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Linkages of forestry and forest industry in the Finnish economy

Olli Haltia & Markku Simula

TIIVISTELMÄ: METSÄ- JA PUUTALOUDEN KYTKENNÄT SUOMEN KANSANTALOUDESSA

Haltia, O. & Simula M. 1988. Linkages of forestry and forest industry in the Finnish economy. Tiivistelmä: Metsä- ja puutalouden kytkennät Suomen kansantaloudessa. Silva Fennica 22 (4): 257–272.

The purpose was to analyze the importance of forestry and forest industry in the Finnish economic development since the 1950s, and to find out how the sector has contributed to the growth of the national economy through other sectors. Data were derived from the input-output tables for 1959, 1970 and 1980. Information provided by Hirschmanian linkages was expanded by taking into account e.g. induced, consumption, final demand and absorption linkages. The linkages of forestry and forest industry had multiplied during the study period. Both final demand linkages and intermediate product linkages were significant. The sector's contribution to the development of metal and machinery and equipment industries as well as that of energy/water supply was significant. Integration with most other sectors has increased. Indirect production coefficients of forestry and forest industry were larger than on average in manufacturing. Because of labour productivity growth, production and employment coefficients were different.

Tarkoituksena oli analysoida metsä- ja puutalouden merkitystä Suomen taloudellisessa kehityksessä 1950-luvun jälkeen sekä selvittää, miten toimialan vaikutus kansantalouden kokonaistuotannon kasvuun on tapahtunut muiden toimialojen kautta. Aineiston muodostivat vuosien 1959, 1970 ja 1980 panos-tuotostaulut. Hirschmanilaisten kytkentämallien informaatiota laajennettiin ottaen huomioon mm. indusoidut, kulutus-, lopputuote- ja absorptiokytkennät. Metsä- ja puutalouden kytkentöjen todettiin kasvaneen moninkertaisiksi. Sekä lopputuote- että välituotekytkennät osoittautuivat merkittäviksi. Metsä- ja puutalouden vaikutus on suuri ainakin metallien, metallituotteiden ja koneiden valmistuksen sekä energian ja veden tuotannossa. Integraatio useimpiin muihin toimialoihin on lisääntynyt. Metsä- ja puutalouden välilliset tuotantokertoimet ovat suurempia kuin tehdasteollisuudessa yleensä. Työn tuottavuuskehityksen vuoksi tuotanto- ja työllisyyskertoimet poikkesivat toisistaan.

Key words: input-output analysis, sectoral growth, employment
ODC 906+79+961

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List of symbols

A	input-coefficient matrix of $(n \times n)$
B	$= (I-A)^{-1}$ Leontief's inverse matrix of $(n \times n)$
B^m	MMC-matrix
B^P	$= B-B^m$; inverse matrix that excludes effects of forestry and forest industry to other sectors
E_1	total output vector of $(n \times 1)$ induced by f^m between years 0 and t
E_2	total output vector of $(n \times 1)$ induced by B^m between years 0 and t
$E_1{}^C$	consumption endogenized E_1
$E_2 1^C$	consumption endogenized E_2
f	final output (final demand) vector of $(n \times 1)$
f^f	vector of final output of forestry and forest industry of $(n \times 1)$
f^m	vector of final output induced by forestry and forest industry of $(n \times 1)$
f^P	vector of final output induced by other sectors than forestry and forest industry
l	direct labor coefficient vector of $(1 \times n)$
l^f	direct labor coefficient vector of forestry and forest industry of $(1 \times n)$
M	Leontief's inverse matrix of $(n-1) \times (n-1)$, obtained by removing the row and the column of a given sector j from A

1. Introduction

Various theories have emerged since the 1950s to establish the role of a particular branch in economic development. The emphasis of intersectorial linkages is common in all of them.

The role of forestry in economic development has been the subject of extensive research. Westoby (1962) suggested that in forest-rich countries the linkage effects of the forestry sector are larger than average. He assumed that backward linkages of forestry were probably limited as labour would be the main input needed. On the other hand, forward linkages should be large if roundwood production is processed locally, as forest industry requires substantial inputs from the other sectors of the economy. This assumption has guided many countries to develop their forest industries. Forestry was seen as an economic activity which could bring along development in other sectors as has happened e.g. in the Nordic countries (cf. Riihinen 1981). In the late 1970s Westoby's theory has been criticized, even by the proposer himself (Westoby 1978). The criticism has, however, been more directed at the implementation rather than at the theory itself.

The earlier research on forestry in development has mainly been based on input-output analysis (e.g. Hughes 1970; Seppälä 1976; Connaughton & McKillop 1979; Flick et al. 1980; Schooley & Jones 1982; Schallau & Maki 1983; Saavalainen et al. 1984; Maa- ja metsätalous . . . 1986).

Riihinen (1984) studied the role of forestry in the Finnish economy and presented a quantitative model implicating the sector's significant direct forward linkages.

Staple theory has been applied to explain forestry's role in economic development in Canada (Watkins 1963) and Finland (Palo 1983; Raumolin 1984). Also this school of thought relied on the existence of intersectorial linkages in the explanation of economic development.

