LABOR PRODUCTIVITY DECOMPOSITION: GENERATION AND BENEFIT SPILLOVER

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Industrial sectoral productivity may be decomposed into the causes behind its generation, *labor reduction* and *output expansion*. Another decomposition may be in its *induced*, *direct* and *indirect* components using the Taylor expansion of output. Such a decomposition may be applied to production and allocation of gross output. Production indicates the *generation* and allocation the *benefit spillover* of productivity. Each round of Taylor's expansion indicates identical overall productivity in both activities that differs in terms of its decomposition. The *change* and the *magnitude* of productivity are examined in a comparative aspect. Furnished empirical evidence is based on Turkish interindustry data.

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1 Methodology

Labor productivity (π) of a given sector (j) is measured as the gross output (x) produced by a unit of labor (L)[3] at a given time (t), as:

$$\pi = x_j/L_j \qquad \text{or} \qquad \pi = \langle \mathbf{L} \rangle^{-1}\mathbf{x} \tag{1}$$

Gross output of sector (j) is generated by a process involving the interdependence among all sectors in the economy in terms of the direct and indirect inputs of this sector, that are sales from other sectors, the sectoral final use and value added. Defining $\mathbf{A}$ as the direct input requirement matrix (value of purchases per unit of output), $\mathbf{B}$ as the direct output allocation matrix (value sales per unit of output), $\mathbf{y}$ as the column vector of final use, and $\mathbf{v}^T$ as the row vector of value added, then gross output is:

$$\mathbf{x} = [\mathbf{I} - \mathbf{A}]^{-1}\mathbf{y} \qquad \text{or} \qquad \mathbf{x}^T = \mathbf{v}^T[\mathbf{I} - \mathbf{B}]^{-1} \tag{2}$$

In accounting terms, gross output is viewed either as intermediate output and final use, $\mathbf{x} = \mathbf{Xi} + \mathbf{y}$, or as intermediate input and value added, $\mathbf{x}^T =$

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[3] $\langle \mathbf{L} \rangle$ indicates a diagonal matrix.

$\mathbf{i}^T\mathbf{X}+\mathbf{v}^T$. In analytical terms, the interdependence among various sectors in terms of gross output may be broken down into the *induced*, $\mathbf{Iy}$, *direct*, $\mathbf{Ay}$, and *indirect*, $\mathbf{A}^*\mathbf{y} = \mathbf{A}^2\mathbf{y}+\mathbf{A}^3\mathbf{y}+\ldots+\mathbf{A}^n\mathbf{y}$, components of the production-final use approach as

$$\mathbf{x} = [\mathbf{I}-\mathbf{A}]^{-1}\mathbf{y} = \mathbf{Iy}+\mathbf{Ay}+\mathbf{A}^2\mathbf{y}+\mathbf{A}^3\mathbf{y}+\ldots+\mathbf{A}^n\mathbf{y} \tag{3.1}$$

or equivalently, the allocation-value added approach as

$$\mathbf{x}^T = \mathbf{v}^T[\mathbf{I}-\mathbf{B}]^{-1} = \mathbf{v}^T\mathbf{I}+\mathbf{v}^T\mathbf{B}+\mathbf{v}^T\mathbf{B}^2+\mathbf{v}^T\mathbf{B}^3+\ldots+\mathbf{v}^T\mathbf{B}^n \tag{3.2}$$

with the *induced*, $\mathbf{v}^T\mathbf{I}$, *direct*, $\mathbf{v}^T\mathbf{B}$, and *indirect* components[4] $\mathbf{v}^T\mathbf{B}^* = \mathbf{v}^T\mathbf{B}^2+\mathbf{v}^T\mathbf{B}^3+\ldots+\mathbf{v}^T\mathbf{B}^n$.

