are working simultaneously experiencing different cost per unit of output. It is further assumed that 50 percent is the level for average techniques. The next step is to convert these coefficients to percentages of the average technique, and finally an index of coefficients for alternative capacity level can be achieved.

Table 1

Index of Marginal Input-Output Coefficients for 3-Digit U.S. Chemical Industries (Base = 50 percent)

	Industrial Inorganic Chemicals (SIC 281)				
Level of Capacity → Variables ↓	10%	25%	50%	75%	90%
AVC	89.84	94.83	100.00	111.45	114.44
EF	78.13	88.87	100.00	124.63	135.37
EE	75.89	87.73	100.00	127.18	139.02
Energy	76.65	88.11	100.00	126.34	137.80
Plastics Materials and Synthetics (SIC 282)					
AVC	89.30	93.35	100.00	106.84	110.88
EF	60.07	75.16	100.00	125.55	140.65
EE	81.15	88.29	100.00	112.07	119.21
Energy	69.15	80.81	100.00	119.70	132.37
Drugs (SIC 283)					
AVC	75.29	84.76	100.00	116.38	125.85
EF	31.73	57.91	100.00	145.18	171.36
EE	50.64	69.57	100.00	132.65	151.58
Energy	41.51	63.95	100.00	138.78	161.22
Soap, Cleaners and Toilet Goods (SIC 284)					
AVC	87.86	92.67	100.00	108.72	113.53
EF	95.45	97.23	100.00	103.16	105.04
EE	81.86	89.06	100.00	113.03	120.22
Energy	89.81	93.84	100.00	107.31	111.40
Paints and Allied Products (SIC 283)					
AVC	93.42	96.05	100.00	104.82	107.46
EF	89.24	93.54	100.00	107.87	112.17
EE	82.20	89.31	100.00	113.06	120.19
CPC	59.55	75.73	100.00	129.69	145.45
Energy	85.44	91.26	100.00	110.68	116.50
Industrial Organic Chemicals (SIC 286)					
AVC	86.75	91.87	100.00	108.92	114.03
EF	53.83	71.66	100.00	131.06	148.88
EE	44.58	65.99	100.00	137.32	158.50
Energy	50.65	69.71	100.00	133.21	152.25
Agricultural Chemicals (SIC 287)					
AVC	91.12	94.53	100.00	105.91	109.33
EF	37.53	61.55	100.00	141.60	165.61
EE	75.57	84.97	100.00	116.29	125.66
Energy	49.83	69.12	100.00	133.41	152.71
Miscellaneous Chemicals (SIC 287)					

EF	52.34	70.20	100.00	129.80	147.72
EE	67.81	80.47	100.00	122.70	135.36
Energy	61.42	76.58	100.00	127.20	142.39

Source: Calculated by authors themselves.

5.1. Marginal Input-Output Coefficients of Variable Cost and Energy Cost Per Dollar Worth of Output

The chemical industry modernised existing facilities by retro-fitting with updated, largely computerised equipment and instrumentation. Computers, programmable controls, computerised sensors for temperature, pressure, flow rate liquid levels, material analysers, and other process equipments have been increasingly diffused. Pneumatic controls have been more and more replaced by electronic signals and apparatus (except in the processing of flammable materials).[2] This throws light on the idea that the chemical industry is in the process of change. Analysis of this section is based on the marginal coefficients of the above mentioned variables of different sectors of US 3-digit chemical industry. At a particular time, there is an economy, where simultaneously layers of techniques are working. After the construction of marginal coefficients for variable cost per dollar worth of output, forecast can be made on the basis of given information, of how much variable cost can be saved after a particular elapse of time. Assuming that the middle value is the average value, how much will be the divergence from both sides of the practices, i.e., worst- and best-practice?

Looking at the marginal coefficients of variable cost per dollar worth of output, in all sectors of the US 3-digit chemical industry, a gradual shift of the coefficient is observed, reflecting the continuous introduction of new-practice technologies. The difference describes the ability to produce output with different technologies.