From the early 1960s to the 1970s the development strategy of the Finnish economy was largely based on the growth of forestry and forest industry. The sector has been seen important as a source of export earnings and employment, both directly and indirectly (Talousneuvoston . . . 1964). While the share of forestry and forest industry of the total national exports has gradually declined, the sector's linkage effects have been valued as increasingly important (cf. Metsä 2000 . . . 1985).

The purpose of this study is to analyze the importance of forestry and forest industry in the economic development of Finland since the 1950s. In particular, it will attempt to establish how the sector has contributed to the growth of national economy through other sectors and how this contribution has changed over time. The main objective is to estimate policy coefficients to measure the multiplicative effects of forestry and forest industry.

Theories dealing with linkage effects are first briefly reviewed as measurement has often been hampered by methodological problems. A suitable method is then proposed. After the review of data, the results are presented by branches. The presentation is an abridged version of Haltia (1987).

2. Measuring linkage effects

2.1 Hirschmanian linkages

Hirschmanian (1958) backward and forward linkages have at least implicitly served as the basis for research on a sector's production and employment effects. Backward linkages refer to input demand and forward linkages to supply of intermediate goods. Total production grows as this increase of producer goods induces intermediate production elsewhere in the economy.

Direct and indirect linkage effects can be measured by Leontief's (1941) inverse matrix. In the simplest case, its column sum has been used as an indicator of backward linkages. Even though forward and backward linkages are included in Leontief's inverse matrix (Jones 1976, 325), the column sum does not incorporate all of them.

The index method by Chenery and Watanabe (1958) was originally developed for international comparison of productive structure but it has also been used for estimating forward and backward linkages. The former was derived as the ratio between the volume of the intermediate goods produced by a sector and its total production. Backward linkages were expressed as the ratio between the demand for intermediate goods of a sector and its total input demand. These indices, which can also be derived for employment, exclude part of linkage effects (Nugent and Yotopoulos 1973, 161) and they suffer from the causality problem (Jones 1976, 324).

Rasmussen (1958) expanded Hirschman's linkages introducing their dispersion effects which are essential also in this study. On the other hand, Rasmussen's indices are technological by character ignoring the effect of changes in other variables (income and employment) and linkages in final demand (Diamond 1974). Furthermore, Rasmussen's index of forward linkages does not sufficiently indicate what happens in the other sectors when the output of a sector changes.

The output approach developed by Ghosh (1958) and Augustinovics (1970) has been suggested to complement the traditional input approach based on the inverse matrix. The method does not, however, allow estimating changes and reasons for them (Cella 1984, 77–78).

Strassert (1962) and Schultz (1977) tried to improve possibilities to analyse causality but they did not separate backward and forward linkages. Their method (fiktive Produktionseinstellung) compared the actual situation to an economy where the sector under study and its influence on the other sectors was eliminated. Based on their work, Meller and Marfan (1981) presented the total linkage model which included the output of the sector under study in the total linkage. They were also able to divide the total linkage into its components. The third contribution of their model was the possibility to express linkages as absolute volumes, not only as indices. Cella (1984) improved the model by breaking the total linkage into backward and forward linkages and presented explicit formulas to estimate them.

The Meller-Marfan-Cella (MMC) model had the following advantages:

(i) total linkage can be explicitly divided into backward and forward linkages
(ii) the model's total linkage does not include the feedback multiplicative effects of the sector
(iii) the dispersion of linkage effects can be measured by sector which is important for policy-oriented research.

2.2 Consumption linkages

In Leontief's model private consumption is exogeneous. It can, however, be treated as endogeneous which will incorporate the Keynesian multiplicative effects of consumption.

Changes in final demand can be analyzed by means of a linear expenditure model where both the internal multiplier effects of production and the multiplier effects between production and consumption are taken into account (Stone 1954; Forssell 1985).

The Meller-Marfan-Cella model with consumption as an endogeneous variable was presented by Haltia (1987).

2.3 Other final demand linkages

Production increase of forestry and forest industry generates demand for investment goods. With Leontief's inverse matrix and a vertical vector representing the sector's demand for investment goods, these linkages as static measures can be established. Their dynamic analysis is possible (Leontief 1970) but necessary data are often lacking.

Demand for such investment goods must reach a certain minimum level before their domestic production becomes profitable. Eventual exports of the investment goods, the production of which has been induced by a sector, can be included in its backward linkage. The linkage can be measured as Leontief's inverse matrix multiplied by the induced exports vector.

If the exports of backward linkage investment goods start to surpass the volume of their domestic demand, or they have reached an important market share regionally or worldwide, it can be questioned to what extent the production of these goods is still induced by the sector which generated the initial backward linkage. *A priori* criteria may be developed but subjective judgement would always be needed is treating such induced exports as part of a sector's linkage. This is a relevant question in Finland where exports of machinery and equipment for forest industry are significant.