Sectoral productivity π then may be analyzed (column-wise) by substituting gross output with the various rounds of production process as they relate labor to final use, direct and indirect input requirement aspects of gross output as

$$\pi = \left(\langle\mathbf{L}\rangle^{-1}\mathbf{Iy}\right)+\left(\langle\mathbf{L}\rangle^{-1}\mathbf{Ay}\right)+\left(\langle\mathbf{L}\rangle^{-1}\mathbf{A}^2\mathbf{y}+\ldots+\langle\mathbf{L}\rangle^{-1}\mathbf{A}^n\mathbf{y}\right) \tag{4.1}$$

or (row-wise) by relating labor to value added, direct and indirect allocation aspects of gross output, as:

$$\pi = \left(\mathbf{v}^T\mathbf{I}\langle\mathbf{L}\rangle^{-1}\right)+\left(\mathbf{v}^T\mathbf{B}\langle\mathbf{L}\rangle^{-1}\right)+\left(\mathbf{v}^T\mathbf{B}^2\langle\mathbf{L}\rangle^{-1}+\ldots+\mathbf{v}^T\mathbf{B}^n\langle\mathbf{L}\rangle^{-1}\right) \tag{4.2}$$

Although there is not a one-to-one correspondence between respective vector elements defined in (4.1) and (4.2), the sectoral summation, on the left hand side of the equations, i.e. the respective column (4.1) or row (4.2) elements are the same. *Table 1* shows productivity rates of the Turkish economy for the 1990 based on the (4.1) and (4.2) formulas.

Induced productivity may be seen either from its final use or value added point of view. Although there is a balance between the two approaches, variations exist between the two aspects of their decomposition. Productivity rate induced by final use $(\langle\mathbf{L}\rangle^{-1}\mathbf{Iy})$ measures the final use part of gross output per sectoral employment. The direct input requirement part of gross output related to employment is the direct input productivity rate $(\langle\mathbf{L}\rangle^{-1}\mathbf{Ay})$, while the indirect input requirement part of gross output related to employment is the indirect input productivity rate $(\langle\mathbf{L}\rangle^{-1}\mathbf{A}^*\mathbf{y})$. The same value of gross output $\mathbf{x}$ viewed from the allocation point of view provides the value added induced productivity rate $(\mathbf{v}^T\mathbf{I}\langle\mathbf{L}\rangle^{-1})$, the direct allocation (sales) productivity rate $(\mathbf{v}^T\mathbf{B}\langle\mathbf{L}\rangle^{-1})$, and the indirect allocation (sales) productivity rate $(\mathbf{v}^T\mathbf{B}^*\langle\mathbf{L}\rangle^{-1})$.

The proposed methodology in this paper, although accepting the conceptual difference between direct and total labor productivity, clarifies previous work[5] on the subject. Previously, direct sectoral productivity was

[4]The related discussion on p. 28 of Adamou (1995) and the numerical evidence in the following sections refute the statement "*Taylor's expansion is an extreme implausible case limited to uneven sector growth in allocation model*" on p. 207 of Oosterhaven (1988).

[5]Panethymitakis A. (1993). The same results are reported in Greek in Panethymitakis (1992) p. 61 and p. 69.

measured as $\alpha = 1/\gamma = \mathbf{x}/\mathbf{L}$, and total productivity was evaluated as $\eta = \mathbf{i}\langle\mathbf{L}/\mathbf{x}\rangle[\mathbf{I} - \mathbf{A}]^{-1}$. Applying such measurements yield total productivity estimates (p. 86) lower than direct productivity (p. 83) estimates, implying negative indirect productivity for all manufacturing sectors of the Greek economy for the years 1958, 1966, 1970 & 1980, as well as all manufacturing sectors for 1970 for France, Germany, Italy, Holland and Belgium.

The clarified methodology associates sectoral total productivity to sectoral total gross output, and direct productivity to output that comes out from direct requirement (allocation) coefficients. Consequently, sectoral indirect productivity is associated to the sectoral indirect requirement (allocation) coefficients. As a result, in this study $\mathbf{x}/\mathbf{L} = \pi$ measures total and not direct productivity.

The assumed total productivity of previous work is the summation of the column elements of the Leontief inverse premultiplied by the diagonal matrix of the employment coefficients

$$\eta = \mathbf{i}\langle\hat{\gamma}\rangle[\mathbf{I} - \mathbf{A}]^{-1} = \begin{pmatrix} 1 & 1 \end{pmatrix} \begin{pmatrix} l_1/x_1 & 0 \\ 0 & l_2/x_2 \end{pmatrix} \begin{pmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{pmatrix}$$

This yields a summation of ratios with different denominators that a computer may add it numerically without an identification of this fact

$$\begin{pmatrix} \frac{l_1}{x_1} z_{11} + \frac{l_2}{x_2} z_{21} & \frac{l_1}{x_1} z_{12} + \frac{l_2}{x_2} z_{22} \end{pmatrix}$$

An algebraic summation of ratios however requires the same denominators. In this case, the resulted formula

$$\begin{pmatrix} \frac{x_2 l_1 z_{11} + x_1 l_2 z_{21}}{x_1 x_2} & \frac{x_2 l_1 z_{12} + x_1 l_2 z_{22}}{x_1 x_2} \end{pmatrix}$$

lacks of a meaning.

