STRUCTURAL CHANGE, INTERSECTORAL LINKAGES AND HOLLOWING-OUT IN THE TAIWANESE ECONOMY, 1976 - 1994

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February 2003

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Abstract

This paper analyses structural change in the Taiwanese economy over the period 1976-1994 using a series of input-output tables. Unlike other studies of structural change this analysis investigates the evolving internal complexity of intersectoral interdependencies using Key Sector Analysis which gauges the strength of forward and backward linkages, and the recently developed method of Minimal Flow Analysis which gauges the degree of connectivity of the system. This analysis indicates that there has been a "hollowing-out" of the Taiwanese economy as the density of intersectoral linkages has declined since the early 1980s, similar to what has been observed of the US and Japanese economies at a much later stage of their development.

Key Words: Taiwan, structural change, input-output analysis, Key Sector Analysis, Minimal Flow Analysis, hollowing-out

JEL Classification: O10; O14.

1. INTRODUCTION

It has long been recognised by economists that the process of economic development requires significant structural change. The study of economic structure can take many paths. At a superficial level, we can observe how key macroeconomic indicators change over time. But there is more to the study of structural change than observing changes in macroeconomic indicators, although these do provide a background within which more complex processes of internal evolutionary economic interdependence reside. Over time we would expect economic growth and development to coincide with increasing internal complexity and perhaps durability. To observe this, we need to delve into the internal organisation of the economy.

Taiwan, one of the East Asian miracle economies (World Bank [44]), developed rapidly from an agrarian society at the time of its takeover in 1949 by the Chinese Nationalists, into a modern industrial economy, with the 1960s generally considered the period of 'take off'. The Taiwanese government has provided much in the way of readily accessible and reliable statistical data concerning its process of economic development which also renders its development experience more amenable to rigorous analysis and hypothesis testing.

The most common approach to analysing structural change revolves around the concept of connectedness, which is a measure of how the economy 'churns', and the mechanisms involved in this process. Studies of connectedness invariably involve the use of interindustry models. The need to understand intersectoral linkages has been recognised in the context of the literature on structural change associated primarily with the work of Chenery and others [12; 36; 37].

A special case of an interindustry model is the input-output (IO) model, which documents the production and disposal of the goods and services in an economic system for a particular period (usually one year). It provides a very detailed picture of the structure of the economy and a basis for the analysis of the intersectoral relationships.[1] The input-output model can be viewed as an equilibrium construct at a point of time, and the study of structural change involves identifying how this equilibrium shifts over time. Traditional input-output analysis is often used to analyse

[1] See, for example, Miller and Blair [27] for a comprehensive discussion on input-output models.

structural change among economies at different stages of development. Attention has been given primarily to the analysis of changes in the structure of (domestic) demand, final and intermediate, and of international trade, which together determine changes in the overall structure of production. The use of an input-output framework moves economists away from a cursory examination of broad macroeconomic aggregates, and on to a detailed analysis accounting for the inter-connectedness of an economy's many different sectors. Also the framework ensures that the economist accounts for the technology of production, and not simply for demand factors.

Despite the regular construction and publication of IO tables for Taiwan by the Directorate General of Budget, Accounting and Statistics (DGBAS), relatively little has been published on the analysis of structural change using IO analysis. Notable exceptions are Liang and Liang [25]; Wang [40;41]; and, Wang, Sun and Chou [39]. discussed in the following section.[2] In this paper we consider a longer time period, and, rather than focusing on the decomposition of structural change, this paper focuses on the degree of "interconnectedness" between sectors of the economy over time. Recent discussion on the evolution Taiwan's economy has drawn attention to what has been termed a "hollowing-out effect" associated with the relocation of Taiwanese firms in mainland China other South-East Asian economies (Amsden and Chu [3]; Lin [26]). In this paper we attempt to address this aspect of Taiwan's structural change; that is, to gauge the extent of changes in internal, intersectoral complexity and inter-connectedness. This requires more complex analyses of intersectoral interdependencies than that offered by traditional IO analysis.

This paper uses a series of input-output tables to study the structural and intersectoral changes which have occurred in the Taiwanese economy over the period 1976 to 1994. The input-output tables were constructed by the Directorate General of Budget, Accounting and Statistics (DGBAS) and refer to the years 1976, 1981, 1986, 1989, 1991 and 1994. Each table contains 39 sectors as given in Table 1. In some applications, the tables are aggregated to 8 sectors. However, unlike other studies that rely exclusively on traditional input-output analysis, this study also employs *Minimal Flow Analysis* (MFA) which is essentially an extended version of qualitatitive input-output analysis (QIOA) developed by Schnabl [32] to analyse changes in intersectoral complexity.

[2] Wang [40] also cites an unpublished Master's thesis (in Chinese) by Chen [9] who uses IO tables for Taiwan over the period 1971-1989 to decompose sectoral output growth attributable to changes in demand and changes in input-output coefficients.

Table 1. Industry 39 Sector Classification, Taiwan

Number	Name
1	Agricultural products and livestock
2	Forestry
3	Fisheries
4	Minerals
5	Processed food
6	Beverages
7	Tobacco
8	Textile mill products
9	Wearing apparel and accessories
10	Wood, bamboo and wooden products
11	Paper, paper products, printing and publishing
12	Chemical materials
13	Man-made fibres
14	Plastics
15	Plastic products
16	Miscellaneous chemical products
17	Petroleum products
18	Non-metallic mineral products
19	Steel and iron
20	Miscellaneous metals
21	Metallic products
22	Machinery
23	Household electrical appliances
24	Electronic products
25	Electrical machinery and apparatus
26	Transport equipment
27	Miscellaneous products
28	Construction
29	Electricity
30	Gas and water
31	Transport, storage and communication
32	Wholesale, retail and foreign trade
33	Finance and insurance services
34	Real estate services
35	Eating, drinking and hotel services
36	Business services
37	Public administrative services
38	Education and medical services
39	Other services

Using *Key Sector Analysis* and MFA we show that the Taiwanese economy reached a peak in terms of intersectoral complexity in 1981 before going into decline through a hollowing-out process. This may be a direct consequence of the shifts in sectoral emphasis, as service industries require less physical inputs, but could also reflect the movement of Taiwanese capital offshore, to mainland China and other low wage economies in the region.

The paper is structured as follows. The following section provides an overview of how conventional input-output analysis is used to examine structural change and evolving inter-industry linkages, with particular reference to Taiwan over the period 1976 to 1994. This provides a backdrop to a more detailed analysis of changes in intersectoral interrelationships and interdependencies using techniques derived from linkage analysis , Key Sector Analysis and Minimal Flow Analysis. The final section then attempts to draw together all this information into a succinct picture of the evolutionary and structural changes which have occurred in the Taiwanese economy over the 19-year period.

2. GROWTH AND STRUCTURAL CHANGE OF THE TAIWANESE ECONOMY, 1976 TO 1994

2.1 Sectoral changes

Over the period 1976 to 1994, Taiwan, like the other East Asian 'Miracle Economies', experienced rapid economic growth. Since the publication of the World Bank's *East Asian Miracle* [44] much of the literature on Taiwan's economic growth has focussed on estimating the relative contributions of factor inputs and technological change to total output growth using growth accounting methods [Young, 45; Chow and Lin, 14; Robertson, 30], and on identifying the possible lessons from Taiwan's experiences for other countries. (See for example, Thorbecke and Wan, [38]; Chow [15].)

In common with what has been observed in developing countries around the world, there has been a progressive and gradual shift away from Primary activities towards Manufacturing and Services up to the mid-1980's. Since 1986, there has also been a pronounced shift away from Manufacturing to Services. This is demonstrated in Figure 1, which shows that *Agriculture* output declined from 11.4% of GDP in 1976 to 3.5% in 1994. *Manufacturing* increased its share of GDP from 36.8% in 1976 to 39.2% in 1986 before declining to 27.4% in 1994. *Services*, on