3. Method of study

3.1 Dynamic linkage model

Production in year t can be expressed as the production of the earlier year 0 and the respective growth

(3.1) $(I-A_t)^{-1}f_t=(I-A_o)^{-1}f_o+(I-A_o)^{-1}(f_t-f_o)+((I-A_t)^{-1}-(I-A_o)^{-1})f_t$

The input coefficient matrices A and the final demand vectors f are expressed in prices of year t. Two elements, i.e. increase in final demand (f_t-f_o) and technical change $((I-A_t)^{-1}-(I-A_o)^{-1})$, define the increase in total production in fixed prices.

From the fixed-priced formula (3.1) the following dynamic linkage model can be derived (Appendix 1).

(3.2) $B_tf_t= B_of_o+B_o(\Delta f^p+\Delta f^m)+(\Delta B^m+\Delta B^p)f_t$

where B means Leontief's inverse matrix. Upper indices m and p refer to demand increase induced by the forestry sector and all the other sectors, respectively.

If $E_1=B_{t/2}\Delta f^m$ and $E_2=\Delta B^m f_{t/2}$ the total linkage of the forestry sector (DITL) in year t can be written

(3.3) $DITL_t=DITL_o+E_1+E_2$, $(E_{i1}, E_{i2}\geq 0, i=1, \ldots, n)$

The total linkage includes Hirschmanian forward and backward linkages (both in E_1) as well as final demand linkages (E_2). The multiplicative effects cannot be assumed symmetric when production increases or decreases and therefore, the condition ($E_{i1},E_{12} \geq 0, i=1, \ldots, n$) is needed. This means that linkages E_1 and E_2 in individual sectors (i) cannot be negative. It is implicitly assumed that the other sectors do not reduce their output because of changes in the input-output technology of forestry and forest industry.

When the forestry sector's domestic demand and supply are met by imports, the respective Leontief's inverse matrix is denoted by M. If, as in (3.3), it is assumed that input coefficients and final demand change linearly in period 0−t, the absorption effects of forestry and forest industry are

(3.4) $ATL_t=ATL_o+M_{t/2}E_1+M_{t/2}E_2$, $(E_{i1}, E_{i2}\geq 0, i=1, \ldots, n)$

The absorption effect ATL represents the production gaps or the difference between the actual output in year t and the respective hypothetical output if the forestry sector were inexistent.

Analogous production-consumption formulas can be written

(3.5) $DCITL_t=DCITL_o+E_1^C+E_2^C$, $(E_{i1},E_{i2}\geq 0,i=1, \ldots, n)$

(3.6) $CATL_t=CATL_o+M_{t/2}^C E_1^C+M_{t/2}^C E_2^C$, $(E_{i1}, E_{i2}\geq 0, i=1, \ldots, n)$

Analogous formulas of static induced linkages are

(3.7) $ITL_t=B_t^m f_t+B_t f_t^m$

(3.8) $CITL_t=B^C{}_t{}^m f_t+B^C{}_t f^m$

where $B_t^m f_t$ is the MMC model, $B^C{}_t{}^m f_t$ is the consumption endogenized MMC model, and B^C is Leontief's inverse matrix when consumption endogenized.

3.2 Linkages within the forest sector

The input coefficient matrix A is transformed into A' by eliminating the diagonal elements of the forestry sector. The total linkage, where the linkages between individual branches (i . . . m) within the forestry sector are eliminated, is

(3.9) $TL'_x=TL_x(1-\sum_j b'_{xj}/\sum_i \sum_j b'_{ij})$

x refers to the individual branch under study and $b'_{ij} \in (I-A')^{-1}$, $i\neq j$, i and j belong to the forestry sector.

3.3 Indirect coefficients

Hirschmanian production coefficient of the forestry sector is derived as the ratio between respective linkages and the final demand of the forestry sector (f^f).

(3.10) $K_1=\sum_i TL_t/\sum_i f_t^f$

Production-consumption coefficient is

(3.11) $K_1^C=\sum_i CTL_t/\sum_i f_t^f$

where CTL is the consumption-endogenized Hirschmanian linkage or $B^C{}_t{}^m f_t$ in formula (3.8).

The respective employment coefficients are

(3.12) $K_1^l=l_t TL_t/l_t^f f_t^f$

(3.13) $K_1^{lC}=l_t CTL_t/l_t^f f_t^f$

where l is the unit labour vector in year t.

It is possible to establish the respective coefficients where final demand linkage and absorption are included:

(3.14) $K_2=\sum_i ITL_t/\sum_i f_t^f$ (including static induced linkage)

$$(3.15)\ K_3 = \sum_i DITL_i / \sum_i f_i^f \text{ (including dynamic induced linkage)}$$

$$(3.16)\ K_4 = \sum_i ATL_i / \sum_i f_i^f \text{ (including absorption effects)}$$

K_2, K_3 and K_4 can be adjusted to employment coefficients as in formulas (3.12) and (3.13). They can also be expanded to account for consumption multiplier and income effects using the production-consumption models presented in formulas (3.5) and (3.6).

4. Data

The main data of the study were obtained from the input-output studies of the Finnish economy in 1959, 1970 and 1980. The studies can be considered comparable as all of them can be assumed to represent years of full capacity utilization (cf. Forssell 1984).