Further, it is assumed that the replacement of all chemical sector is 5 percent per annum, then our calculations at the 10 percent level of capacity describes the marginal marginal coefficients of the previous two years. At the 25 percent level of capacity level, it means the coefficients of five years, and so on. The 50 percent level of capacity represents the average technology. The ratio between the best practice and least efficient will be clarified by examining Table 2.

Table 2

Ratio of Marginal Coefficients (Best Practice to Least Efficient Techniques) for Variable Cost Per Dollar Worth of Output

Name of Industry	90% / 10%	75% / 25%
Industrial Inorganic Chemicals (SIC 281)	1.30	1.18
Plastics Materials and Synthetics (SIC 282)	1.24	1.14
Drugs (SIC 283)	1.67	1.37
Soap, Cleaners and Toilet Goods (SIC 284)	1.29	1.17
Paints and Allied Products (SIC 285)	1.15	1.09

[2]For the advancement of the chemical industry see the various issues of Chemical Engineering News, Chemical Engineering, and Chemical and Engineering News.

Industrial Organic Chemicals (SIC 286)	1.31	1.19
Agricultural Chemicals (SIC 286)	1.20	1.12
Miscellaneous Chemicals (SIC 287)	1.21	1.12

Source: Calculated by authors themselves.

It is clear that the ratio between the best- and worst-practice 90 percent and 10 percent of capacity (in terms of percentage) is maximum (1.67) in Drugs (SIC 283) and minimum (1.15) in Paints and Allied Products (SIC 285). If there is continuous change in technology, establishments can save more. On the basis of this information, forecasts can be made and much variable cost can be saved in the future. When large ratios are observed, it means that the rate of obsolescence is very fast, however, when the ratio is small it means that rate of obsolescence is not very fast.

5.2. Marginal Coefficients for Energy

Information on the quantities of energy required per unit of output is interesting for two reasons. First, such information will indicate how the industrial demand for energy changes with the mix of output. Second, it will indicate how the pattern of commodity prices will, initially, respond to change in energy prices.

Since the early 1970s when it was realised that energy prices might be below their true scarcity value, various methods of analysing energy use and energy substitution possibilities have been developed and refined. Among the methods used for determining levels of energy content in producing goods is "energy input-output analysis" which recognises the interdependence of all sectors of the economy and their contribution to the energy embodied in specific goods and services.

All the work on these lines is based on average input-output analysis, which is based on the average technique, so it is not very helpful in forecasting of demand. For accurate forecasting it is better to construct the marginal input-output coefficients, which are based on different layers of techniques.

Table 3 indicates the ratio of marginal coefficients for energy of best and least efficient practices. We construct the marginal coefficients for three energy variables of US 3-digit chemical industry.

Table 3

Marginal Coefficients for Energy: Ratio of the Best to the Worst Practice

Name of Industry	EF		EE		Energy	
Industrial Inorganic Chemicals (SIC 281)	1.73	1.40	1.83	1.45	1.80	1.43
Plastics Materials and Synthetics (SIC 282)	2.34	1.67	1.47	1.27	1.90	1.40
Drugs (SIC 283)	5.40	2.51	2.99	1.91	3.88	2.16
Soap, Cleaners and Toilet Goods (SIC 285)	1.10	1.06	1.47	1.27	1.24	1.14
Paints and Allied Products (SIC 285)	1.26	1.15	1.46	1.27	1.36	1.21
Industrial Organic Chemicals (SIC 286)	2.77	1.83	3.56	2.08	3.01	1.91
Agricultural Chemicals (SIC 287)	4.41	230	1.66	1.37	3.06	1.93
Miscellaneous Chemicals (SIC 289)	2.54	1.75	2.00	1.52	2.32	1.66

Source: Calculated by authors themselves.