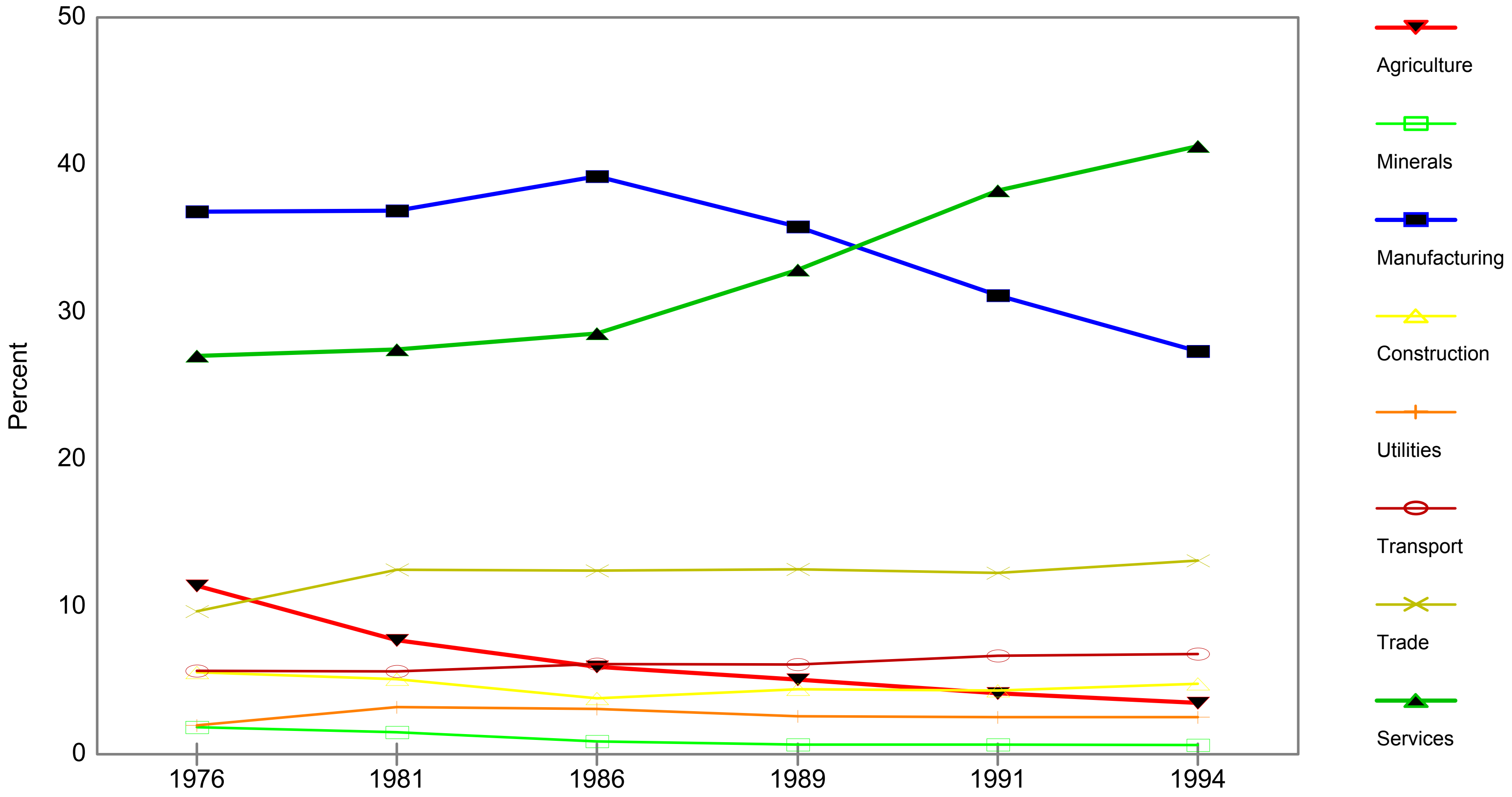


Figure 1. Sectoral Shares of GDP, Taiwan

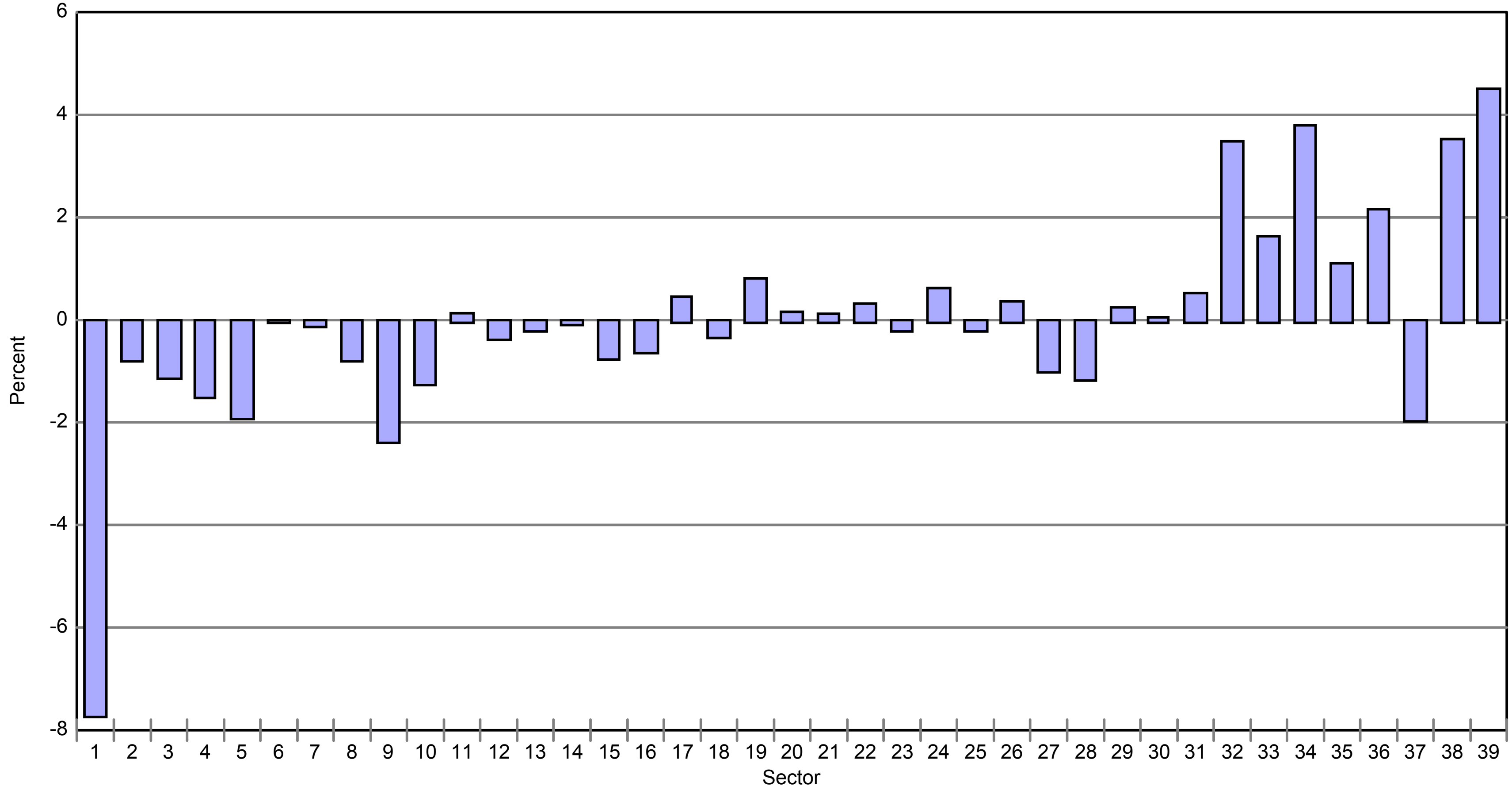


Figure 2. Change in Value Added Shares, Taiwan 1976 - 1994

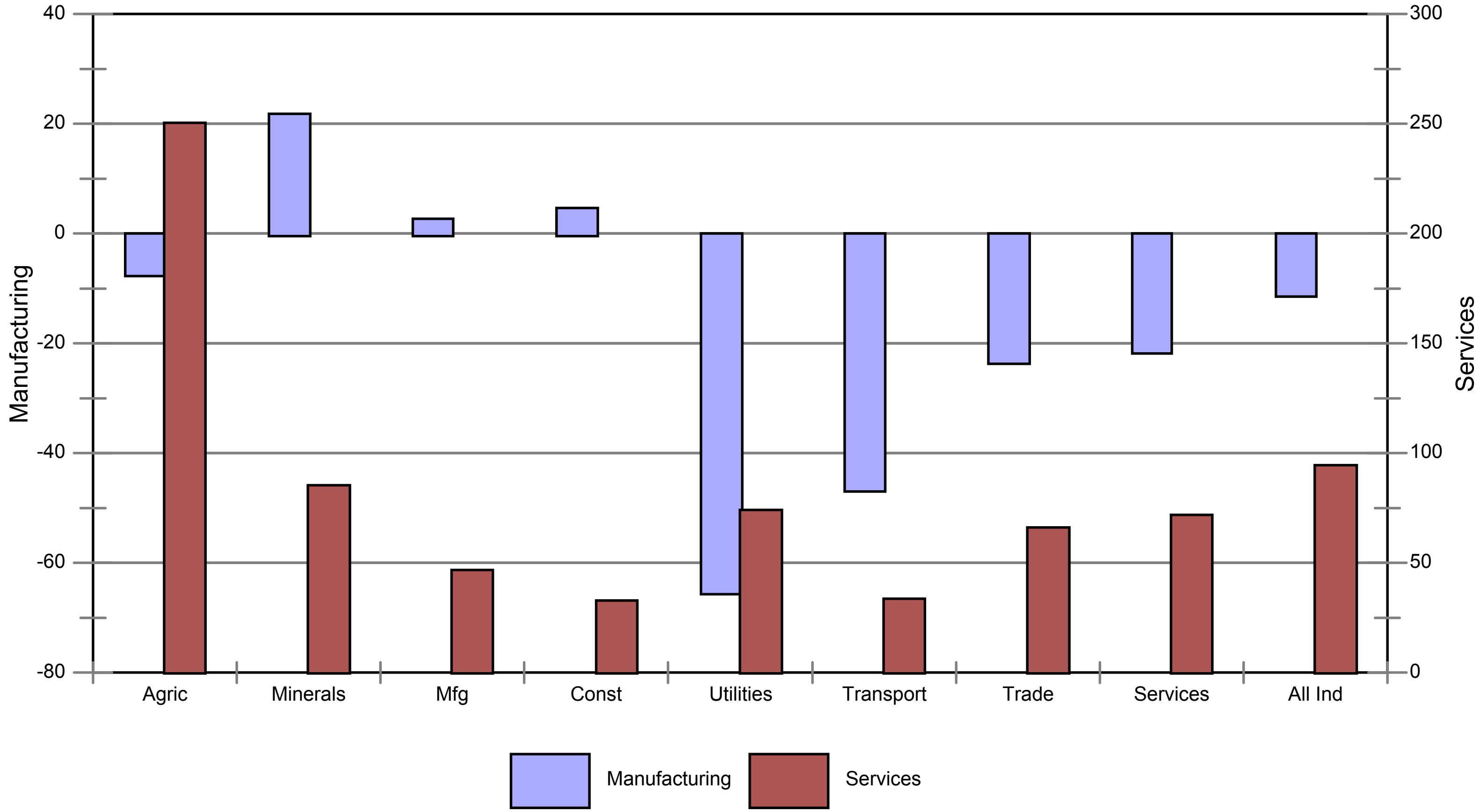


Figure 3. Percentage Change in Consumption of Manufactures and Services per unit Output, Taiwan 1976 -1994

the other hand, consistently increased its share of GDP from 27.0% in 1976 to 41.3% in 1994. *Minerals*, *Construction*, *Utilities*, *Transport* and *Trade* retained relatively constant shares of GDP over the period.

The shift from primary to tertiary activities can also be clearly seen in Figure 2, which shows the change in value added shares by sector over the period 1976 to 1994. All primary activities decline in share with *Agricultural products and livestock* experiencing the largest decline from 10.5 to 2.8 percent. Conversely, all service sectors except *Public administrative services* increase their shares. In aggregate terms, primary activities decreased their value added share by 2.7%, manufacturing fell by 0.3%, and services increased their share by 2.1%.

Figure 3 shows the percentage change in the consumption of services and manufactures per unit of output for a group of more highly aggregated sectors. In all cases, consumption of services has increased, and except for *Minerals*, *Manufacturing* and *Construction*, consumption of manufactures has decreased. Over all industries, the consumption of services increased by 94.5% and the consumption of manufactures decreased by 11.4% over the sample period.

The Taiwanese experience is mirrored in studies of international comparative analysis using input-output tables from countries at all levels of development which have demonstrated that over the course of the transition from low- to high-income there is a strong shift in value-added from primary production to manufacturing and nontradables, and, at high income levels the share of manufacturing declines and of services increases (Syrquin and Chenery [37]). This finding is consistent with the earlier work of Clark [16] and Fisher [21] predicting the emergence of the "service economy" and the "de-industrialisation" of highly developed countries, which they attributed to the relatively higher income elasticities of demand for services. This became known as the Clark-Fisher hypothesis. Despite later studies questioning Clark and Fisher's demand-side explanation, Clark and Fisher were at least correct in highlighting that structural change in the economic system accompanies the process of economic development.

2.2 Interindustry linkages

Surprisingly, much less attention has been given to the analysis of the evolution of interindustry linkages over the transition, even though it was more than 40 years ago that Chenery and Watanabe [13] demonstrated the use of IO analysis in identifying and comparing patterns of interdependence among sectors. It was found then that during the process of development, the total use of intermediate inputs relative to gross output increases and its composition shifts as the importance of primary products declines and of heavy industrial products and nontradables, particularly services, increases. What is important to note here is that these changes in the structure of production were found to be attributable not so much to changes in the composition of final output, as predicted by the Clark-Fisher hypothesis, but rather to increases in the *density* of the input-output matrices as the economy evolves from relatively simple handicrafts production to a more complex, factory-based system with a higher degree of fabrication.

Deutsch and Syrquin [18], in an analysis of structural change inspired by Chenery and Watanabe [13], studied the relationship between economic development and structural change for 30 countries, of which Taiwan was one, over the period 1950–75, making use of IO tables, each of which, for the purpose of comparison, was condensed to 10 sectors. As expected, it was discovered that economic development is associated with an increasing share of intermediate goods in total output.[3] Korea and Taiwan, as countries which experienced rapid industrialisation, were notable for the large increase in demand for intermediates that they experienced. The analytical tools relied upon by Deutsch and Syrquin [18, p. 448] were measures of sectoral linkages, especially the forward linkage index, which is the ratio of intermediate to total demand. It has been shown that the internal connectedness or complexity of the economic structure, measured in terms of the strength of intermediate linkages, increased systematically in Taiwan during the initial phases of its development. Its input-output coefficients increased faster in manufacturing than elsewhere, and, by the mid-1970s, Taiwan had attained the same overall level of industrial interdependence as Japan (Albala-Bertrand [2]). Similarly, Brown and Hooper [7] have shown that over the period 1976 to 1991, Taiwan's dependency of tradable goods sectors on non-tradables increased significantly, again suggesting a more complex or 'roundabout' production structure as the economy developed.

2.3 Sources of structural change

Other studies indicate that changes in Taiwan's economic structure are attributable more to changes in the pattern of final demand than to changes in interindustry linkages. Wang, Sun and Chou [39] decomposed structural change into its sources, which are final demand, export expansion, import substitution and technological change. Using Taiwan's IO tables for 1979 and

[3] This reaffirmed an earlier finding to the same effect by Chenery [10; 11].

1984 they found the relative contributions to structural change were: 47.84 percent for demand; 38.04 percent for exports; 2.11 percent for import substitution; and, 5.21 percent for technological change (Wang, Sun & Chou [39, p.393–94]). The residual was composed of cross-terms of the sources of structural change. These findings suggest that most of the change in the structure of the Taiwanese economy is attributable to changes in final demand rather than inter-industry relationships.

Wang [40;41] also applied a multiplicative decomposition method within an IO framework. Structural change was identified using the rowscaler method pioneered by Carter [8] and Feldman & Palmer [20] in their analyses of structural change in the United States. The main purpose of this method is to estimate the extent to which changes in the composition of output can be attributed to changes in IO coefficients (rowscalar) *versus* final demand (columnscalar).[4] Applying this method to Taiwan over the period using IO tables comprising 29 sectors for the years 1966, 1976, 1981, 1986, and 1991, Wang discovered large changes in intermediate transaction and final demand coefficients for the miscellaneous services sector, and significant changes in other sectors notable for producing intermediate requirements *viz.*, electronics, transport equipment and machinery. This is to be expected of a developing economy becoming more interconnected.

2.4 Hollowing-out

However, it is noteworthy that the shifts in Taiwan's economic structure have also been accompanied by increased outsourcing of inputs, as shown in Figure 4. There have been massive increases in import levels per unit output for *Textile mill products* (4597.3%), *Miscellaneous chemical products* (3624.3%), *Tobacco* (1476.6%), *Wearing apparel and accessories* (559.6%) and *Household electrical appliances* (372.9%). Over all industries, the average increase in imports per unit output was 12.3% between 1976 and 1991.

It is also significant that from the mid-1980's Taiwanese capital began relocating offshore, associated with a sizeable appreciation of the currency (NT$) and rising real wages (Li and Hu [24]). This relocation process became of concern to policy makers who saw it as a source of

[4] For an application of a similar, biproportional method to China using IO tables for 1987 and 1995, see Andreosso-O'Callaghan and Yue [4].

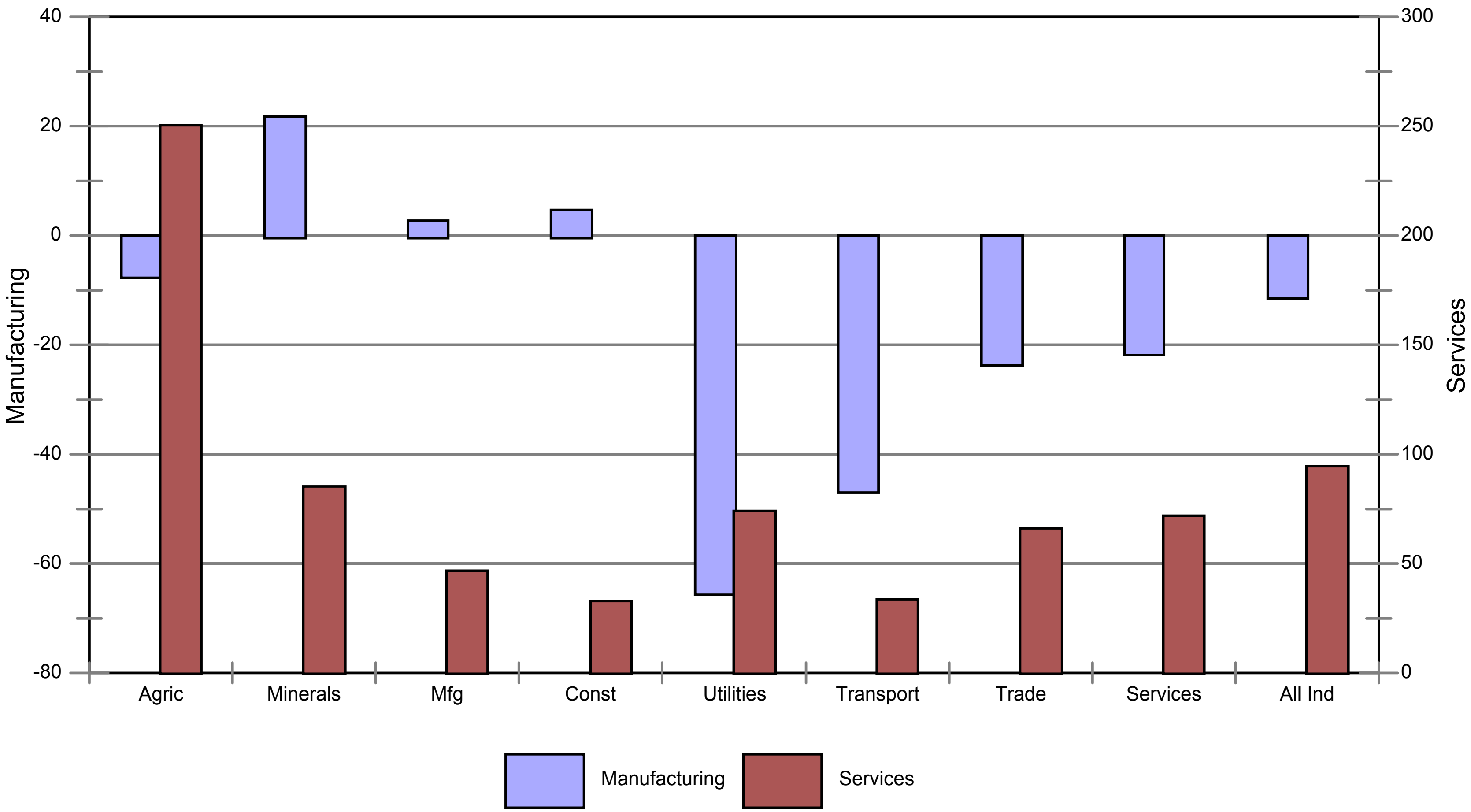


Figure 3. Percentage Change in Consumption of Manufactures and Services per unit Output, Taiwan 1976 -1994

increased reliance on imported intermediate inputs. It was also seen as contributing to a weakening of internal, inter-sectoral linkages; a 'hollowing-out' process believed by some as contributing to the diminishing comparative advantage of Taiwan's indigenous, home-based intermediate good producers (Lin [26]).[5]

Neither traditional IO methods nor the multiplicative decomposition methods are suitable for addressing the issue of connectivity or for gauging the extent of the hollowing-out process. Alternative methods of analysing this aspect of an economy's structural change are needed. In this paper we apply to Taiwan recently developed methods which gauge changes in the degree of "interconnectedness" between sectors of the economy over time. We also consider a longer and more recent time period (1976-94) which would allow us to capture any hollowing-out effects from the relocation of intermediate industries that has been most marked since the mid-1980s.