The original data were aggregated into 21 branches, three of which belonging to the forestry sector (forestry, mechanical wood industry, pulp and paper industry, i.e. SIC 12, 331, 341, respectively). Aggregation was necessary to ensure intertemporal comparability. The current price tables were deflated using the price indices of gross output prepared for this study by the Central Statistical Office of Finland. This ensured that the deflators referred to the input-output sectors of the study.

Household expenditure was estimated by deducting taxes and savings from wages and salaries generated by sector i in year t. Income tax rate and household savings rate were derived from the national accounts. Tax rate was assumed constant in year t. Savings were calculated based on marginal propensity to consume of 0.9 which was estimated for this study. The stability of propensity was established by comparing estimates from periods 1954–1964, 1965–1974 and 1975–1984.

In the production-consumption linkage model, a matrix is needed to link the consumer expenditure generated by sector i and production in sector j. The expenditure coefficients estimated by Svento (1980) for 21 groups of commodities for the period 1960–1980 were used, as sufficient data for new estimation were not available. The share of housing was estimated based on Forssell (1985).

To estimate final demand linkages, the shares of the forestry sector in the total demand of the investment goods by branches (building and construction, transport equipment, machinery and equipment) were established. Data were derived from the unpublished series of the Central Statistical Office.

The second element of the final demand linkage were exports of machinery and equipment for forestry and forest industry. The data were derived from the official foreign trade statistics by individual commodity.

Labour input was measured as a flow measure, i.e. hours paid, using the national accounts data.

5. Results

5.1 Production linkages

5.1.1 Hirschmanian linkages

In 1959 and 1970, the total linkage of forestry and forest industry in the other sectors was about 3 % of the total output calculated based on the 1959 final demand. In 1980, the share reached 4.3 %. Linkage effect has increased almost in all sectors in the 1970s which is a result of higher capital intensity (Simula 1979, 173). In 1959 transportation and energy/water supply accounted for about 55 % of the total linkage of the forestry

Table 1. Sectoral distribution of Hirschmanian total linkage of the forestry sector based on the 1959 final demand (per cent).

	1959	1970	1980
Agriculture, fishery	11.8	3.2	1.3
Mining and quarrying	1.2	0.8	1.2
Consumer goods	1.4	1.6	2.5
Printing, Publishing	0.3	3.4	2.3
Ind. chemicals	6.5	10.6	9.1
Petroleum refineries	1.8	5.1	6.8
Rubber and plastics	0.4	1.1	0.7
Earthenware, glass, stone	0.9	2.2	2.3
Metal	0.7	1.8	3.8
Machinery and equipment	1.3	6.2	7.5
Electrical appliances	0.3	1.4	1.8
Transport equipment	2.6	0.8	0.9
Electricity, gas, water	26.2	33.6	31.4
Building & construction	3.6	2.5	2.1
Wholesaling and retailing	4.1	5.1	4.6
Transportation	29.4	12.5	11.7
Communication	1.0	1.2	1.1
Services	6.5	6.9	9.1
Total	100.0	100.0	100.0
of which			
–forward	41.0	57.0	49.0
–backward	59.0	43.0	51.0

sector, while in 1980 the respective figure was only 43 %. This has been compensated by the increased shares of chemicals, oil and petrochemicals, machinery and equipment, and services (Table 1). These changes have been associated with trends in the product mix and the degree of conversion of forest industry.

In 1959, 59 % of the total linkage was backward and 41 % forward effects. In 1970 the respective figures were reversed, i.e. 43 % and 57 %. Technical change in the other sectors had favoured forest products as intermediate inputs. In 1980 the share of backward effects of the total linkage had again increased to 51 % which can be interpreted as an indication of accelerated technical change in forest industry.

The comparison of results calculated based on the 1959 final demand and the current-year final demand revealed that the growth and structure of final demand have not significantly influenced the sectoral distribution of backward and forward linkages even though their shares of total linkage have changed. The share of backward linkage would have dropped less in 1959–1970 and increased more in 1970–1980 than indicated above, had the current-year final demand been used.

The growth of forestry and forest industries was more rapid than the economy average in the 1960s but since 1970 it has been slower than average. Rapid output growth in the 1960s compensated the declining share of backward linkage while the final demand of the other sectors has fostered forward linkages in the 1970s. The rate of increase of capital intensity was apparently higher in the other sectors than in forestry and forest industry in the 1960s, while in the 1970s, the situation was reverse. Furthermore, the investments implemented after the 1967 devaluation were fully utilized only in the 1970s because of the time lag between mill construction and full production.

5.1.2 Induced linkages

Induced linkages include Hirschmanian and final demand linkages. In forestry and forest industry they accounted for 7.0 % of total production in 1959 increasing to 7.3 % in 1970 and further to 7,8 % in 1980. The growth contributions of technical change and induced final demand (E_1 and E_2 in formula 3.3) were (%)

	Technical change	Induced final demand
1959–70	22	78
1970–80	65	35

Technical change here refers to the net effect of forestry and forest industry and its interaction with the other sectors but it excludes changes in Leontief's inverse matrix generated by mutual effects of the other sectors. The direct and indirect contribution of forestry and forest industry in the total growth of the Finnish economy were 23 % in 1959 and 17 % in 1970–1980.