Note: For every variable, the left column is the ratio 90 percent to 10 percent, and the right column is ratio 75 percent to 25 percent.

Drugs (SIC 283), Industrial Organic Chemicals (SIC 286) and Agricultural Chemicals (SIC 287) are saving more energy than other sectors due to technology. Soap, Cleaners and Toilet Goods (SIC 284) and Paints and Allied Products (SIC 285) are the lowest savers of energy among the eight sectors US chemical industry. Fuel is saved more by Drugs (SIC 283) and more electricity is saved by Industrial Organic Chemicals (SIC 286). The variation in ratios is from 1.14 (Soap, Cleaners and Toilet Goods) to 2.16 (Drugs). Whereas the variations in fuel is from 1.10 (Soap, Cleaners and Toilet Goods) to 5.40 (Drugs) and in electricity it is from 1.46 (Paints and Allied Products) to 3.56 (Industrial Organic Chemicals). For electricity three groups can be distinguished, one is 1.46 to 1.65 (Plastics Materials and Synthetics; Soap, Cleaners and Toilet Goods; and Paints and Allied Products), another is from 1.65 to 2.00 (Agricultural Chemicals, Industrial Inorganic Chemicals, and Miscellaneous Chemicals) and the third is above 2.00 (Drugs, and Industrial Organic Chemicals), but under the column of fuel (EF) more variations can be observed than in the case of electricity; this effect is also reflected under the column of energy.

Another way in which marginal input-output coefficients can be estimated is based on the estimated values of coefficients corresponding to percentages of total capacity, i.e., the last and first estimated observation of each techniques represents the marginal coefficients of worst and best practice technique respectively. So each and every technique has two marginal coefficients, worst and best. Table 6 depicts these coefficients. Table 4 shows that the coefficients of least efficient side of every technique is higher than the coefficient of most efficient side of the next new technique. Even best-practice has also two coefficients, and the same is true for the worst practice groups of firms.

Table 4

Marginal Coefficients of Energy for Each Technique: The Best and the Least Efficient

Name of Industry	Most Efficient	Least Efficient
Industrial Inorganic Chemicals (SIC 281)		
01	0.116	0.216
02	0.104	0.108
Plastics Materials and Synthetics (SIC 282)		
01	0.169	0.171
02	0.151	0.162
03	0.076	0.173
Drugs (SIC 283)		
01	0.349	0.352
02	0.103	0.149
03	0.099	0.160
04	0.034	0.102
Soap, Cleaners and Toilet Goods (SIC 285)		
01	0.131	0.133
02	0.059	0.104
Paints and Allied Products (SIC 285)		
01	0.124	0.131
02	0.151	0.153
03	0.120	0.132
04	0.097	0.121
05		
Industrial Organic Chemicals (SIC 286)		
01	0.139	0.143
02	0.115	0.116
03	0.113	0.115
04	0.062	0.090
05	0.063	0.064
Agricultural Chemicals (SIC 287)		

01	0.265	0.266
02	0.102	0.113
03	0.081	0.101
04	0.039	0.046
Miscellaneous Chemicals (SIC 289)		
01	0.211	0.215
02	0.080	0.115

Source: Calculated by authors themselves.

6. FORECASTING IN AN ECONOMY WITH SEVERAL LAYERS OF TECHNIQUES

As already discussed in previous sections, new techniques are producing output with less variable cost, labour cost, and energy cost per dollar worth of output. At the same time if demand is not increasing *pari passu*, the old vintage will fetch its scrap value. These are the marginal input-output coefficients, *de facto* which explain the real situation of the economy, when the economy is working under a spectrum of techniques, having different productive efficiencies.

If it is assumed that new capacity is increasing 5 percent by the installation of new technology, then 5 percent of old capacity which is on the verge of obsolescence, will no longer be working. Table 5 shows that how many groups of old vintages close down in each sector if *ceteris paribus*, new capacity is created (5 percent) by the new techniques. The same methodology can be used for the forecasting of energy cost and labour cost per dollar worth of output in each sector of US chemical industry. Table 5 analyses the effect on energy cost per dollar worth of output in the US 3-digit chemical industry when 5 percent new capacity is created, assuming demand to be constant.