3. STRUCTURAL ANALYSIS

3.1 Introduction

It could be argued that, on the surface, Taiwan is a good example of a successful growing economy. However, traditional economic theory suggests that such development is also normally associated with increasingly internal complexity and self-sustainability. In other words, we would expect an increasing number of structural linkages and internal trading interactions. Sector shares, as depicted in the previous section, do not provide this information, but simply give overall trends. To answer the questions of internal complexity and self-sustainability requires more complex analyses of intersectoral interdependencies. We attempt to address this aspect in this section.

This section draws from a number of fields of analysis which come under the umbrella of economic structure. In particular, linkage analysis, key sector analysis and minimal flow analysis are used to study the underlying structural changes which have occurred in the Taiwanese economy.

[5] The concept 'hollowing-out' has been applied mainly in the context of the deindustrialization of Japan. See for example: Okazaki [28]; Cowling and Tomlinson [17]; Abe [1]; Okina nd and Kohsaka [29]. In the context of the US see Hewings et al [22] and in relation to Canada see Feinberg and Keane [19].

3.2 Linkage Analysis

The concept of key sectors is generally regarded as initially being conceived with the work of Rasmussen [31] and Hirschman [23]. West [42] develops a technique for determining the effects of coefficient changes on the multiplier values which is demonstrated on an 11-sector table for South Australia. More recently, Sonis, Hewings and Guo [35] provide a theoretical framework for key sector analysis based on a minimum information approach which is then applied to Chinese IO tables for 1987 and 1990. Central to the concept of key sectors is the notion of backward and forward linkages. The aim of linkage analysis is to measure the potential stimulus to other activities from investment in any sector, and to identify those sectors which create an above average stimulus to the rest of the economy.

3.2.1 Background linkages

The numerator in the backward linkage index for sector *j* (L_j) is essentially an output multiplier and denotes the average stimulus imparted to other sectors by a unit's worth of demand for sector *j*'s output. In order to make comparisons between sectors, a normalisation procedure is carried out by dividing by the average stimulus to the whole economy when all sectors' final demands are increased by unity. If $L_j > 1$, investment in sector *j* yields above average multiplier effects, while if $L_j < 1$, investment in sector *j* produces below average multiplier effects.

These linkages can be disaggregated across the *n* input sectoral components which provides information on the distributional effects of the initial investment stimulus across the *n* sectors in the economy. A useful dichotomy of disaggregated linkage effects is the *self* and *non-self* contributions. In the former, changes in output can be traced to intrasectoral changes within the industry itself, while in the latter the changes impact on other sectors.

Selecting sectors with a high index on its own is insufficient for policy and planning purposes, since only one or two sectors may stand to gain from the stimulus. Ideally, we require any stimulus to sector *j* to spread as widely as possible throughout the economy. A measure of this backward spread is the coefficient of variation. Normalising gives the backward spread index (V_j). A low V_j means that investment in sector *j* would stimulate a large number of other sectors, while a high V_j indicates the stimulus would only have localised effects. A *key* backward sector is defined as one which has both a high backward linkage index and a low spread index.

3.2.2 Forward linkages

Backward linkages only provide part of the story. Backward linkages provide information on the effects of investment in a given industry on upstream activities in a demand driven sense, i.e. through increased demands for other sector inputs. But what about downstream activities? The increased output in sector *j* may alleviate bottlenecks to supply to other industries which can in turn increase production, or alternatively all the increased output may be exported. To measure the effect of investment in sector *j* on these downstream activities, forward linkages and spread effects can be calculated.

The basic idea of forward linkages is to trace the output increases which occur or might occur in using industries when there is a change in the sector supplying inputs, in contrast to backward linkages which trace the output increases which occur in supplying industries when there is a change in the sector using its products as inputs. The forward linkage index is calculated from the supply-side model in an analogous manner to the backward linkage index.

The forward linkages are now defined in terms of input multipliers, which measure the effect on total output of all sectors associated with a unit change in the primary inputs of sector *i*. For example, we may want to decide where to place an additional investment in primary factors (labour or capital) so that it would be most beneficial to the total economy, in terms of potential for supporting expanded output.

3.2.3 Backward and forward linkages for Taiwan

The backward and forward linkages for Taiwan are given in Tables 2 and 3, and in Figures 5 and 6 for a more aggregated set of sectors.

From Figure 5, it can be seen that only three sectors can be classified as having above average (i.e. above 1) backward linkages over the full sample period: *Construction*, *Manufacturing* and *Utilities*. *Utilities* has the highest ranking of all sectors in terms of backward linkages in 1976 but quickly drops to third place by 1986. *Construction* attains first place in 1981 and retains that position for the remainder of the sample period. *Manufacturing* keeps a consistent second ranking for the whole sample period. It is also of interest to note that *Agriculture's* backward linkage index gradually increases over the period, becoming greater than one in 1989. *Minerals* has the lowest backward index over the whole period. Figure 6 shows that the sectors with above

Table 2. Backward Linkages, Taiwan

	1976			1981			1986			1989			1991			1994		
SECTOR	**SELF**	**NSELF**	**TOTAL**	**SELF**	**NSELF**	**TOTAL**	**SELF**	**NSELF**	**TOTAL**	**SELF**	**NSELF**	**TOTAL**	**SELF**	**NSELF**	**TOTAL**	**SELF**	**NSELF**	**TOTAL**
1	0.703	0.268	0.971	0.653	0.289	0.942	0.654	0.310	0.964	0.698	0.328	1.027	0.685	0.319	1.004	0.727	0.326	1.053
2	0.547	0.048	0.595	0.527	0.029	0.556	0.546	0.024	0.570	0.573	0.019	0.592	0.566	0.011	0.577	0.571	0.011	0.582
3	0.592	0.411	1.003	0.539	0.425	0.965	0.556	0.336	0.893	0.584	0.340	0.924	0.564	0.338	0.903	0.585	0.356	0.941
4	0.566	0.068	0.633	0.517	0.033	0.550	0.539	0.072	0.612	0.576	0.078	0.654	0.565	0.079	0.644	0.575	0.095	0.671
5	0.691	0.662	1.353	0.653	0.615	1.269	0.658	0.592	1.250	0.694	0.606	1.301	0.671	0.608	1.280	0.684	0.633	1.317
6	0.545	0.368	0.913	0.507	0.306	0.813	0.519	0.369	0.889	0.549	0.371	0.920	0.549	0.417	0.965	0.558	0.402	0.960
7	0.587	0.169	0.755	0.540	0.172	0.713	0.555	0.195	0.750	0.580	0.148	0.728	0.570	0.181	0.751	0.583	0.156	0.739
8	0.783	0.686	1.469	0.691	0.706	1.397	0.703	0.640	1.343	0.738	0.642	1.380	0.729	0.626	1.355	0.749	0.627	1.376
9	0.607	0.825	1.432	0.559	0.773	1.333	0.588	0.741	1.330	0.613	0.705	1.318	0.623	0.670	1.294	0.623	0.614	1.238
10	0.622	0.466	1.088	0.629	0.446	1.075	0.651	0.408	1.059	0.672	0.369	1.041	0.682	0.355	1.037	0.670	0.285	0.954
11	0.843	0.412	1.255	0.791	0.432	1.223	0.801	0.348	1.149	0.789	0.327	1.116	0.791	0.339	1.130	0.784	0.328	1.112
12	0.697	0.216	0.913	0.698	0.341	1.039	0.712	0.217	0.929	0.703	0.148	0.851	0.691	0.162	0.853	0.710	0.170	0.879
13	0.645	0.533	1.178	0.631	0.746	1.376	0.587	0.650	1.237	0.620	0.639	1.259	0.631	0.639	1.270	0.650	0.655	1.305
14	0.564	0.432	0.997	0.522	0.706	1.228	0.528	0.620	1.149	0.559	0.556	1.115	0.557	0.544	1.102	0.571	0.558	1.128
15	0.648	0.647	1.295	0.616	0.743	1.358	0.641	0.692	1.333	0.670	0.663	1.333	0.648	0.640	1.288	0.642	0.640	1.283
16	0.671	0.404	1.075	0.588	0.492	1.079	0.607	0.414	1.021	0.641	0.406	1.047	0.633	0.384	1.017	0.641	0.371	1.012
17	0.575	0.415	0.989	0.538	0.441	0.980	0.545	0.310	0.855	0.574	0.318	0.892	0.569	0.331	0.900	0.582	0.282	0.864
18	0.585	0.442	1.027	0.563	0.476	1.038	0.576	0.445	1.021	0.606	0.415	1.021	0.634	0.411	1.045	0.639	0.399	1.038
19	0.903	0.292	1.195	0.869	0.345	1.215	0.918	0.334	1.253	0.890	0.305	1.195	0.882	0.313	1.194	0.908	0.328	1.236
20	0.679	0.259	0.939	0.640	0.297	0.937	0.672	0.246	0.918	0.675	0.179	0.854	0.705	0.196	0.900	0.689	0.180	0.869
21	0.615	0.531	1.145	0.570	0.646	1.216	0.568	0.650	1.219	0.586	0.589	1.175	0.593	0.614	1.207	0.606	0.604	1.210
22	0.571	0.256	0.827	0.531	0.297	0.827	0.555	0.387	0.942	0.582	0.354	0.936	0.583	0.408	0.990	0.593	0.401	0.994
23	0.593	0.576	1.169	0.526	0.588	1.114	0.570	0.651	1.221	0.583	0.592	1.174	0.585	0.587	1.172	0.595	0.581	1.176
24	0.776	0.354	1.131	0.696	0.391	1.087	0.774	0.366	1.140	0.760	0.373	1.133	0.783	0.343	1.126	0.783	0.315	1.097
25	0.618	0.414	1.032	0.578	0.457	1.035	0.640	0.499	1.139	0.648	0.460	1.108	0.670	0.492	1.162	0.678	0.462	1.140
26	0.663	0.383	1.047	0.642	0.443	1.086	0.663	0.483	1.146	0.692	0.389	1.080	0.698	0.392	1.090	0.703	0.371	1.074
27	0.604	0.446	1.050	0.563	0.491	1.055	0.570	0.583	1.152	0.596	0.510	1.106	0.590	0.486	1.077	0.600	0.439	1.039
28	0.546	0.626	1.172	0.505	0.662	1.167	0.518	0.655	1.173	0.544	0.655	1.199	0.543	0.683	1.225	0.555	0.680	1.235
29	0.591	0.513	1.104	0.567	0.446	1.013	0.593	0.323	0.916	0.631	0.337	0.968	0.623	0.366	0.989	0.639	0.338	0.978
30	0.571	0.620	1.190	0.553	0.666	1.219	0.576	0.509	1.085	0.628	0.449	1.077	0.612	0.522	1.134	0.654	0.458	1.112
31	0.578	0.292	0.870	0.540	0.342	0.882	0.580	0.272	0.853	0.614	0.262	0.876	0.607	0.247	0.854	0.616	0.237	0.853
32	0.548	0.219	0.767	0.508	0.231	0.740	0.522	0.240	0.762	0.548	0.236	0.784	0.552	0.268	0.820	0.565	0.266	0.831
33	0.574	0.079	0.653	0.680	0.105	0.785	0.722	0.115	0.837	0.709	0.119	0.828	0.651	0.150	0.801	0.657	0.153	0.810
34	0.545	0.098	0.643	0.504	0.147	0.651	0.517	0.259	0.776	0.544	0.188	0.731	0.545	0.205	0.749	0.557	0.211	0.768
35	0.546	0.245	0.790	0.504	0.228	0.731	0.516	0.225	0.741	0.543	0.186	0.729	0.541	0.188	0.729	0.554	0.197	0.750
36	0.558	0.262	0.820	0.527	0.337	0.864	0.541	0.297	0.837	0.567	0.321	0.888	0.562	0.312	0.874	0.578	0.301	0.879
37	0.544	0.298	0.842	0.503	0.388	0.891	0.516	0.382	0.898	0.542	0.396	0.938	0.540	0.383	0.923	0.553	0.327	0.880
38	0.544	0.160	0.704	0.504	0.224	0.727	0.516	0.222	0.738	0.543	0.218	0.761	0.541	0.210	0.752	0.554	0.192	0.746
39	0.580	0.388	0.968	0.534	0.289	0.823	0.550	0.351	0.901	0.582	0.357	0.939	0.564	0.253	0.817	0.576	0.295	0.872