The importance of technical change has clearly increased since the mid–1960s which

Table 2. Static induced linkages of the forestry sector in selected sectors (per cent of their gross production).

	1959	1970	1980
Mining and quarrying	19.2	13.9	16.1
Printing, publishing	0.5	6.3	5.4
Ind. chemicals	9.4	15.7	13.8
Petroleum refineries	16.5	10.7	9.2
Rubber and plastics	5.0	4.8	6.4
Metal	29.6	14.3	12.9
Machinery and equipment	69.8	46.3	29.0
Electrical appliances	3.1	6.6	6.8
Transport equipment	42.3	29.0	28.3
Electricity, gas, water	5.1	5.5	3.5
Transportation	13.0	8.4	9.4
Services	1.3	1.7	3.3

has been associated with extensive investments. Exports of machinery for forestry and forest industry also rapidly increased so that in the 1970s they accounted for 60 % of the growth of induced final demand. Part of export growth may have been motivated by the slowing growth of domestic demand for investment goods.

Staple theory obtains other support from Table 2. In spite of increasing absolute linkage between the forestry sector and the rest of the economy, the dependence in relative terms has clearly reduced in such branches as machinery and equipment, metals, and energy/water supply. On the other hand, in printing and publishing, chemicals, electrical appliances, and private services, also the relative importance of the forestry sector's induced linkage has increased. Part of the activities which were earlier implemented as industrial operations have been transferred to other sectors and appear now as purchased inputs. For instance, maintenance, cleaning and guarding have been transferred from the industry to the service sector in many mills.

Forestry and forest industry are more and more extensively integrated with other domestic production. Moreover, linkage effects have particularly strengthened in the high-growth sectors such as electrical appliances and services.

Correlation between changes of the sectoral structure of the Finnish economy and the linkage effects of forestry and forest industry was tested by Spearman's rank correlation coefficient and Pearson's variation coefficient. In the 1960s, rank correlation was higher and variation was smaller than in the 1970s. This supports the assumption that the earlier national development strategy with emphasis on forestry and forest industry resulted in a relatively balanced growth. In the 1970s, when no such strategy can be observed, the growth of the other sectors as a whole was less associated with the forestry sector. It is emphasized that the tests are no more than indicative by nature in spite of the good statistical validity.

5.1.3 Absorption effects

Absorption effects (Table 3) were calculated as the difference betweeen the actual total production and that without the forestry sector (formula 3.4). They are *a priori* large for branches with large induced effects in 1959 when, by definition, absorption and induced effects are identical. Absorption is defined as the difference between absorption effects and static induced linkage.

Table 3. Absorption effects (ATL) and absorption (AB) of the forestry sector in selected sectors (per cent of their gross production).

	1959	1970		1980	
	ATL	ATL	AB	ATL	AB
Mining and quarrying	19.2	41.6	27.7	47.3	31.2
Petroleum refineries	16.5	13.2	2.5	11.8	2.6
Metal	29.6	38.2	23.9	25.5	12.6
Machinery and equipment	69.8	46.3	0.0	29.5	0.5
Electrical appliances	3.1	7.1	0.5	7.1	0.3
Electricity, gas, water	42.3	33.9	4.9	37.7	9.6
Transportation	13.0	22.2	13.8	18.7	9.3

Petroleum refining has become less dependent on the forestry sector. The declining absorption effects suggest the sectoral final demand has been growing faster than demand for its intermediate goods. On the other hand, forestry and forest industry have lost their direct linkage in this sector in the 1970s as absorption slowly increased. In transportation, the development was reverse: both the share of absorption effects and absorption have declined in 1970–1980.

Machinery and equipment production has also become less dependent on forestry and forest industry both through other sectors and induced effects. In energy/water supply, the forestry sector has had an increasing effect through linkages via other sectors. The impact on mining has been strong through machinery and equipment production. The linkage between forestry sector and the production of electrical appliances has also increased more than average.

As a whole, the absorption effects of forestry and forest industry in 1970 accounted for 10.0 % of the total production of the other sectors while absorption was 2.7 %. The respective figures in 1980 were 10.9 % and 3.1 %. This can be interpreted as an indication of higher sectoral interdependence of the Finnish economy.

5.2 Production-consumption linkages

Hirschmanian static production-consumption linkages in the other sectors (the first term in formula 3.8) were 4.5 times the production multiplier-based linkage of forestry and forest industry (cf. ch. 5.1.1). The respective figures in 1970 and 1980 were 3.2 and 2.0. The decline of the importance of consumption linkages can be explained by drop in labour's factor share and gross margin of forest owners based on input-output data (cf. Ovaskainen 1986). Together with slower than average sectoral growth rate and the increased direct tax rate, the relative importance of direct disposable income generated by the forestry sector has reduced in the Finnish economy.