The *rate of productivity change* is measured by the natural logarithm of the productivity ratio between two time periods,

$$\lambda_{t,t+T} = \log \frac{\pi_{t+T}}{\pi_t} \tag{5}$$

while the *annual average rate of labor productivity* change for the period weights the rate of productivity change by the length of the examined time interval, as

$$\Lambda_{t,t+T} = \frac{\lambda_{t,t+T}}{T} \quad \text{or} \quad \Lambda_{t,t+T} = \frac{\log\left(\frac{x_{t+T}/L_{t+T}}{x_t/L_t}\right)}{T}. \tag{6}$$

It is important to identify sectors with high labor productivity as well as sectors with significant annual average rate of labor productivity change.

Furthermore, it is useful to decompose the average annual rate of productivity change into average annual rate of productivity change due to *employment reduction*, and average annual rate of productivity change due to *output expansion. Figure 2* depicts such a classification. There is an additive relationship between the above two components

$$\Lambda_{t,t+T} = \frac{\log L_t - \log L_{t+T}}{T} + \frac{\log x_{t+T} - \log x_t}{T} \,. \tag{6.1}$$

When attempting to compute average annual rates of productivity change of the induced, direct and indirect elements of gross output of production and allocation approaches, one must be careful since there is not additive principle here that leads to the average annual rate of the overall productivity change.

A summary index for the examined period is provided utilizing the Mahalanobis distance. Mahalanobis distance is the distance of each point from the multivariate mean (centroid) (Stevens, 1992, p. 39). Mahalanobis distance takes into account the correlation structure of the involved data as well as their individual scales, and it is calculated as:

$$d_i = \sqrt{(q_i - \overline{q})^T S^{-1} (q_i - \overline{q})} \,, \tag{7}$$

where q_i is the data of the ith row, $\overline{q}$ is the row of means, and S^{-1} the estimated covariance matrix. Since the extreme multivariate outliers can be identified by the highlighting points with the largest distance values, it is useful to identify the sectors where most of the productivity, productivity change, output and employment occur.

2 An Empirical Perspective: Productivity in Turkey

The 1973, 1979, 1985 and 1990 input-output tables for Turkey in constant 1973 prices of 23 sectors provide an empirical evidence for the above methodological arguments. The sectoral composition of the employment structure does not show significant changes throughout the examined period. One of the characteristics of the import substitution era is low employment generation due to capital intensive technology adoption in industry partly in response to the high ratio of labor cost to capital cost. The liberal era produced a similar outcome regarding employment; suppressed real wages in the early years have not encouraged a shift to labor intensive production. There was indeed a manufacturing exports boom during the '80s, but employment generation in the manufacturing industry was lowest when compared to agriculture and services (Senses, 1990).

Table 1 provides the productivity rates for the last Turkish interindustry table for 1990 based on the formulas (4.1) and (4.2). The ranking of industrial sectors is based on the magnitude of the overall labor productivity rate. The overall productivity rate is decomposed into the productivity rate induced by final demand, productivity rate of direct purchases and productivity rate of the indirect purchases from one side and into the productivity rate induced by value added, productivity rate of direct sales and productivity rate of indirect sales on the other.