Table 3. Forward Linkages, Taiwan

SECTOR	1976 SELF	1976 NSELF	1976 TOTAL	1981 SELF	1981 NSELF	1981 TOTAL	1986 SELF	1986 NSELF	1986 TOTAL	1989 SELF	1989 NSELF	1989 TOTAL	1991 SELF	1991 NSELF	1991 TOTAL	1994 SELF	1994 NSELF	1994 TOTAL
1	0.659	0.588	1.247	0.647	0.551	1.198	0.615	0.551	1.167	0.650	0.526	1.176	0.643	0.480	1.123	0.683	0.475	1.158
2	0.513	0.791	1.304	0.521	0.869	1.390	0.514	0.865	1.378	0.534	0.861	1.394	0.531	0.856	1.386	0.536	0.868	1.404
3	0.555	0.127	0.682	0.534	0.169	0.703	0.523	0.222	0.746	0.544	0.177	0.721	0.529	0.132	0.661	0.550	0.118	0.668
4	0.530	1.171	1.701	0.512	1.310	1.822	0.507	1.340	1.847	0.536	1.301	1.837	0.530	1.308	1.839	0.541	1.260	1.800
5	0.647	0.163	0.810	0.647	0.192	0.839	0.619	0.186	0.805	0.647	0.198	0.845	0.630	0.157	0.786	0.643	0.149	0.792
6	0.511	0.020	0.531	0.502	0.014	0.516	0.488	0.021	0.510	0.512	0.020	0.531	0.515	0.007	0.522	0.525	0.008	0.532
7	0.550	0.005	0.555	0.535	0.003	0.537	0.521	0.005	0.526	0.540	0.003	0.543	0.534	0.001	0.536	0.548	0.001	0.549
8	0.734	0.370	1.104	0.684	0.398	1.082	0.661	0.412	1.073	0.687	0.361	1.048	0.683	0.287	0.970	0.704	0.228	0.932
9	0.569	0.092	0.661	0.554	0.076	0.629	0.553	0.083	0.636	0.570	0.088	0.659	0.584	0.088	0.673	0.586	0.101	0.687
10	0.583	0.228	0.811	0.623	0.230	0.853	0.612	0.198	0.809	0.626	0.255	0.880	0.640	0.292	0.932	0.629	0.361	0.991
11	0.790	0.607	1.397	0.782	0.675	1.458	0.753	0.656	1.410	0.735	0.671	1.406	0.742	0.669	1.411	0.737	0.683	1.420
12	0.653	1.135	1.788	0.691	1.179	1.870	0.669	1.138	1.807	0.654	1.164	1.818	0.648	1.111	1.759	0.667	1.040	1.707
13	0.605	0.765	1.369	0.624	0.718	1.342	0.552	0.765	1.317	0.577	0.756	1.333	0.592	0.647	1.239	0.611	0.580	1.190
14	0.529	0.774	1.303	0.517	0.859	1.376	0.497	0.832	1.329	0.520	0.790	1.311	0.523	0.763	1.286	0.536	0.705	1.242
15	0.608	0.235	0.843	0.609	0.249	0.858	0.603	0.255	0.858	0.624	0.310	0.934	0.608	0.323	0.931	0.604	0.378	0.981
16	0.629	0.591	1.220	0.582	0.553	1.135	0.571	0.596	1.167	0.597	0.588	1.184	0.594	0.589	1.183	0.603	0.556	1.159
17	0.539	0.793	1.332	0.533	0.889	1.422	0.513	0.955	1.468	0.534	0.917	1.452	0.533	0.911	1.444	0.547	0.840	1.387
18	0.549	0.536	1.085	0.557	0.491	1.047	0.542	0.502	1.044	0.565	0.511	1.075	0.595	0.539	1.134	0.600	0.575	1.175
19	0.847	0.704	1.551	0.861	0.682	1.542	0.863	0.705	1.569	0.829	0.676	1.504	0.827	0.671	1.498	0.854	0.668	1.522
20	0.637	0.906	1.542	0.633	0.868	1.501	0.632	0.824	1.455	0.628	0.786	1.415	0.661	0.776	1.437	0.648	0.752	1.400
21	0.576	0.521	1.097	0.564	0.432	0.996	0.534	0.368	0.902	0.545	0.363	0.909	0.556	0.396	0.953	0.569	0.371	0.941
22	0.535	0.170	0.705	0.525	0.167	0.692	0.522	0.231	0.753	0.542	0.165	0.707	0.546	0.157	0.703	0.557	0.149	0.707
23	0.556	0.073	0.629	0.520	0.076	0.596	0.536	0.090	0.626	0.542	0.064	0.607	0.548	0.068	0.616	0.559	0.077	0.636
24	0.728	0.033	0.761	0.689	0.041	0.730	0.728	0.057	0.785	0.708	0.056	0.763	0.735	0.058	0.793	0.736	0.055	0.790
25	0.579	0.431	1.009	0.572	0.367	0.939	0.602	0.403	1.005	0.603	0.339	0.942	0.629	0.379	1.008	0.638	0.367	1.005
26	0.622	0.131	0.752	0.636	0.064	0.700	0.624	0.108	0.732	0.644	0.091	0.734	0.655	0.088	0.743	0.660	0.086	0.747
27	0.566	0.101	0.667	0.558	0.080	0.638	0.536	0.087	0.623	0.555	0.099	0.654	0.554	0.110	0.663	0.564	0.129	0.693
28	0.511	0.048	0.559	0.500	0.058	0.557	0.487	0.120	0.607	0.507	0.087	0.594	0.509	0.111	0.620	0.522	0.107	0.629
29	0.554	0.937	1.491	0.561	0.896	1.457	0.557	0.859	1.416	0.587	0.846	1.434	0.584	0.846	1.430	0.601	0.793	1.394
30	0.535	0.266	0.801	0.548	0.250	0.798	0.542	0.305	0.846	0.585	0.356	0.941	0.574	0.400	0.974	0.615	0.380	0.995
31	0.541	0.358	0.899	0.535	0.350	0.884	0.546	0.362	0.908	0.572	0.386	0.958	0.569	0.332	0.901	0.579	0.327	0.906
32	0.513	0.290	0.803	0.503	0.285	0.789	0.491	0.337	0.828	0.510	0.297	0.808	0.518	0.343	0.861	0.531	0.325	0.856
33	0.538	0.606	1.144	0.673	0.768	1.441	0.679	0.794	1.472	0.660	0.544	1.204	0.610	0.687	1.298	0.617	0.678	1.296
34	0.511	0.117	0.628	0.499	0.047	0.546	0.486	0.086	0.572	0.506	0.085	0.592	0.511	0.179	0.690	0.524	0.165	0.688
35	0.511	0.328	0.839	0.498	0.171	0.670	0.485	0.175	0.661	0.505	0.160	0.666	0.507	0.137	0.644	0.520	0.136	0.656
36	0.523	0.665	1.188	0.522	0.772	1.294	0.508	0.761	1.270	0.528	0.766	1.294	0.527	0.749	1.275	0.543	0.779	1.323
37	0.510	0.000	0.510	0.498	0.000	0.498	0.485	0.000	0.485	0.505	0.000	0.505	0.507	0.000	0.507	0.519	0.000	0.519
38	0.510	0.046	0.556	0.499	0.045	0.544	0.485	0.052	0.538	0.506	0.056	0.562	0.508	0.048	0.556	0.521	0.049	0.570
39	0.544	0.582	1.125	0.529	0.582	1.111	0.517	0.534	1.051	0.542	0.517	1.060	0.529	0.487	1.017	0.542	0.413	0.955

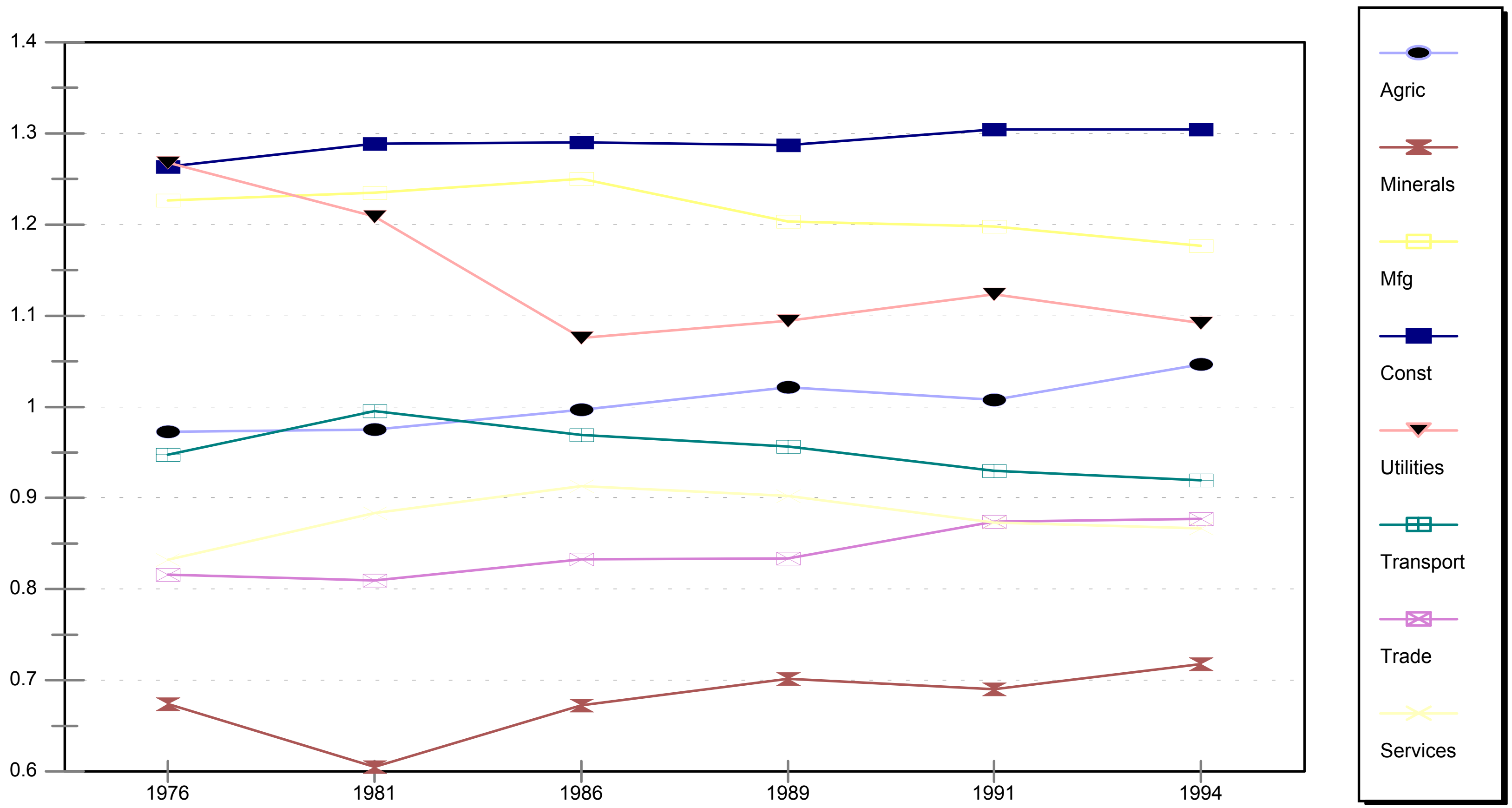


Figure 5. Total Backward Linkages, Taiwan 1976 - 1994

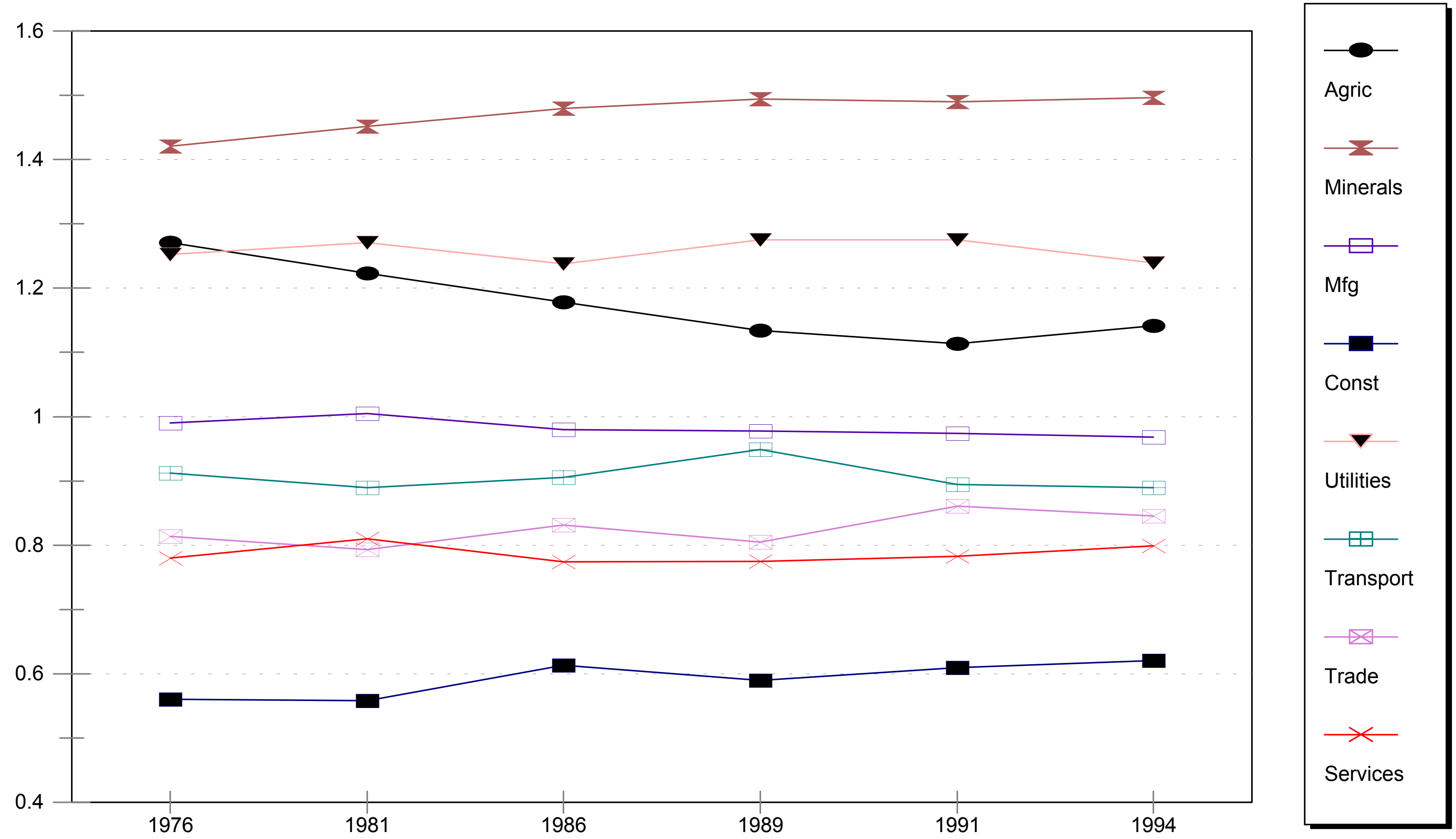


Figure 6. Total Forward Linkages, Taiwan 1976 - 1994

average forward linkages are *Minerals*, *Utilities* and *Agriculture*.

Study of Table 2 shows that the self-component of the backward linkage in virtually all cases (the notable exception is *Construction*) is greater than the non-self component. This indicates that a stimulus to the industry impacts more on intrasectoral firms within that industry than firms outside that industry, indicating a high degree of integration within industry structures. This is also true, but to a less obvious extent, for the forward linkages shown in Table 3. Further analysis of these tables indicates that the proportion of self-component within each sector does not change much over time, so that the degree of integration appears relatively constant.

3.3 Key Sector Analysis

Backward and forward linkages are central to the concept of key sectors. A *key* sector is defined as one which exhibits both high backward and forward linkage indexes and low backward and forward spread indexes (West [42]).