Compared to production multiplier, consumption multiplier of forestry and forest industry appears to have raised the level of linkage rather than accelerated intertemporal production change. The growth contributions of the dynamic consumption linkage model (formula 3.5) and induced final demand were (%)

	Production-consumption multiplier	Induced final demand
1959–70	6	94
1970–80	36	64

The direct and indirect contribution by the forestry sector of the total growth of the Finnish economy dropped from 34 % to 19 % in the same period. In the 1970s, accelerated technical change compensated the declining production-consumption multiplier (cf. ch. 5.1.2).

5.3 Production coefficients

Production coefficients indicate how much production is generated in the other sectors as a result of unit change in the sectoral final demand of forestry and forest industry (Table 4). The internal and mutual multiplier effects of the forestry sector's individual branches have been eliminated (column 1 in Table 4). The coefficients have also been calculated as net effects created by the forestry sector (column 2). (C)TL indicates how much output is generated by the sector through its demand for and supply of intermediate goods per output unit.

(C)ITL is the total production linkage when the multiplier effects of induced final demand have been included. D(C)ITL indicates how much forestry and forest industry have increased total production per their sectoral final demand unit since 1959. In (C)ATL absorption has been added. C refers to the inclusion of consumption multiplier.

Table 4. Production coefficients of the forestry sector.

	1959		1970		1980	
	1	2	1	2	1	2
Production coefficients (K)						
TL	0.68	0.39	0.80	0.40	1.06	0.64
ITL	1.07	0.77	1.22	0.80	1.42	0.99
DITL		0.77		0.86		1.00
ATL		0.77		1.09		1.38
Production-consumption coefficients (KP)						
CTL	2.28	1.96	1.62	1.27	1.61	1.27
CITL	2.92	2.57	2.15	1.82	2.07	1.72
DCITL		2.57		2.47		2.32
CATL		2.57		3.80		3.84

1– the internal and mutual effects of the forestry sector's individual branches are eliminated
2– net effects in the other sectors

Marginal absorption indicating change in absorption (AB) in relation to change in final demand is defined as follows:

(5.1) $\delta AB/\delta f^f = \delta ATL/\delta f^f - \delta ITL/\delta f^f$

f^f refers to final demand of the forestry sector. An increase in absorption implies higher dependence between forestry and forest industry and the other sectors through technical change. ITL depends mainly on the forestry sector's technical change and gross capital formation, while ATL depends on the other sectors' technical change through growth effects of the forestry sector. The more extensive absorption, the stronger effect the forestry sector has on the output of the other sectors. Marginal absorption (AB) was also estimated taking consumption multiplier (CAB) into account:

	1959–1970	1970–1980
$\delta AB/\delta f^f$	0.65	0.71
$\delta CAB/\delta f^f$	4.53	2.39

Technical change has increased the forestry sector's absorption effects while consumption multiplier has reduced them. The latter can be explained by slower growth of disposable income compared to gross value of production (cf. Ovaskainen 1986, 13).

Production coefficients can duly be evaluated only if they can be compared to other sectors. In Appendix 2 Hirschmanian forward, backward and total linkage coefficients have been presented for the other manufacturing sectors calculated per a common unit, in this case per a final demand unit of the forestry sector.

Production coefficients of forestry and forest industry are higher than in the other manufacturing sectors excluding consumer goods industries.

Production (total linkage) coefficients of most manufacturing sectors have increased. In general, backward linkages have grown faster than forward linkages in the 1960s, while in the 1970s, the importance of the latter has increased. This can be interpreted as an indication of improved possibilities for intensive growth in the economy as a whole.

It is emphasized that there are other production chains comparable to the forestry sector, such as e.g. agriculture and food industry, mining and metal industry, which would deserve an analogous treatment in sectoral comparisons. On the other hand, the economic benefits of these production chains are influenced by subsidies and overproduction in agriculture, and extensive import inputs in metal industry.

Table 5. Employment coefficients of the forestry sector.

	1959		1970		1980	
	1	2	1	2	1	2
TL	1.20	0.79	1.12	0.66	1.58	1.10
ITL	2.73	2.30	1.95	1.47	2.32	1.82
DITL		2.30		1.76		1.97
ATL		2.30		2.18		2.67
CTL	5.10	4.66	3.50	3.19	3.61	3.20
CITL	7.25	6.76	4.78	4.44	4.67	4.25
DCITL		6.76		6.67		6.76
CATL		6.76		10.76		11.48

1– the internal and mutual effects of the forestry sector's individual branches are eliminated
2– net effects in the other sectors

5.4 Employment coefficients

The employment coefficients presented in Table 5 are analogous to production coefficients. Apart from output changes, the employment coefficients are influenced by labour productivity. In forestry and forest industry, growth in labour productivity has been more rapid than on average in the Finnish economy.

Hirschmanian employment coefficient (TL) in the forestry sector has increased in 1959–1980. If induced final demand (ITL) is taken into account, the coefficients declined indicating that induced effects have primarily taken place in sectors with high growth in labour productivity. If absorption is included (ATL), employment coefficient has increased during the study period, as labour productivity in the forestry sector has grown faster than in the other sectors. The intertemporal negative effect of income multiplier can be observed in the respective consumption-endogenized employment coefficients which was also present in production-consumption linkages (ch. 5.2).