Table 5

Forecasting the Obsolescence of the Groups

Name of Industry	Variable Cost per Dollar Worth of Output of New Created Capacity (5%)	Variable Cost per Dollar Worth of Output of Group, After New Created Capacity (5%) (on the Verge of Obsolescence)	Number of Groups Closing Down, after New Created Capacity (5%)
Industrial Inorganic Chemicals (SIC 281)	0.572	0.973	1
Plastics Materials and Synthetics (SIC 282)	0.727	0.929	2
Drugs (SIC 283)	0.432	0.778	2
Soap, Cleaners and Toilet Goods (SIC 284)	0.610	0.820	6
Paints and Allied Products (SIC 285)	0.715	0.841	2
Industrial Organic Chemicals (SIC 286)	0.683	0.933	2
Agricultural Chemicals (SIC 287)	0.782	0.963	3
Miscellaneous Chemicals (SIC 289)	0.690	0.857	3

Source: Calculated by authors themselves.

Suppose that autonomous demand is increased by 5 percent, in the short run it is impossible for the producers to fill the gap between demand and supply by installing new technology. The establishments will try to use unutilised capacity. The minimum condition for restarting the capacity is that the prevailing price must not be less than their average variable cost. There are two possibilities, either variable cost goes down or price will go up to cover their average variable cost. The first is unlikely so normally price will go up, which is cost push inflation; price is determined by cost instead of the market mechanism. Table 6 shows the highest level of variable cost and energy cost per dollar worth of output, if 5 percent new autonomous demand is fulfilled in the short run by using the old vintage.

Table 6

Forecasting of the Energy Cost per Dollar Worth of Output after 5 Percent Capacity Created by New Technology

Name of Industry	Energy Cost per Dollar Output of New Created Capacity (5 %)	Energy Cost per Dollar Worth of Output of the Group, which is on the Verge of Obsolescence After Created (5 %) Capacity
Industrial Inorganic Chemicals (SIC 281)	0.010	0.061
Plastics Materials and Synthetics (SIC 282)	0.040	0.088
Drugs (SIC 283)	0.010	0.038
Soap, Cleaners and Toilet Goods (SIC 284)	0.015	0.019
Paints and Allied Products (SIC 285)	0.010	0.014
Industrial Organic Chemicals (SIC 286)	0.038	0.140
Agricultural Chemicals (SIC 287)	0.040	0.152
Miscellaneous Chemicals (SIC 289)	0.018	0.048

Source: Calculated by authors themselves.

Table 7 shows that when demand increases the utilisation of resources will also increase, but without increase in the price levels the supply will not increase. The same phenomenon will occur in the labour market and here the relationship between cost-push inflation and unemployment can be seen. New capacity increases the rate of obsolescence, and non-profit firms on the verge of obsolescence cannot bear the burden of a cut in prices due to increase in supply. Without an increase in demand, they are not able to survive and disappear causing unemployment, so the Phillips curve will be pushed horizontally eastward. Section 7.1 discusses this relationship in detail.

Table 7

Variable Cost and Energy Cost per Dollar Worth of Output of That Group, which is on the Verge of Obsolescence, after Generating the Autonomous Demand (5 Percent)

Name of Industry	Variable Cost per Dollar Worth of Output	Energy Cost per Dollar Worth of Output
Industrial Inorganic Chemicals (SIC 281)	0.805	0.062
Plastics Materials and Synthetics (SIC 282)	0.940	0.090
Drugs (SIC 283)	0.797	0.041
Soap, Cleaners and Toilet Goods (SIC 284)	0.832	0.020

Paints and Allied Products (SIC 285)	0.848	0.014
Industrial Organic Chemicals (SIC 286)	0.947	0.143
Agricultural Chemicals (SIC 287)	0.973	0.159
Miscellaneous Chemicals (SIC 289)	0.866	0.050

Source: Calculated by authors themselves.