If we collect the backward linkage indexes at time *t* in the *n*-element row vector L_t , and the forward linkage indexes in the *n*-element column vector $\vec{L}_t$, then we can define the *Linkage Product Matrix* as $M_t = \vec{L}_t \ L_t$. The elements of *M* are uniquely associated with each combination of backward and forward linkage indices; large elements will be associated with large backward and forward linkages, and small elements will be associated with small backward and forward linkages. In graph theoretic terms, the matrix depicts an economic landscape of linkages which will highlight the strengths and weaknesses of the economic interactions between sectors.

3.3.1 Spread indices and the Key Sector Matrix

To completely identify the key sectors, we also need to take into account the spread indices. Noting that the mean of the spread indices is unity, an adjusted set of indices symmetric to the original set about unity can be constructed by $U_t = 2\,i' - V_t$ and $\vec{U}_t = 2\,i - \vec{V}_t$, where V_t is the *n*-element row vector of backward spread indices, $\vec{V}_t$ the *n*-element column vector of forward spread indices, and *i* denotes an *n*-element column vector of ones. Unlike V_j and $\vec{V}_i$ which ideally should by small, we want U_j and $\vec{U}_i$ to be large to maximise the spread effects of a stimulus to sector *j*. The companion matrix to *M*, termed the *Spread Product Matrix*, is now defined as $S_t = \vec{U}_t \;\; U_t$, from which a *Key Sector Matrix* can be constructed as $K_t = M_t \bullet S_t$ where $\bullet$ denotes an element by element product.

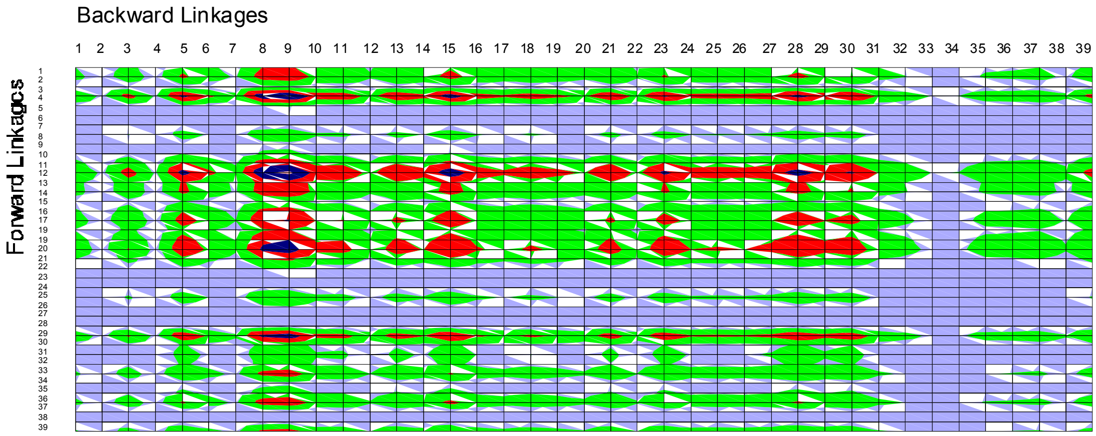
The key sector matrix provides a unique insight into the underlying structural core and highlights the key interactions in terms of their contribution to the direct and indirect flow-ons to the rest of the economy. Large elements reflect strong interconnections and indicate sectoral links which form a fundamental bonded core of the economy.

The *K* matrix exhibits some interesting properties and can be analysed and depicted in a number of ways. For example, all the rows are proportional to each other and similarly for the columns. The matrix can therefore be rank-sorted by both rows and columns to provide a hierarchial picture of key sectors. In this paper, a simpler approach is taken. For the six time periods under consideration, the *K* matrix is depicted as a contour map which provides a clear visual representation of the similarities and differences in the linkage structure of the Taiwanese economy over the twenty-year time span. These are given in Figure 7.

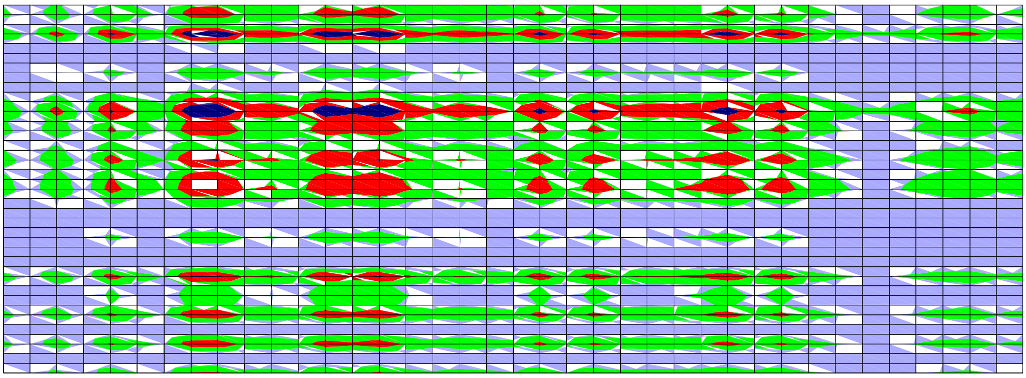
In each of the maps, darker shading represents stronger linkages. Intersectoral links are defined by the intersection of grid lines with the columns representing backward linkages and the rows forward linkages. Thus, in 1976, for example, *Wearing apparel and accessories* (sector 9) has the strongest backward linkages in terms of direct and indirect inputs, and *Chemical materials* (sector 12) has the strongest forward linkages in terms of other industry uses. *Plastic products* (sector 15) ranks as the second most significant sector in terms of backward linkages in 1976.

From a comparison of the landscape maps in Figure 7 over time, it can be seen that density reaches a peak in 1981 and thereafter there is a noticeable decline. While *Minerals* (sector 4) and *Chemical materials* (sector 12) retain a significant key sector status in terms of forward linkages, and *Wearing apparel and accessories* (sector 9) and *Plastic products* (sector 15) retain significant backward linkage status over the period 1976 to 1994, their status had noticeably diminished by 1994. The landscape maps appear to be becoming less dense over time, implying a decrease in the level and complexity of the internal structure.

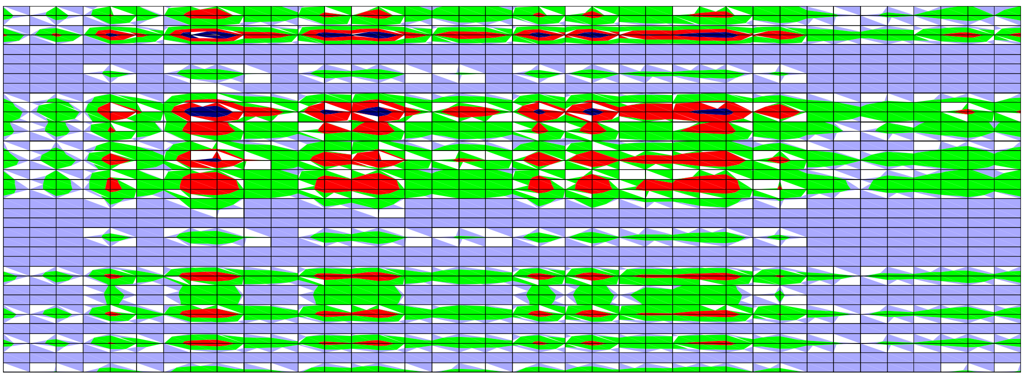
This trend is verified by the finding that the largest key sector index has progressively fallen over the period from 4.189 in 1976 to 3.924 in 1994.



1976

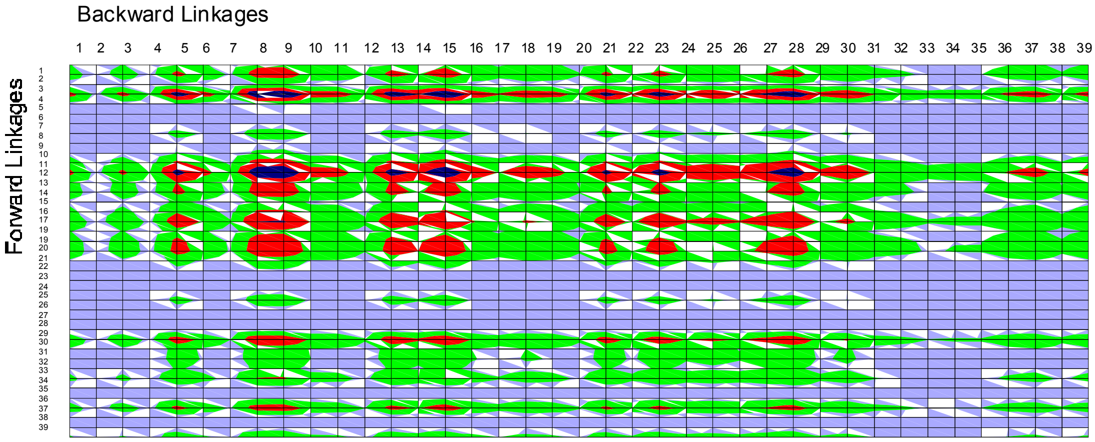


1981

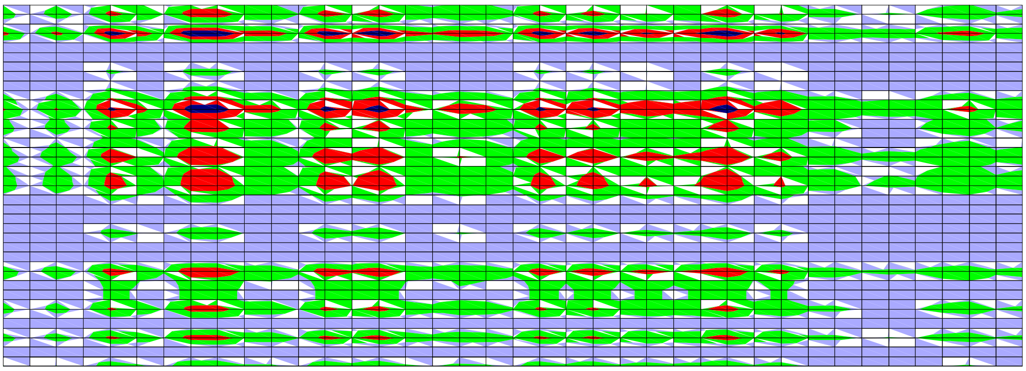


1986

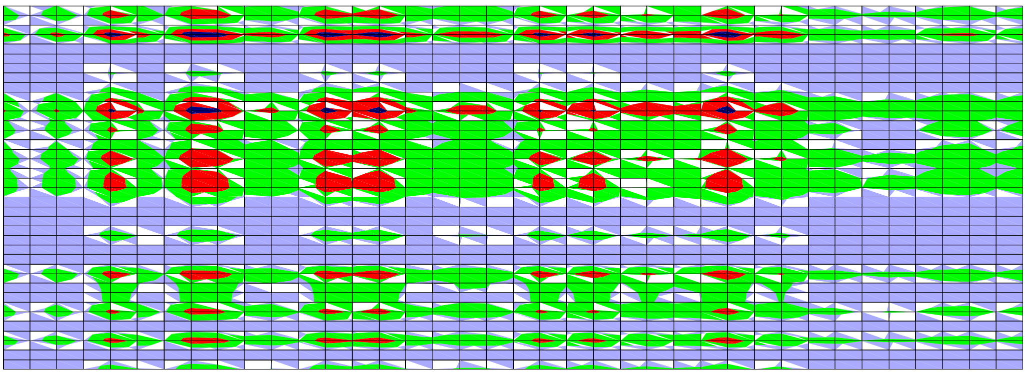
Figure 7a. Key Sector Maps, Taiwan



1989



1991



1994

Figure 7b. Key Sector Maps, Taiwan

3.3.2 Intermediate requirements and hollowing-out

Further evidence to support the observation of diminishing internal complexity in the Taiwanese economy can be seen in Figure 8 which shows total direct and direct plus indirect requirements coefficients. After the growth spurt from 1976 to 1981, the total intermediate requirements, which measures the volume of intersectoral flows, dips back to the 1976 levels in 1989 before recovering slightly in 1991 and falling again in 1994. Moreover, the direct and indirect requirements are falling faster than the direct requirements (average growth rates of -0.52 per cent for direct requirements compared to -1.62 per cent for direct and indirect requirements over the period 1976 to 1994), which indicates a definite thinning of the indirect intersectoral core which is a leading indicator of the internal complexity of the economy.

Table 4 gives the sectoral percentage changes in direct and indirect requirements over the sample period. Only 16 of the 39 sectors experienced positive growth in direct inputs and in all these cases the indirect inputs grow at a slower rate than direct inputs. In other words, the backward linkages in these sectors have not kept pace with direct purchases. The most noticeable of these sectors were *Finance and insurance services* (sector 33) and *Real estate services* (sector 34) where direct inputs increased by approximately 119 per cent and indirect inputs increases by only 9 per cent. The remaining 23 sectors experienced a decline in intermediate input shares which indicates either greater outsourcing of inputs and/or disproportionate increasing returns to labour and capital, and/or increasing agglomeration of intra-industry firms within sectors. The former is supported by the shift from primary and secondary activities to service industries as shown from Figures 1 to 3. The latter argument is supported by close examination of Table 2 which shows that in only 16 sectors the non-self backward linkage component outgrew the self component over the period 1976 to 1994, and in 13 cases, the growth in self component was positive while the growth in non-self component was negative. Over all industries, direct requirements fell by an average of 0.5 per cent while indirect requirements fell by 2.0 per cent over the period 1976 to 1994. A similar story can be told with respect to the intermediate demands.