		Total	(4.1)			(4.1)		
			Induced by Final Demand	Direct Purchases	Indirect Purchases	Induced by Value Added	Direct Sales	Indirect Sales
8	Oil Refining	0.887	0.041	0.499	0.346	0.740	0.107	0.040
			5%	56%	39%	83%	12%	4%
5	Wood-Furnit.	0.454	0.160	0.219	0.075	0.149	0.177	0.128
16	Other Manuf.	0.369	0.315	0.037	0.017	0.264	0.065	0.040
17	Utilities	0.322	0.079	0.113	0.130	0.220	0.072	0.031
9	Rubber-Plast.	0.279	0.109	0.102	0.068	0.169	0.072	0.038
3	Food-Bever.	0.259	0.186	0.050	0.023	0.100	0.102	0.057
11	Iron-Steel	0.253	0.046	0.132	0.076	0.146	0.068	0.039
7	Chemicals	0.241	0.113	0.072	0.056	0.143	0.064	0.034
14	Electrical M.	0.232	0.152	0.053	0.027	0.151	0.051	0.030
20	Transp Serv.	0.199	0.130	0.043	0.026	0.136	0.043	0.019
12	Metal Prod.	0.192	0.124	0.044	0.023	0.081	0.067	0.043
15	Transport V.	0.170	0.091	0.050	0.029	0.079	0.051	0.040
13	Machinery	0.168	0.131	0.022	0.015	0.089	0.047	0.032
6	Paper-Print.	0.151	0.063	0.046	0.042	0.060	0.051	0.040
18	Construction	0.126	0.126	0.000	0.000	0.064	0.036	0.026
4	Textiles	0.118	0.081	0.025	0.012	0.042	0.042	0.033
19	Trade	0.084	0.059	0.016	0.009	0.059	0.017	0.008
10	Glass-Cement	0.081	0.014	0.059	0.008	0.043	0.025	0.013
23	Public Serv.	0.075	0.075	0.000	0.000	0.075	0.000	0.000
2	Mining	0.067	0.027	0.019	0.021	0.052	0.010	0.005
22	Pers Serv&H.	0.065	0.041	0.015	0.009	0.054	0.008	0.004
21	Banking	0.053	0.005	0.030	0.019	0.038	0.011	0.004
1	Agriculture	0.029	0.018	0.007	0.004	0.022	0.005	0.002
	Over All	0.078	0.050	0.018	0.010	0.050	0.018	0.010

Table 1. Sectoral Productivity Rates (x/L) in Turkey - 1990

It is noticeable that the distribution of sectors according to their productivity is skewed, with few productive, and other not very productive sectors. The sector with the highest productivity rate is Oil Refining. Figures 1-A and 1-B provide the intertemporal view of the productivity rates of Oil Refining. *Figure 1-A* presents the double view of the formation of productivity's magnitude, while *Figure 1-B* reveals the percentage unit decomposition. The right side of each figure presents the production (cost) aspect of productivity's decomposition while the left side the allocation (revenue) side. Production and allocation aspects of the analysis are equivalent. The symmetrical similarity of the two approaches (Adamou, 1995) resolves the discussion about the plausibility of the supply side model in its relation to the original Leontief ones. Since the value of gross output appears as revenue from sales (row transactions) or cost from purchases (column transactions).

The productivity rate of Oil Refining [8] is outstanding, indeed quite above average. This sector is highly capital intensive employing qualified labor, and not only is the sector reflecting the highest productivity, but it has larger productivity fluctuations as well. Labor productivity declines in 1979 and 1990, while it is much higher in 1973 and 1980. Total productivity decomposition of Oil Refining from its demand side indicates that direct requirements dominate the picture, holding from 47% to 56%.

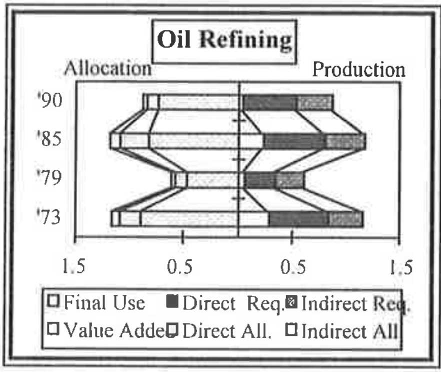

Figure 1-A

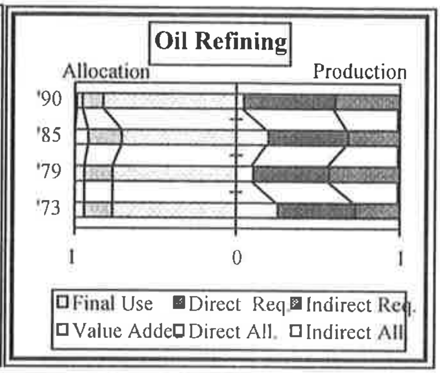

Figure 1-B

On the other hand, there is a significant increase of the indirect productivity from 28% to 39%, and reduction of the final use induced productivity from 26% to 5%. On the allocation side, the high productivity in Oil Refining results in a significant portion of value added, that increases from 77% to 83%. A single common characteristic of the examined above sectors indicating high productivity is that all furnish a serious component of value added, and all, with the exception of Oil Refining, have their highest productivity in 1990. This reveals that the change in economic policies did have an impact on the sectors with the highest productivity.