6.1. Movement of Energy Cost in an Economy with Several Layers of Techniques

As discussed above the economy has a spectrum of techniques working simultaneously with different structures of average variable cost of production, i.e., technological surplus. It is the technique with almost zero surplus that determines the price structure.

All techniques which are better than these marginal ones would be working at full capacity. New establishments will be using less energy per dollar worth of output than the old establishments which will be closing down, so there will be generation of surplus if demand does not increase *pari passu*. If the strategy of a new establishment is to increase the price of energy, the establishments on the verge of obsolescence would try to recoup the higher energy-bill by increasing prices. If simultaneously demand also increases, it will be able to save itself. If not, its attempt to increase the price will be abortive and it will have no alternative but to close down. This will create surplus with price rises. At the other extreme there will be a rise in prices as the increased rates of energy instigated by new establishments could only be thus absorbed by the old establishments. In the real world, the result will be somewhere in between. Thus it does not determine the trade-off between inflation and surplus but is the result of the introduction of energy-saving technological progress and the struggle of firms becoming obsolete to remain in business. Thus when innovations are being translated into new investment a rise in prices and energy cost can be expected coupled with a decline in surplus.

When the burst of activity resulting from innovation is over, surplus will be generated from the following sources:

(i) The extra activity generated in the capital goods sector will taper off and together with it a lot of secondary production activity generated as a consequence. This will of course, throw out energy used in sub-marginal establishments that activated during this period.

(ii) The newly created capacity will make some old technology redundant and obsolete, i.e., the new techniques of production are likely to use less to produce the same amount of goods as the one on its way out.

This will indicate not only a slowing down of price rises but even its reversal. However, the energy cost of those remaining in use may still increase. That may be the market signal to less efficient firms to close down when their extra output is not required. So the phenomenon of the co-existence of rising real energy cost and rising surplus is to be expected.

After explaining the basic theory of this phenomenon, it is easy to understand Table 9, which assumes that 5 percent of output is produced by new capacity, implying that the price level will fall, and old vintages which are on the verge of obsolescence are closing down, creating unemployment. When autonomous demand rises, the price level will increase due to increasing costs; however, employment level will increase.

From Table 7 it is clear that when autonomous demand increases, prices will also increase due to the cost-push phenomenon, and more resources will be employed. The increase is likely to be different in different sectors depending upon their input requirement per unit of output.

The above approach gives the empirical evidence for the analysis of the relationship between inflation and the uses of energy resources on the basis of the structural requirement for the energy in the different sectors in an economy with several existing layers of techniques with different productive efficiencies.

Is there any theoretical explanation of the above phenomenon? High nominal interest rate affects the economy in two ways. Firstly it increases the rate of obsolescence. No-profit firms on the verge of obsolescence cannot bear the burden of extra nominal interest rates at current prices. There is only one way to escape. That is to increase prices. If they are able to do so they survive creating inflation and those which are not able to do so just disappear, creating surplus.

Recapitulation

Since the early days of input-output analysis, input-output forecasts of total demand based on a given final bill of goods have been made. Thus far, however, it seems that all studies have made use of what we call “Average” input-output coefficients, i.e., those shown in published input-output tables. Do these represent the real situation of the economy? In fact an economy consists of several layers of techniques, and these average coefficients are simply a weighted average of them, and are therefore not suitable for many aspects of analysis and policy.

An economy having continuous technical advance will embody a portion of improving know-how in the new investment being undertaken. Investment of different vintages will work with different productive efficiencies, and may require different amounts of various inputs to produce a unit of output. At a particular time, fixed capital equipment of several vintages may be expected to be in place for production. When investment involves equipment of the latest technique, the older equipment may also continue in production, though by the very nature of things it is likely to be earning lesser returns. The old equipment will go on producing until enough capital of the newer vintages is accumulated to satisfy total demand for that commodity.