This apparent decline in density in a developing economy is not a unique observation. A similar phenomenon has been observed for the Japanese economy, a procedure referred to as a "hollowing out" effect (Okazaki [28] ; Abe [1]; Okina and Kohsaka [29]). The process can be likened to scooping out the inside of a large fruit; the size of the fruit remained the same or

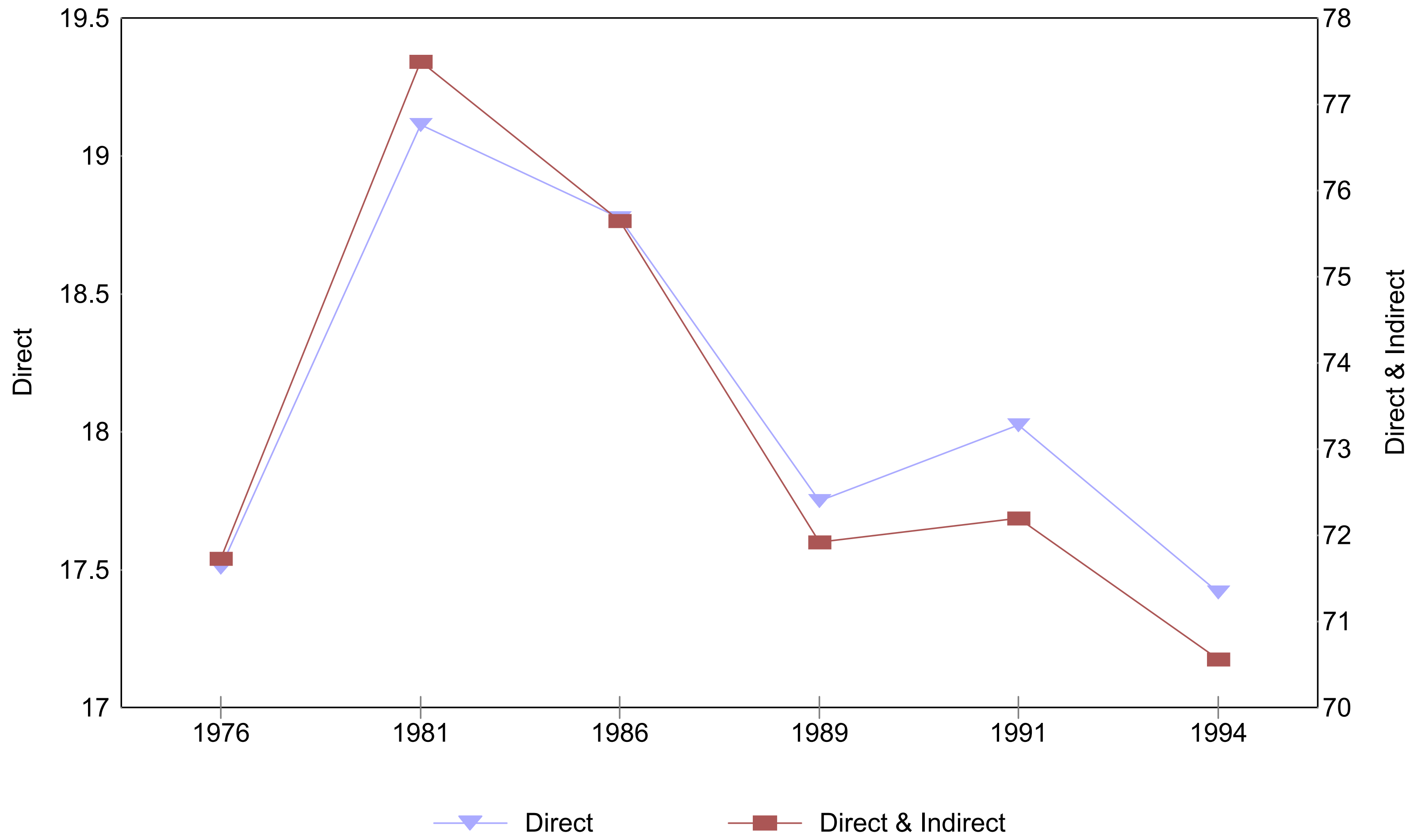


Figure 8. Total Intermediate Requirements

slowly increases but its density decreases, an analogy to the loss of flows between sectors within the intermediary part of the economy. Hewings *et al*. [22] observed a similar trend in the Chicago economy and West [43] in the Queensland economy.

3.4 Measuring connectivity

3.4.1 Qualitative I-O analysis

Another variation of graph theoretic applications to analysing the economic structure of an economy can be derived from qualitative input-output analysis (QIOA) (Bon [6]). This procedure converts the input-output matrix into a Boolean matrix to facilitate and enable some generalisations to be made about the degree of connectivity of the system. While quantitative input-output analysis is concerned with value information, QIOA emphasises the interdependencies within the economy. Like a road map, it highlights the main features of interest but treats as background those characteristics not crucial to the purpose at hand. Through simplification, less is held in view so that more can be understood of what is retained.

The basic concept of classical QIOA consists of the correspondence mapping of the entries of the input-output table $\boldsymbol{T}$ into a qualitative binary adjacency matrix $\boldsymbol{W}$ according to an arbitrarily predefined filter rate:

$$w_{ij} = \begin{cases} 1 \text{ if } t_{ij} \geq filter \\ 0 \text{ if } t_{ij} < filter \end{cases} \quad \forall\, i,\ j = 1, \ldots, m$$

After the binarisation step, several graph-theoretical methods can be applied to the adjacency matrix which trace the connections contained therein. To obtain the complete structure, both direct and indirect linkages are taken into account. As shown by Busacker and Saaty [5] the indirect links can be traced to the k^{th} step by applying the equation $\boldsymbol{W}^k = \boldsymbol{W}\,\boldsymbol{W}^{k-1}$, where the power sequence of the $\boldsymbol{W}^k$ shows how many paths of length k exist between the sectors. For example, the il^{th} entry in $\boldsymbol{W}^2$ contains a 1 if and only if both the elements w_{ij} and w_{jl} are 1 thus reflecting a 2-step connection between sectors i and l via sector j. Additionally a so-called dependency matrix $\boldsymbol{D}$ can be derived by Boolean summation (i.e. 1 + 1 = (#)1) of the matrices $\boldsymbol{W}^k$. Thus an entry $d_{ij} = 1$ shows that there exists a linked flow from sector i to j no matter how many steps are taken which makes $\boldsymbol{D}$ a 'qualitative' inverse of the original table.

Table 4. Percentage Change in Intermediate Requirements and Demands, Taiwan 1976 - 1994

Sector	Intermediate Requirements			Intermediate Demands		
	Direct	Indirect	Total	Direct	Indirect	Total
1	19.6	3.1	6.6	-10.5	-8.1	-8.9
2	-20.2	-2.9	-3.8	-2.2	9.8	5.7
3	-9.4	-7.3	-7.8	-11.0	-2.5	-3.9
4	35.8	1.3	4.2	7.0	2.6	3.8
5	-8.3	-2.3	-4.2	0.5	-5.2	-4.1
6	15.7	0.5	3.5	-8.6	-1.6	-1.7
7	-13.8	-1.8	-3.8	-30.7	-0.7	-2.8
8	-10.6	-6.9	-7.9	-27.7	-12.4	-17.2
9	-15.2	-14.9	-15.0	13.5	0.1	2.0
10	-32.3	-4.6	-13.7	40.2	12.8	19.9
11	-13.7	-12.5	-12.8	-3.3	1.0	-0.3
12	-10.9	-3.4	-5.2	-2.4	-7.8	-6.3
13	11.5	8.0	9.1	-13.8	-15.0	-14.7
14	31.4	4.2	11.4	-19.8	0.8	-6.5
15	-1.1	-3.2	-2.6	30.0	9.0	14.3
16	-9.6	-6.6	-7.4	1.8	-10.3	-6.8
17	-34.8	-2.3	-14.1	1.3	2.6	2.2
18	-2.7	0.3	-0.6	6.2	6.3	6.3
19	6.7	0.0	1.8	-1.0	-4.9	-3.7
20	-14.5	-7.1	-8.9	-6.0	-13.1	-10.9
21	10.3	1.6	3.9	-19.5	-14.3	-15.9
22	53.9	10.5	18.2	0.6	-2.0	-1.6
23	-1.8	-0.7	-1.0	-4.6	-0.1	-0.7
24	-4.0	-4.7	-4.5	4.2	1.2	1.9
25	20.3	4.9	8.7	-6.6	-0.3	-2.3
26	0.3	1.1	0.9	-2.6	-2.6	-2.6
27	-1.6	-3.0	-2.7	-3.4	3.0	2.0
28	7.0	2.4	3.7	115.1	3.5	10.3
29	-16.0	-11.6	-12.9	-7.6	-8.6	-8.3
30	-7.6	-8.3	-8.1	56.3	12.6	21.8
31	-2.9	-3.8	-3.6	-5.1	0.3	-1.1
32	26.0	2.4	6.6	17.2	1.3	4.6
33	119.9	9.3	21.9	14.5	9.7	11.2
34	118.8	9.0	17.5	40.1	3.7	7.6
35	-14.9	-5.0	-6.6	-58.0	-12.8	-23.3
36	23.7	1.4	5.4	10.8	8.4	9.2
37	8.9	1.2	2.8	0.0	0.0	0.0
38	28.4	0.8	4.2	2.1	0.5	0.6
39	-17.0	-9.7	-11.4	-27.1	-12.7	-16.7
All Industries	-0.5	-2.0	-1.6	-2.0	-1.8	-1.9

The connectivity matrix $\boldsymbol{H}$ is obtained from the dependency matrix as $h_{ij} = d_{ij} + d_{ji}$. The connectivity matrix qualifies the connections into a 3-level hierarchical structure, where

$$h_{ij} \begin{cases} 0 \text{ if sector } i \text{ and } j \text{ are } \textit{isolated} \\ 1 \text{ if a } \textit{unidirectional} \text{ link from sector } i \text{ to } j \text{ exists} \\ 2 \text{ if a } \textit{bi-directional} \text{ link between sector } i \text{ and } j \text{ exists} \end{cases}$$

This is an efficient standard graph-theoretical procedure which labels each sector with respect to its place within the total structural plot and degree of interconnectivity with other sectors.

3.4.2 Minimal Flow Analysis

While the binarisation of the table enhances the visualisation of the structure, it suffers from some obvious limitations, namely the loss of important quantitative information, and hence has been subject to criticism. An extended version of QIOA, termed *Minimal Flow Analysis* (MFA), derived by Schnabl [32], attempts to overcome some of these limitations and is used here to give an alternative perspective to the structural characteristics and changes which have occurred in the Taiwanese economy.

Minimal Flow Analysis differs from QIOA in that the (minimal) filter rate is applied to each production stage or expenditure round from the initial to the last relevant downstream stage. By applying the usual power series expansion to the input-output flow matrix [27, p.22], a series of quantitative direct and indirect flow tables $\boldsymbol{T}_o$, $\boldsymbol{T}_1$, $\boldsymbol{T}_2$, $\boldsymbol{T}_3$, ... are mapped into corresponding binary adjacency matrices $\boldsymbol{W}_o$, $\boldsymbol{W}_1$, $\boldsymbol{W}_2$, $\boldsymbol{W}_3$,... This results in each individual $\boldsymbol{W}_k$ being different from all others, as opposed to $\boldsymbol{W}_k = \boldsymbol{W}$ in traditional QIOA. These adjacency matrices provide the basis for structural development corresponding to conventional QIOA (Schnable and Holub [33]). The power sequence necessary for the dependency matrix $\boldsymbol{D}$ is now calculated according to the equation $\boldsymbol{W}^k = \boldsymbol{W}_k \ \boldsymbol{W}^{k\text{-}1}$.[6]

The calculation of the $\boldsymbol{H}$ matrix implies a certain given minimum filter value. Which filter value is the most appropriate remains to be defined. There is, however, another advantage of the MFA in comparison to conventional QIOA which helps in determining the optimal filter value. With MFA, a scanning process can be employed whereby a number of filter values are tried, ranging

[6] The condition of symmetry of $\boldsymbol{W}_k$ with respect to multiplication from left or right in conventional QIOA is no longer valid. In MFA, left-side multiplication is necessary for input-oriented analysis as given above.

from zero to a value where the last bilateral link is destroyed. The resultant $\boldsymbol{H}$ matrices corresponding to the different filter-levels are then summed to give the matrix $\boldsymbol{H}_{\mathrm{cum}}$ which forms the basis for further analysis. The individual $\boldsymbol{H}$ matrices stemming from the scanning process and the $\boldsymbol{H}_{\mathrm{cum}}$ matrix narrow the range of possible filter values to a minimum width or even a single value. This results from two divergent structural features of the MFA procedure:

- *High filter values* provide a good structure at the $\boldsymbol{T}_0$ or $\boldsymbol{W}_0$ and consequently on the $\boldsymbol{H}$ level although it reduces scope, i.e. additional expenditure rounds or indirect flows are depicted incompletely. This results in a "flat" structure.
- *Low filter values* allow sufficient detail in order to include downstream stages. On the other hand they result in only reduced structural differentiation because they tend to include too many flows into the analysis so that a meaningful differentiation in respect of the significance of flows is not provided.

The optimum filter value is obviously located somewhere in the middle of the scanning range, i.e. at a filter value which combines sufficient comprehensiveness of structure with reduction to the substantial part of the structure. Both "comprehensiveness" and "reduction to the substantial part" are qualitative conditions which need to be operationalised. The significance of flows is given by the volume of depictable minimal flows. The condition of comprehensiveness though, is more difficult. In this case, it could be thought of as an analogous application of the information measure developed by Shannon and Weaver [34]. Shannon's concept states that information is maximal if the probability of occurrence of a sign is equal for all individual signs. If this is applied to the MFA problem, the content of information could be maximised by choosing a point at which a nearly equal number of differently qualified sectors with $h_{ij} = 0,1,2$ exists.

If the process of scanning starts at a filter value of 0 and is augmented by equal steps up to a filter value for which there are no more bilateral connections, the following pattern can be observed: At the filter value 0, $h_{ij} = 2$ for most non-zero cells. As the filter value increases, the links increasingly become unidirectional connections ($h_{ij} = 1$) until, at the highest filter value, most sectors are isolated. It can be concluded that within the series of filter specific $\boldsymbol{H}$ matrices there is an optimal one or 'correct' filter level to use. Procedures available to aid in selection include finding the $\boldsymbol{H}$ matrix for which the maximum of the entropy function exists.

3.4.3 Central, source and sink sectors for Taiwan

There are several ways of graphically representing the results of MFA.[7] In this paper, the connection structure is depicted by an ellipse containing the relevant sectors. Here, orientation of delivery and degree of integration into the total structure are considered simultaneously. To determine the position of an individual sector on the ellipse, the centrality coefficient *z* is used (see Table 5) which is defined as the ratio of input and output flows, measured as the difference between row and column totals of the $\boldsymbol{H}_{\text{cum}}$ matrix over their sum, which projects into the interval of -1 to +1. A centrality coefficient of 0 would represent roughly as many input relations as output relations. This would denote the centre of the structure, and are referred to here as *central sectors*.

Those sectors which are not central can be divided into *source sectors* (in the left part of the ellipse where $z < 0$) and *sink sectors* (in the right part of the ellipse where $z > 0$). The individual sectors can be identified with regard to belonging to one group or the other in an intertemporal comparison. Single lines with an arrow denote the direction of delivery (whether positioned in the top or bottom half of the ellipse is not relevant). Bilateral sourcing is denoted by a bold line, and here the direction is irrelevant.