The exceptionally low indirect employment coefficients in 1970 may be explained by the rapid growth of forestry's final demand which was substantially higher than that of labour productivity.

The same hold true in pulp and paper industry while in mechanical wood industry the difference is less significant. The result has been an increase in direct employment effects while the 1970 indirect coefficient has remained lower than in 1959 and 1980.

6. Discussion

The development strategy of the Finnish economy in the 1960s emphasized investment in forest industry as a source of foreign exchange and growth in other sectors. Based on Hirschmanian linkage criteria, this appears to have been justified as the forestry sector's forward and backward linkages were larger than average in manufacturing. This is an indication of the importance of intermediate products in the sector's inputs and outputs. Furthermore, the sector's positive impact on the current account has been significant.

It was concluded that the linkage effects of the forestry sector are more important than in other manufacturing excluding consumer products. The comparison was made for 11 branch aggregates and more detailed calculations could reveal other individual branches with high linkages.

The shares of backward and forward effects in the sectoral total linkage have not developed trendwise in forestry and forest industry. The rate of output growth and its product pattern influence the distribution of effects. These factors have to be analyzed together and the years of observation have to be seen in the context of sectoral production development.

Induced linkages were estimated both as static and dynamic measures. Investments (included in E_2 in formula 3.3) are an essential element determining the sector's growth effects. It appears that investments' influence on technical change (E_1 in formula 3.3) is lagged but the statistical evidence cannot be established with the available data.

Static induced effects suggested that forestry and forest industry have played an important role in the development of such branches as metal industry, machinery manufacturing, and energy/water supply. In 1980, still about a third of the total output in these sectors was induced by forestry and forest industry. This share has, however, had a declining trend since 1959. On the other hand, the linkage effect, in absolute terms, has multiplied because of volume growth. Of the total induced linkage in 1980, about 65 % was Hirschmanian forward and backward linkage and about 35 % final demand linkage.

Absorption effects suggested that the intersectorial dependence has generally increased in the Finnish economy. This also means that the multiplier effects of output generated by forestry and forest industry in the other sectors, have become larger. Internal transactions within the economy have increased which tends to contribute to final demand linkages and absorption.

The results of this study suggest that the efficiency conditions of similar investment strategy to that in the 1960's have improved because of the increasing integration of forestry and forest industry with the other sectors and the volume growth of intermediate product linkages.

The results presented are subject to the validity of assumptions implied in input-output models (cf. Forssell 1970, 18). Homogeneity cannot be assumed because of aggregation and other reasons (Simula 1983). Aggregation may have at least two channels of influence: its cross-section effect may distort static intersectoral linkages, and it may hide intertemporal changes. To eliminate these sources of error, minimum aggregation was applied to branches with high *a priori* linkages with the forestry sector. Because of the nature of the model, the statistical validity of the results cannot be established.

It should be noted that the compilation of the 1959 input-output table was different from those in 1970 and 1980 (Suomen . . . 1977). This may explain some of the apparent anomalies in production coefficients.

A number of reservations have to be made with regard to the results of the production-consumption model. The branchwise commodity breakdown was assumed constant over the whole study period.

Supply factors had to be ignored in this kind of input-output model where consumption was endogeneous. Demand adjustment was only reflected in volumes, while in reality, it is distributed between volume and price. The production-consumption linkages presented must therefore be interpreted as upper limits of such effects.

It is not easy to compare the results of this study to earlier research as the internal multiplier effects were here eliminated. Indirect or net coefficients including effects only to the other sectors can, however, to some extent be compared.

The latest input-output study on Finland's forestry sector (Maa- ja metsätalous . . . 1986, 119) suggests an implicit employment coefficient of 0.52 indicating how much employment in the other sectors indirectly depends on one employment in the forestry sector. The respective figure modified from the results of this study is 0.74. The difference can be explained by different methodologies and the final demand linkages included in this study.

Comparison to studies by Hughes (1970) and Schooley and Jones (1982) in North America shows differences which can be easily explained by different structures within forestry and forest industry and the economy at large. In Finland, the sector's importance is significantly larger than in the United States. The main methodological difference is that in this study all the coefficients were weighted by sectoral final demand. The coefficients estimated in North America consequently reflect less their real values.

There are at least three avenues to explore in future research. First, a suitable modification of the output matrix could provide additional information on the sectoral dispersion of Hirschmanian *ex post* total linkage. Secondly, the approach could be applied to estimate the net balance-of-payment effects of forestry and forest industry. Finally, comparative international research using the same methodology would yield more general information on the role of forestry and forest industry in economic development. In such research, the countries could represent different typical situations with regard to resource endowment, the relative importance of forestry and forest industry in the economy, and the level of economic development.

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Appendix 1. Derivation of dynamic linkage model.