Highly productive sector may not necessarily indicate significant productivity change, like Wood & Furniture [5] and Utilities [17]. Thus, we can identify highly productive sectors from the above analysis, but the change with respect to sub-periods calls for further analysis. Besides the fact that productivity declined for Oil Refining, Oil Refining is still the sector with the highest total productivity in all examined years, and the sector with the largest average annual rate of productivity change. On the other hand, Rubber & Plastics [9], Construction [18], and Other Manufacturing [16] turn out to be those sectors with the highest productivity increases in the long run. As noted above the sub-period 1973-1979 suffers from the bottlenecks due to foreign exchange unavailability, which hit payments for petroleum most, a commodity Turkey has to import for more than 75% of its consumption. The recovery for Oil Refining during 1979-1985 is partly offset by declines in the other subperiods.

Figure 2 syntheses the Mahalanobis distances of total productivity and the Mahalanobis distances of annual rate of total productivity change over the entire period under examination. Sectors Oil refining [8], Other Manufacturing [16], Iron & Steel [11], Rubber & Plastics [9] and Electrical Machinery [14] are those with the higher overall productivity and at the same time larger annual rate of productivity change. Although Wood & Furniture [5] and Utilities [17] show high productivity they do not have significant productivity changes.

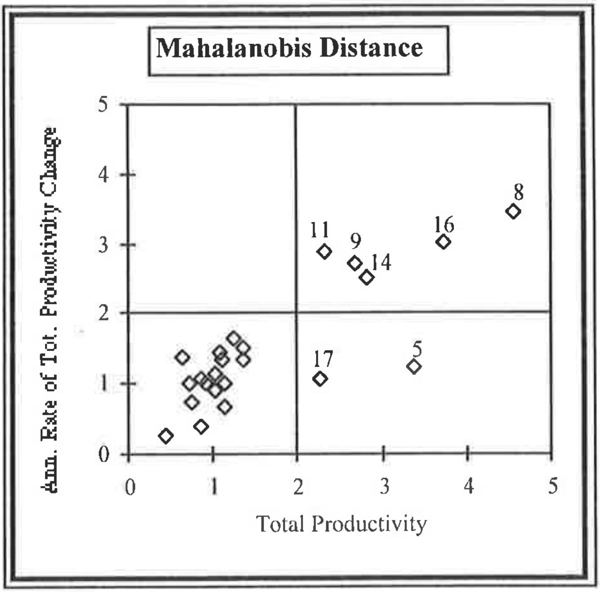

Figure 2

The decomposition of *average annual rate of productivity change* into the two aspects that contribute to productivity, *output expansion* and *labor reduction*, shows that all sectors show significant gains in average annual rate of productivity change with respect to output expansion, but not to labor reduction (*negative results*). While Electrical Machinery [14] for example had the highest change in productivity due to output expansion, it had the second largest reduction in productivity rate due to labor increase. Utilities [5], although the third highest sector in terms of productivity and the forth sector in terms of average annual rate of productivity change due to output expansion, indicates the highest (negative) rate of change in labor increase.

Figure 3 summarizes average annual rate of productivity change of output expansion and labor reduction in terms of their Mahalanobis distance. All sectors do not indicate employment reduction as a source for productivity change for the period 1973-1990, with the exception of Agriculture [1] for the first two subperiods and Mining [2] and Food & Beverage [3] for the last subperiod. The sectors with the most output expansion are Electrical Machinery [14] and Other Manufacturing [16], while those with the largest change in employment are Rubber and Plastics [9] and Oil Refining [8].

Figure 4 provides a different view of the above picture, focusing on the annual average change of the labor productivity rates for the entire period under examination. Data of the labor productivity rates and not the Mahalanobis distance based upon them are sorted in this picture from the largest to the smallest overall annual average change in the labor productivity rate.