Figures 9a to 9f and Tables 5 and 6 provide the MFA results for Taiwan. The procedure is applied to the eight sector tables (the sector classification is given in Table 1). The number of intersectoral linkages identified as being significant is 26 (out of a possible 64) for 1976, 1981 and 1986, increasing to 27 for 1989, 1991 and 1994, indicating a slight increase in economic complexity.

Source Sectors**:** *Minerals* is a dominant source sector over the full period of the study. *Utilities* enters as a major source sector in 1981, while *Trade* is initially a source sector but disappears in 1986. *Agriculture* appears only temporarily in 1981.

Central Sectors**:** Central sectors are denoted by a bold circle in Figure 9. The central group of sectors usually encompasses 2 or 3 core sectors in the economy. In Taiwan, *Agriculture*,

[7] A very simple method (not used here), which is effective with respect to the identification of sectors, is a chessboard pattern in which a filled or hatched square represents a significant link (from the row- sector to the column-sector) in the characteristic structure.

Table 5. Centrality Coefficients (z), Taiwan 1976 - 1994

Sector	1976	1981	1986	1989	1991	1994
Agriculture	0.00	-0.05	0.00	0.05	0.05	0.05
Minerals	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
Manufacturing	0.00	0.00	0.05	0.05	0.05	0.05
Construction	1.00	1.00	0.56	0.60	0.60	0.60
Utilities	0.00	-0.05	-1.00	-1.00	-1.00	-1.00
Transport	0.33	0.33	0.18	0.05	0.05	0.05
Trade	-0.33	-0.05	0.05	0.05	0.05	0.05
Services	0.00	0.00	0.08	0.08	0.08	0.08

Note: $z < 0$ denotes a source sector
$z = 0$ denotes a neutral sector
$z > 0$ denotes a sink sector

Table 6. Synoptic Table of Sectoral Changes, Taiwan 1976 - 1994

Year	Source Sectors	Central Sectors	Sink Sectors	Number Unidirectional	Number Bilateral
1976	Minerals Trade	Agriculture Manufacturing Utilities Services	Construction Transport	16	10
1981	Agriculture Minerals Utilities Trade	Manufacturing Services	Construction Transport	14	12
1986	Minerals Utilities	Agriculture	Manufacturing Construction Transport Trade Services	16	10
1989	Minerals Utilities		Agriculture Manufacturing Construction Transport Trade Services	16	11
1991	Minerals Utilities		Agriculture Manufacturing Construction Transport Trade Services	16	11
1994	Minerals Utilities		Agriculture Manufacturing Construction Transport Trade Services	16	11