If fixed price Leontief models in years t and 0 are expressed

$$B_t=(I-A_t)^{-1}$$
$$B_o=(I-A_o)^{-1}$$

we obtain by partitioning the following MMC-matrices for two-sector economy

$$B_t^m= \begin{bmatrix} H^t-B_{11}^t & H^tA_{12}^tB_{22}^t \\ B_{22}^tA_{21}^tH^t & B_{22}^tA_{21}^tH^tA_{12}^tB_{22}^t \end{bmatrix}$$

$$B_o^m= \begin{bmatrix} H^o-B_{11}^t & H^oA_{12}^oB_{22}^o \\ B_{22}^oA_{21}^oH^o & B_{22}^oA_{21}^oH^oA_{12}^oB_{22}^o \end{bmatrix}$$

where $H = (I-A_{11}-A_{12}\,B_{22}A_{21})^{-1}$
and $B_{22} = (I-A_{22})^{-1}$

Because $B_t=B_t^m+B_t^P$ we can write matrix equations for B^P in years t and 0

$$B_t^P= \begin{bmatrix} B_{11}^t & 0 \\ 0 & B_{22}^t \end{bmatrix}$$

$$B_o^P= \begin{bmatrix} B_{11}^o & 0 \\ 0 & B_{22}^o \end{bmatrix}$$

Final demand can be written

$$f_t= \begin{bmatrix} f_1^t \\ f_2^t \end{bmatrix}$$

$$f_t^P= \begin{bmatrix} f_1^t \\ f_2^t \end{bmatrix} - \begin{bmatrix} f_1^{m\,t} \\ f_2^{m\,t} \end{bmatrix}$$

Final demand induced by forestry and forest industry in year t can now be expressed as

$$\begin{bmatrix} f_1^{m\,t} \\ f_2^{m\,t} \end{bmatrix} = f_t^m$$

The respective final demand in year 0 is

$$f_o= \begin{bmatrix} f_1^o \\ f_2^o \end{bmatrix}$$

$$f_0^P= \begin{bmatrix} f_1^o \\ f_2^o \end{bmatrix} - \begin{bmatrix} f_1^{m\,o} \\ f_2^{m\,o} \end{bmatrix}$$

and $\begin{bmatrix} f_1^{m\,o} \\ f_2^{m\,o} \end{bmatrix} = f_o^m$

Differences between years 0 and t can be expressed as

$$\Delta B^m=B_t^m-B_o^m$$
$$\Delta B^P=B_t^P-B_o^P$$
$$\Delta B=B_t-B_o=\Delta B^m+\Delta B^P$$
$$\Delta f^m=f_t^m-f_o^m$$
$$\Delta f^P=\Delta f-\Delta f^m$$
$$\Delta f=f_t-f_o=\Delta f^P+\Delta f^m$$

The dynamic linkage model can now be written as follows

$$B_tf_t=B_of_o+B_o\Delta f+\Delta Bf_t$$
$$=B_of_o+B_o(\Delta f^P+\Delta f^m)+(\Delta B^m+\Delta B^P)f_t$$

Appendix 2. Production coefficients per final demand unit of the forestry sector in selected sectors.

	1959 BL	1959 FL	1959 TL	1970 BL	1970 FL	1970 TL	1980 BL	1980 FL	1980 TL
Forestry sector	0.40	0.28	0.68	0.38	0.42	0.80	0.57	0.49	1.06
Consumer goods	0.17	1.35	1.47	0.25	1.13	1.38	0.32	1.08	1.40
Printing, publishing	0.09	0.08	0.17	0.15	0.14	0.27	0.19	0.20	0.39
Ind. chemicals	0.22	0.09	0.31	0.17	0.11	0.27	0.23	0.23	0.46
Petroleum refineries	0.05	0.02	0.07	0.17	0.02	0.19	0.28	0.04	0.32
Rubber and plastics	0.02	0.01	0.03	0.07	0.02	0.09	0.05	0.05	0.10
Earthenware, glass, stone	0.08	0.08	0.16	0.26	0.09	0.35	0.20	0.14	0.33
Metal	0.10	0.06	0.16	0.15	0.09	0.24	0.29	0.17	0.46
Machinery and equipment	0.05	0.06	0.11	0.20	0.21	0.40	0.28	0.43	0.71
Electrical appliances	0.05	0.06	0.11	0.07	0.08	0.15	0.13	0.11	0.24
Transport equipment	0.09	0.07	0.16	0.03	0.03	0.06	0.04	0.19	0.24

BL = backward linkage
FL = forward linkage
TL = total linkage (Hirschmanian)

Appendix 3. Sectoral SIC-codes

	SIC-code		SIC-code
Forestry sector	12, 331, 341	Machinery and equipment	381, 382
Agriculture, fishery	111, 112, 13, 113	Electrical appliances	383, 385
Mining and quarrying	23, 29	Transport equipment	384
Consumer goods	31, 32	Electricity, gas, water	41, 42
Printing, publishing	342	Building & construction	51, 52
Ind. chemicals	351, 352	Wholesaling and retailing	61, 62, 63
Petroleum refineries	353, 354	Transportation	71
Rubber and plastics	355, 356	Communication	72
Earthenware, glass, stone	332, 36, 39	Services	81, 82, 83, 92, 93, 94, 95
Metal	37		