However, after installation of fixed capital equipment, when it eventually becomes not economically worthwhile to produce with, it may only fetch its scrap value. Thus its opportunity cost is almost zero. Therefore, in taking the decision whether to continue in production, the unit will not consider whether it can get any return on fixed capital by continuing production. It should continue production as long as it can cover the average variable cost of production. In other words, a unit will remain in production until its technological surplus is not negative.

So, looking at the economy as consisting of several layers of techniques gives a way to spell out the implications of macro economic situations for micro levels. For instance, if macro economic consideration points to reducing total use of the resources, a map of the layers of the techniques of the economy should be able to pinpoint the different regions or industries that are likely to be affected. In such cases, to be able to delineate the effects of extra demand or of new investment on the production or utilisation of the resources in the economy, we require marginal input-output coefficients instead of the weighted average that are at present computed worldwide. Similarly, for capacities going out of production either because of lack of demand, or obsolescence, knowledge of the least efficient techniques of production is essential.

It is observed from the previous analysis that every best-practice in US 3-digit chemical sector saves energy per dollar worth of output.

Interestingly, it is observed that it is the marginal coefficients, which allow input-output analysis to meet the challenge of precision for the fast-developing forecasting industry. And the technique developed by P. N. Mathur, allows analysis of the effect of monetary and fiscal policy down to the level of establishments, providing the detailed effects of the policy or any economic activity, and giving a way to spell out the implications of macro economic situation to micro economic phenomena.

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Comments

Tauseef Azid has written several articles on various economic issues on the basis of his specialisation, the *Layers of Techniques* approach. Although I had some idea about the working of this methodology, this is the first time that I read the material seriously and somewhat understood its working.

Before I comment on the paper itself I must mention that I find the technique much more appealing that I had imagined. I do not hesitate in making even a proposal that would certainly provoke all those critics who think enough is enough and who find it difficult to absorb any more layers. In my opinion, so far only one pile of layers has been analysed. The framework can be extended to various other applications, for example in models of consumer demands and household production.

Coming to the paper itself, apart from a few points relating to technical aspect and presentation, the paper makes an excellent contribution to knowledge and it provides a practical framework for exploring energy conservation in a growing industry. Within its given framework the paper has no weakness worth mentioning and it is of high academic standard.

Looking at other side of the picture, I would first like to seek a few clarifications. First, in Equation (3) why there are exactly as many labour inputs and capital inputs as the number of material inputs, n, associated with any particular layer of technique, k, in each industry j? Second, can the 'residual' S be interpreted as profit or rent. Dose it measure the rent on superior techniques compared to the marginal technique? Third, why in the equation for the least efficient technique (5) we still have the term S present? Should it be dropped?

It also appears that Section 3 is not of much relevance in the paper and it may better be dropped. It only attempts to explain business cycle in the *Layers of Techniques* framework, while the paper at hand is to do with energy consumption as an input.

Finally, a few questions that may be of interest to the authors are as follows. First, according to *Layers of Techniques* framework efficient techniques tend to drive out inefficient techniques. First, within the given framework the energy coefficient of a more efficient technique is necessarily smaller. In practice a more efficient technique with respect to capital and labour may be more energy intensive. Can the framework be suitably modified to allow this possibility? Second, can the assumption of fixed input-output coefficient be completely done away, while still keeping intact the concept of layers of techniques. Is it reasonable to assume that in terms of relative efficiency two techniques may have anyone of the following patterns? (a) Technique A is strictly more efficient to technique B at all ranges of output; (b) Technique A is no less efficient than technique B at all ranges of output and A is strictly more efficient in a certain range of output; and (c) Technique A is strictly more efficient than technique B in a certain range of output, and less efficient in the remaining range of output.

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