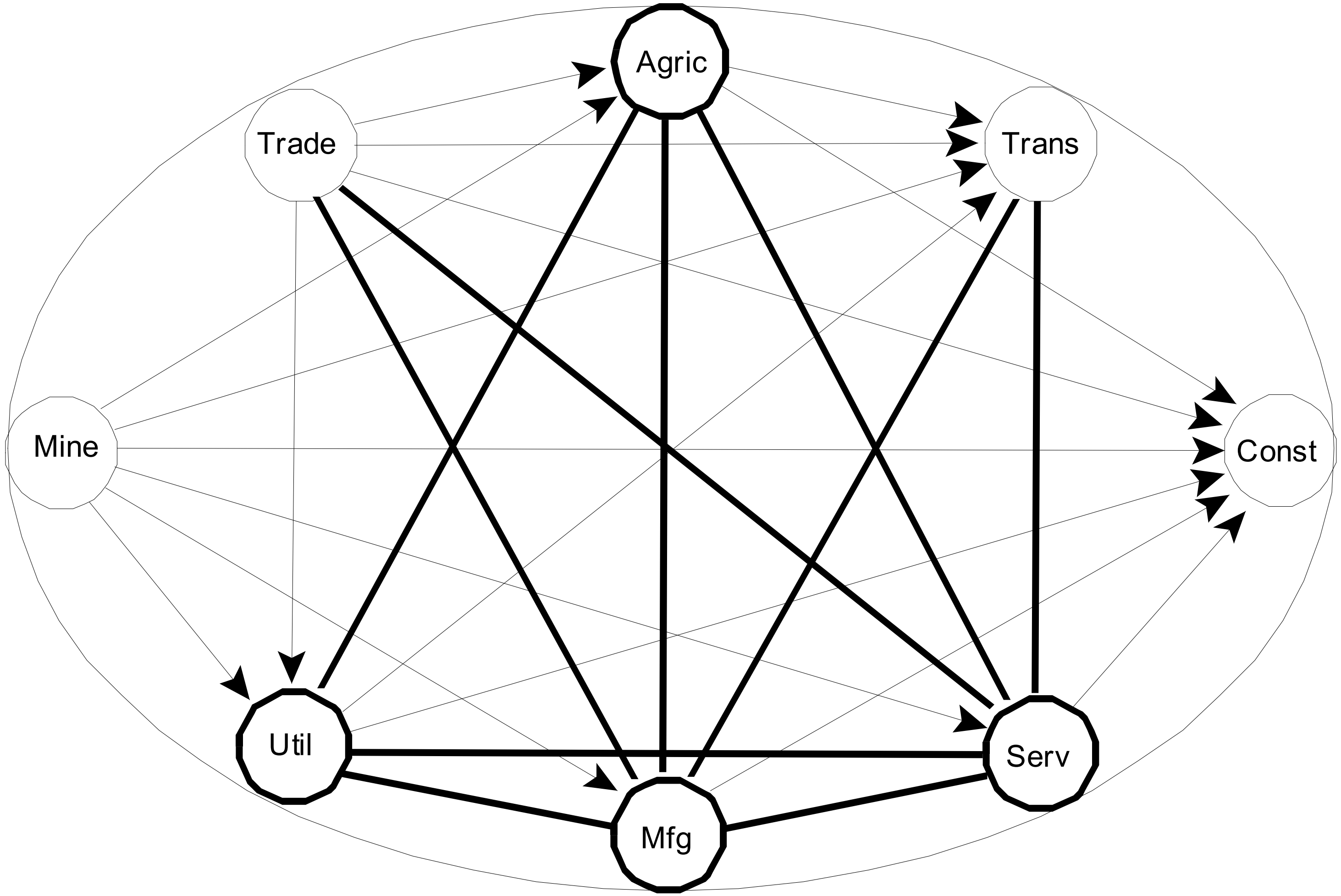


Figure 9a. MFA Structural Links, Taiwan 1976

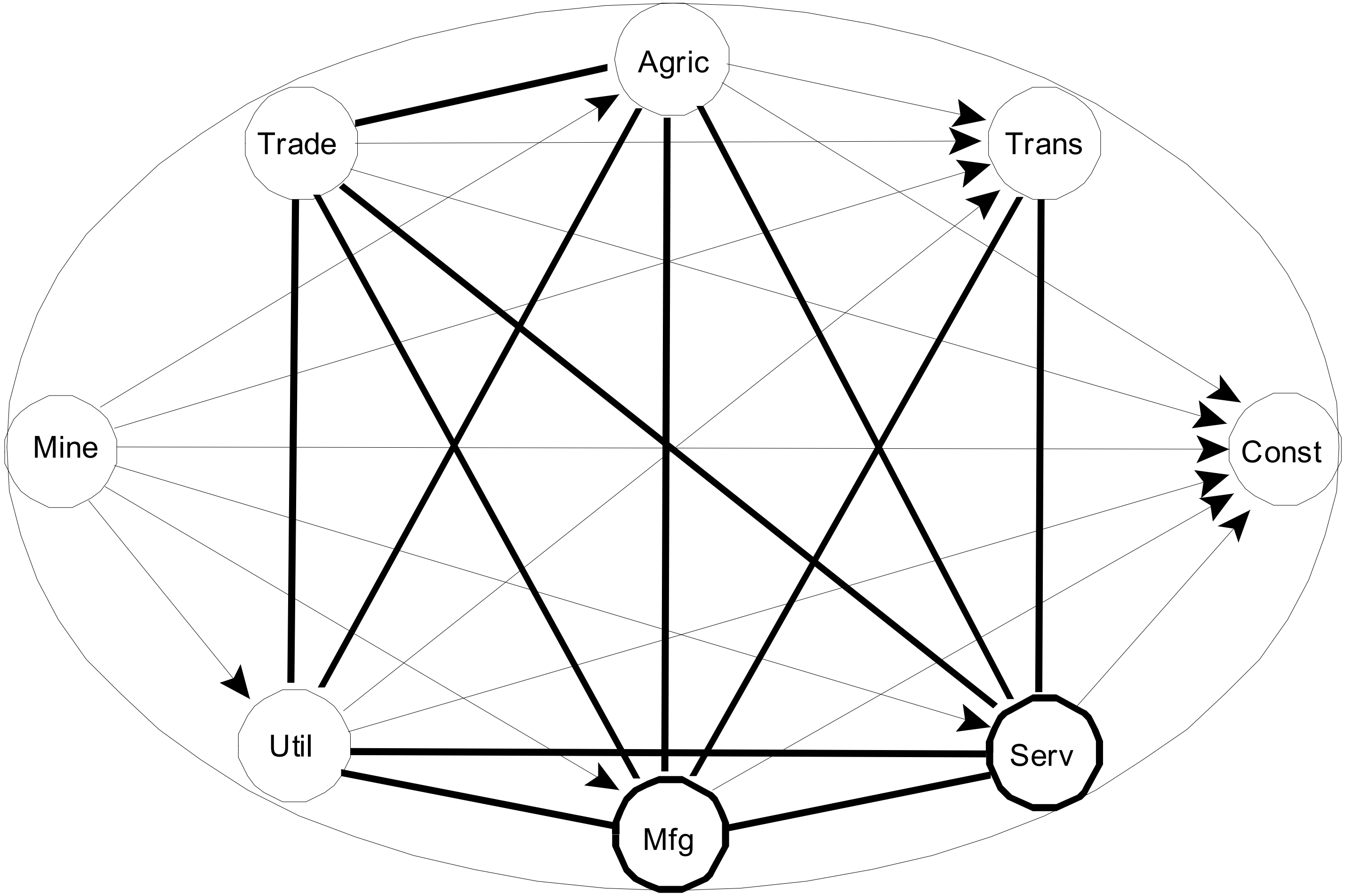


Figure 9b. MFA Structural Links, Taiwan 1981

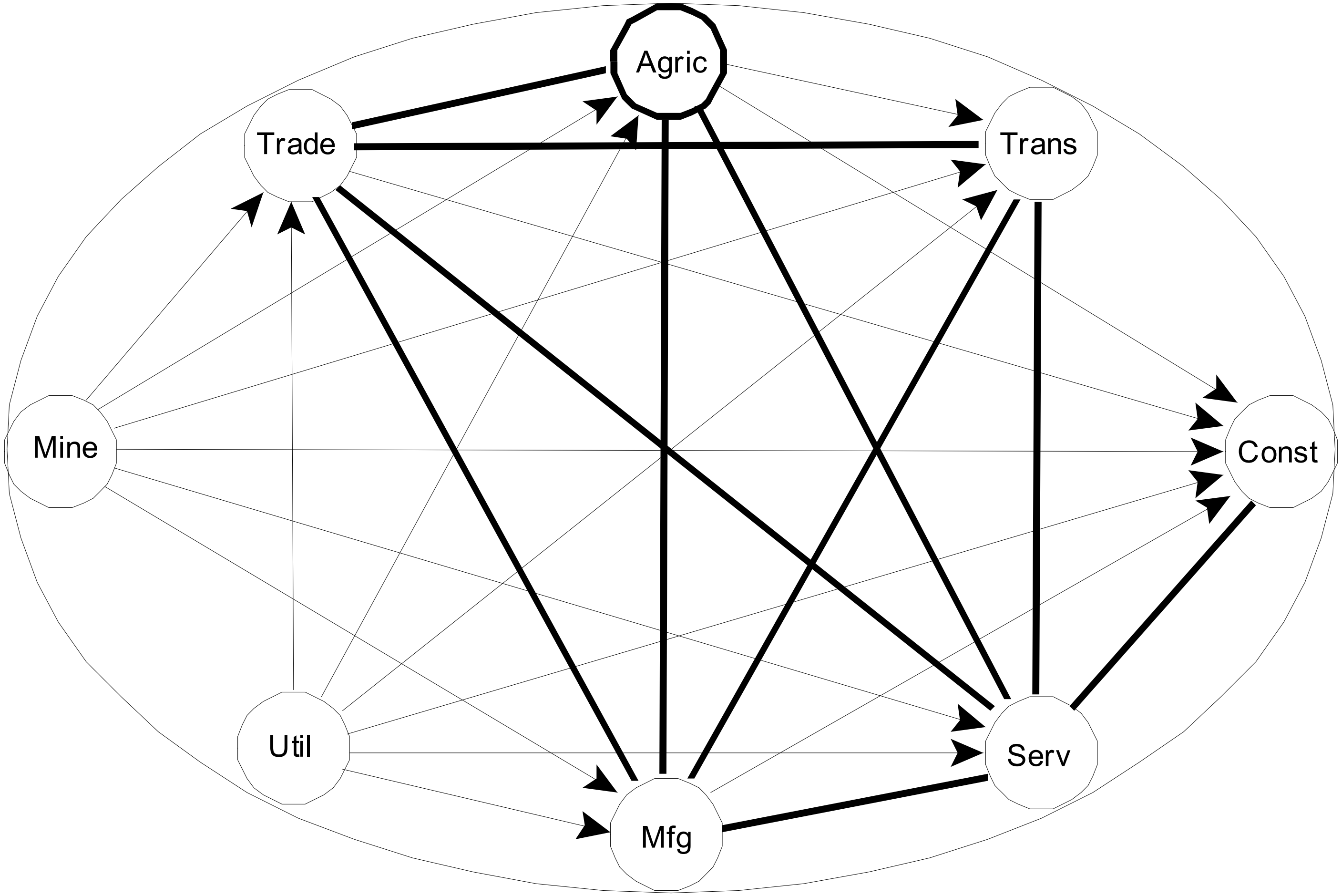


Figure 9c. MFA Structural Links, Taiwan 1986

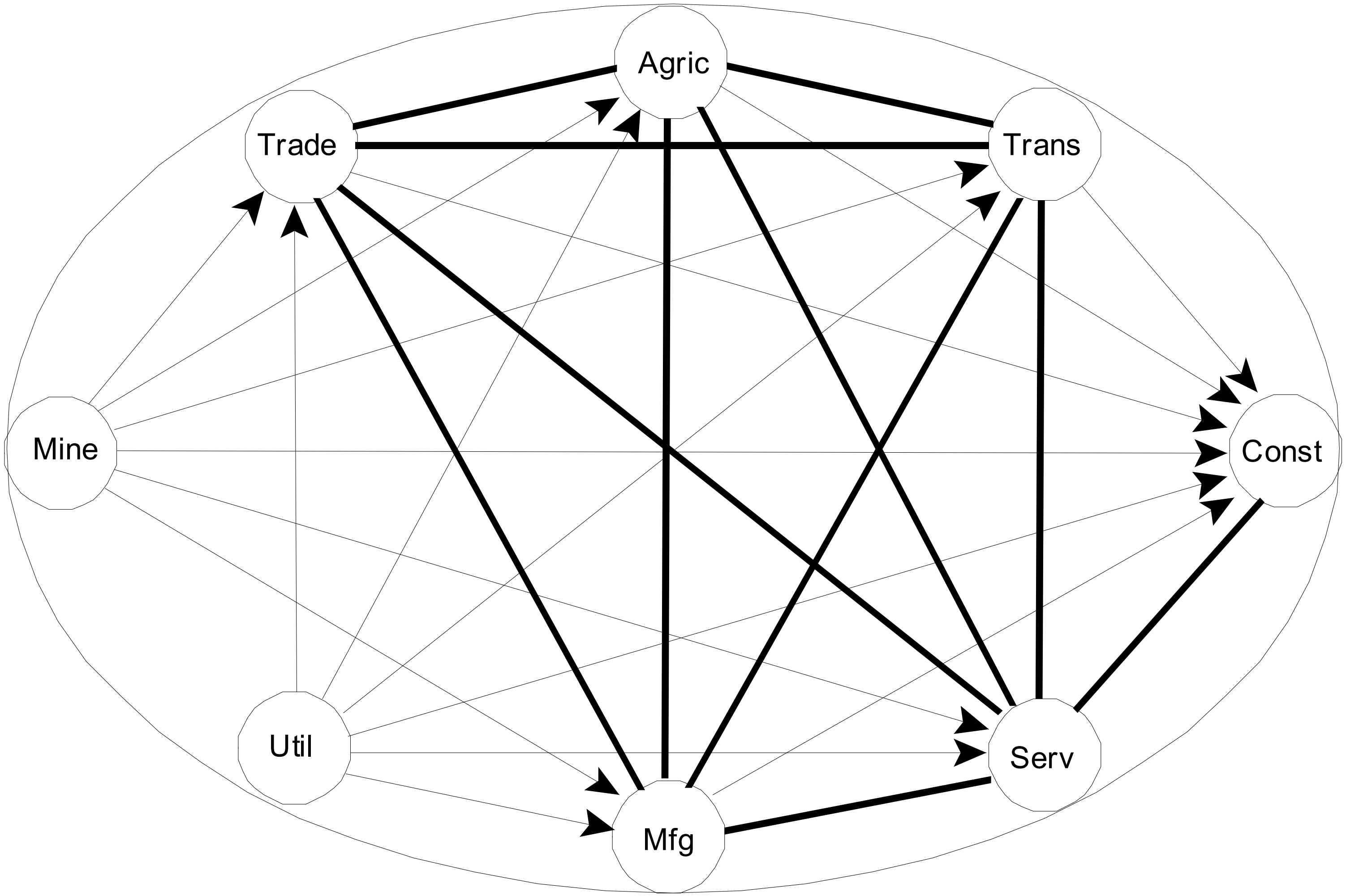


Figure 9d. MFA Structural Links, Taiwan 1989

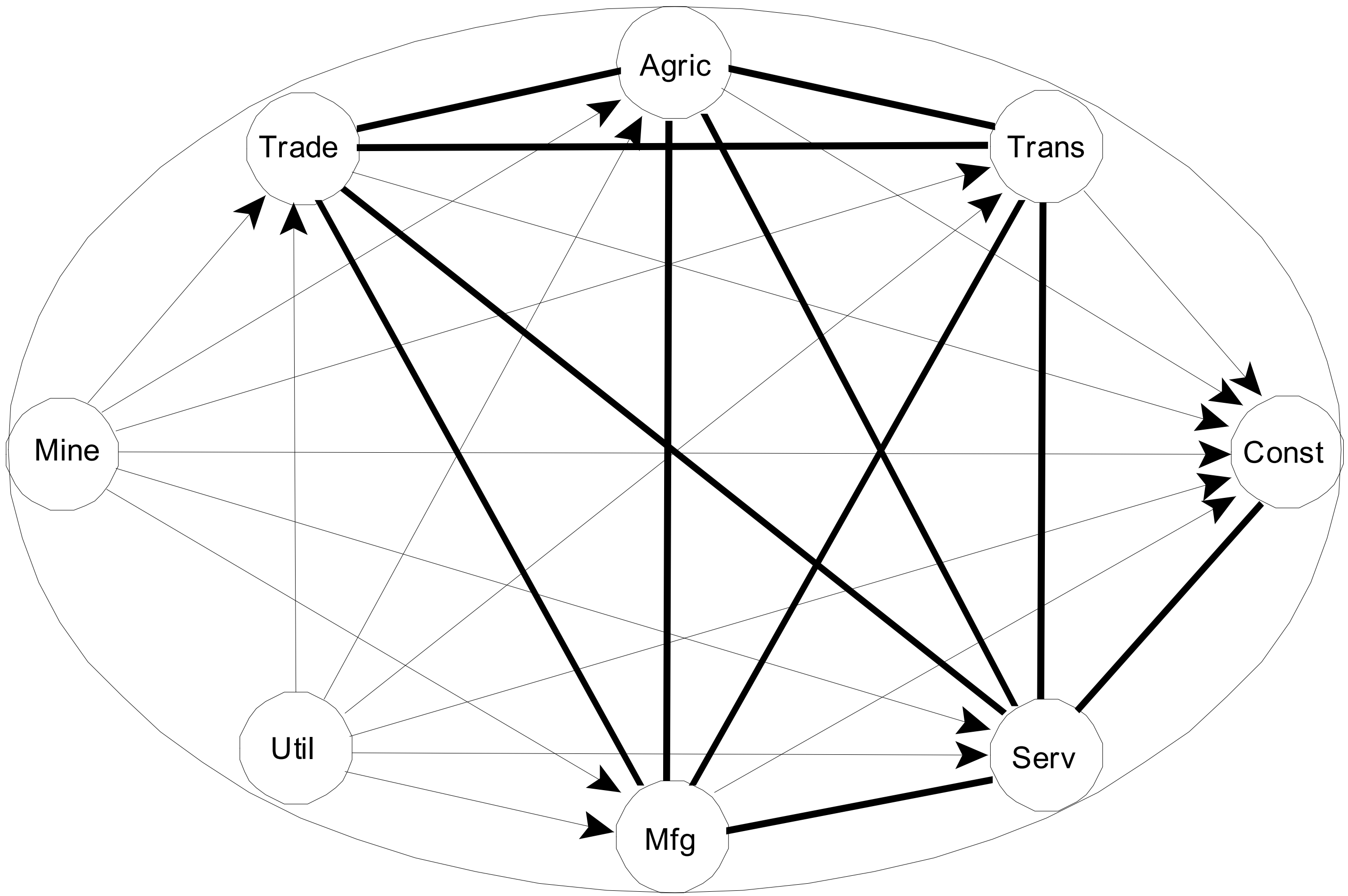


Figure 9e. MFA Structural Links, Taiwan 1991

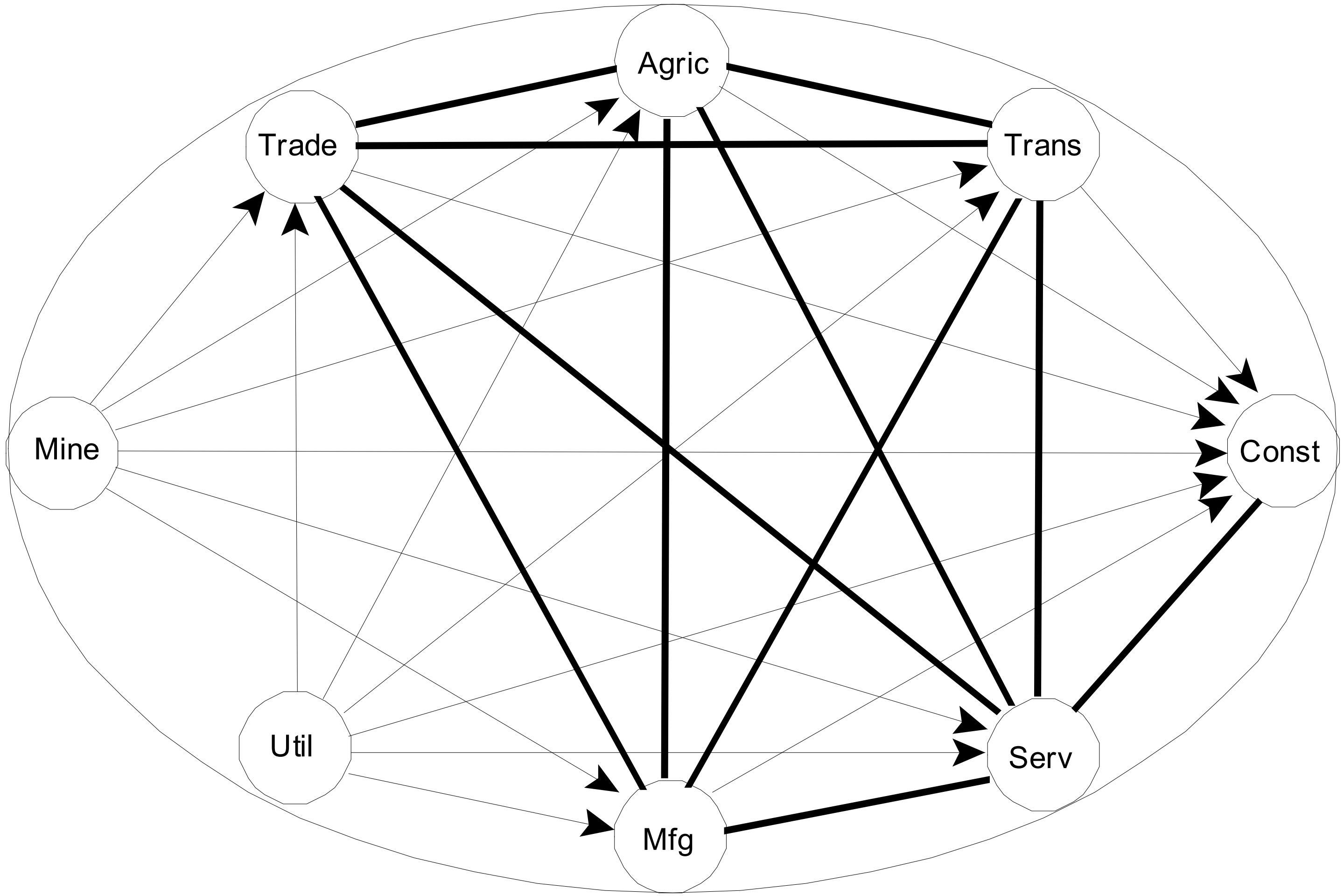


Figure 9f. MFA Structural Links, Taiwan 1994

Manufacturing, *Utilities* and *Services* are initially classified as central sectors in 1976, but *Agriculture* and *Utilities* drop out by 1981. By 1989 there are no central sectors left.

***Sink Sectors*:** Initially, in 1976 and 1981, only *Construction* and *Transport* were identified as sink sectors. Since then, there has been a progressive shift of all sectors except *Minerals* and *Utilities* into the sink category. This again reinforces the notion of a weakening of the intersectoral core, with no central sectors of substance to act as intermediaries and a predominance of flows from *Minerals* and *Utilities* to the other sectors. Whilst there are bilateral trade links with *Trade*, *Agriculture*, *Manufacturing*, *Transport* and *Services*, the flows are predominately out rather than in.

3.4.4 Bilateral links between sectors

Bilateral links denote connections where sector *i* is both a source and sink sector for goods and services to/from sector *j* to the extent that both deliveries are above the MFA-filter level. This is due to the fact that both input coefficients a_{ij} and a_{ji} are considered high compared to other sectoral links. As a consequence we could view both sectors *i* and *j* as a growth dipol, since if one sector enhances its production (for whatever reason) this will stimulate the other sector which in turn will result in higher demand for products from the first sector. Thus sectors *i* and *j* form a growth core of the economy which in principle can even be linked to a (bilateral) chain, star or triangle.

In Taiwan, bilateral connections initially revolve around the *Agriculture-Utilities-Manufacturing-Services* group of sectors with *Trade* and *Transport* linked to a lesser degree. Over time, *Trade* and *Transport* become more important as they occupy a central position between the source and sink sectors. *Utilities*, on the other hand, loses its status as an intermediary and becomes a pure source sector by 1986.

The MFA clearly shows that Taiwan has experienced structural shifts over the sample period. For example, we can clearly see how *Transport* and *Trade* have emerged as significant nodes and how *Utilities* has diminished in standing from being a part of 4 growth diapoles to a simple source sector. This would seem to indicate a gradual and progressive shift towards a developed market economy, where economic coordination occurs, to an increasing extent, through market intermediation. This also coincides with a slowing-down of Taiwan's economic growth, associated with a rapid appreciation of the currency, rising real wages and declining exports (Wang [40]). Since the mid-1980s there has been a rapid decline in the more labour-intensive industries as Taiwanese capital started to move offshore, to mainland China and other South-East Asian economies with lower labour costs (Amsden and Chu, [3]; Lin [26]).

4. SUMMARY AND CONCLUSION

The analysis confirms that there has been a shift in economic structure of the Taiwanese economy. Firstly, there has been a pronounced shift in emphasis from primary activities to secondary and tertiary activities. This has resulted in a more dichotomous structure emerging in the sense that sectors can be identified as belonging predominately to either a source or sink category. For example, *Minerals* has dominant forward linkages (i.e. is a source sector), as demonstrated by all three techniques used in this paper (linkage, key sector and minimal flow analyses), whereas *Construction* is similarly shown to have dominant backward linkages (i.e. is a sink sector). Even the demand for manufactures has decreased, shifting *Manufacturing* out of the central category into the sink category. This has been associated with an increase in import reliance.

Secondly, it can be clearly seen from both the key sector analysis and minimal flow analysis that the Taiwan economy reached a peak in terms of intersectoral complexity in 1981 before going into decline. This may be a direct consequence of the shifts in sectoral emphasis noted above, as service industries require less physical inputs. This phenomenon is not unique and may be associated with the movement of more labour intensive, intermediate industries to low-wage countries, especially China, as part of the globalization process. As trade barriers fall and 'microeconomic' reform policies bite, there is increased specialisation and both vertical and horizontal integration of industry structures. Government agencies no longer feel the need to support inefficient industries, with consequent shifts in economic structure towards perceived industries with comparative advantage and increased import reliance for other commodities.

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