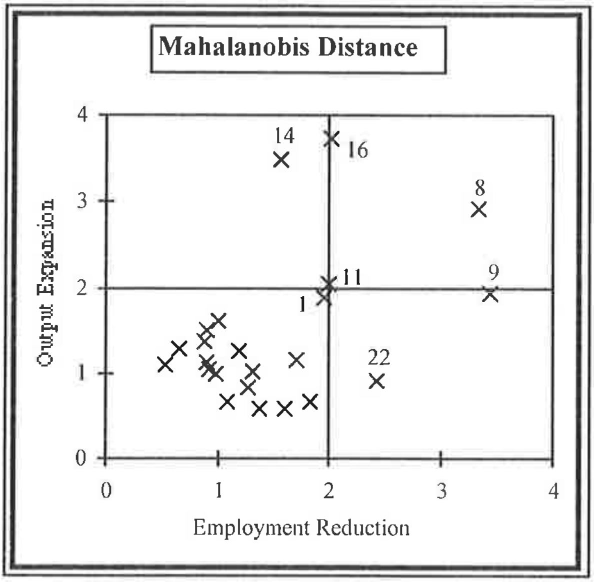

Figure 3

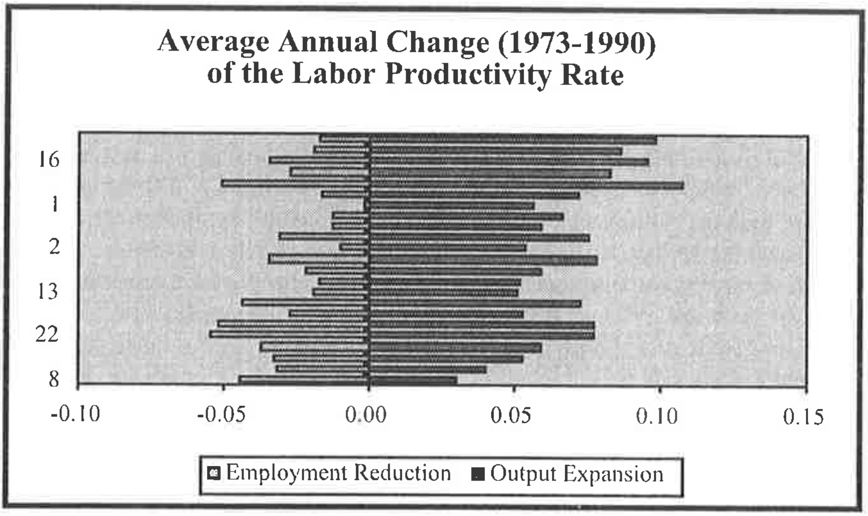

Figure 4

The three general results of our step-wise type of analysis are as follows: Firstly, dominant sectors in the economy in terms of gross output and employment are not necessarily high productive sectors. Secondly, dominant sectors in terms of productivity (π) in selected years are not necessarily leading in productivity changes (Λ). Thirdly, sources of both productivity rates and productivity changes might not be the same for the sectors. Depending on their significant roles as purchasers and/or sales of intermediate inputs and/or as final use suppliers and/or value added generators, sectors have differing impacts in the dynamics of the production system.

The findings of previous research on Turkish productivity are not directly comparable to this study (e.g., Aydogus, 1990; Eser and Eser, 1995; Günlük-Senesen, 1998; Özmucur and Karatas, 1990; Senesen and Erol, 1995; Yildirim, 1989). It should be noted that a general increase of productivity in the economy is observed, mainly due to the increased capacity utilization in the post-1980 era, with a downward investment trend, mainly in public investments. Findings of Karakayali (1995) regarding total factor productivity change in the post 1980 era show that Oil Refining, Iron & Steel, Rubber & Plastics and Electrical Machinery are significant sectors, Oil Refining being the most significant. The relationships of total productivity with scale, capital per worker and exports are found to be insignificant. A tentative conclusion then would be that the export-promotion era has had little impact on productivity, investment being stagnant, while increased labor productivity might be considered as a very significant contributing factor in productivity.

The Turkish production system is highly import dependent in intermediate inputs besides oil. A foreign exchange bottleneck hit the production system very severely as was observed in 1979. The post-1980 period is marked by accumulated foreign debt. This phenomenon then calls for an examination of productivity focusing on the contribution of imports. Such research would also facilitate an evaluation of the performance of the import substitution policies.

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