IPS Working Papers

SINGAPORE INFORMATION SECTOR: A STUDY USING INPUT-OUTPUT TABLES

TOH MUN HENG
and
SHANDRE M THANGAVELU

September 2010
IPS Working Papers No. 18

Institute of Policy Studies

About Institute of Policy Studies (IPS)

The Institute of Policy Studies (IPS) was established in 1988 to promote a greater awareness of policy issues and good governance. Today, IPS is a think-tank within the Lee Kuan Yew School of Public Policy (LKYSPP) at the National University of Singapore. It seeks to cultivate clarity of thought, forward thinking and a big-picture perspective on issues of critical national interest through strategic deliberation and research. It adopts a multi-disciplinary approach in its analysis and takes the long-term view. It studies the attitudes and aspirations of Singaporeans which have an impact on policy development and the relevant areas of diplomacy and international affairs. The Institute bridges and engages the diverse stakeholders through its conferences and seminars, closed-door discussions, publications, and surveys on public perceptions of policy.

IPS Working Papers No. 18

SINGAPORE INFORMATION SECTOR: A STUDY USING INPUT-OUTPUT TABLES

TOH MUN HENG
Associate Professor
Department of Business Policy, School of Business
National University of Singapore

and

SHANDRE M THANGAVELU*
Associate Professor
Department of Economics, Faculty of Arts and Social Sciences
National University of Singapore
e-mail: ecssmt@nus.edu.sg

September 2010

CONTENTS

SINGAPORE INFORMATION SECTOR: A STUDY USING INPUT-OUTPUT TABLES

Abstract

The paper measures the impact of information technology on the output growth of Singapore economy. A vibrant Information sector will play an important catalytic role in developing Singapore into a knowledge-based economy. The analysis provided in the paper support the assertion that the Information Economy will be a precursor to a knowledge-based economy. The Information sector grew in tandem with the expansion of export in the first half of the 1990s. By the second half of the 1990s, it developed sufficient momentum and capability to expand domestically as a cluster. The use of ICT as intermediate input is found to be generally pervasive in the economy.

The paper also investigates the impact of falling prices of information input on sectoral GDP. It is found that for a 10% decrease in information input prices, the sector GDPs increase by 0.05% to 2.2%. The overall impact for the economy is a positive 0.84% increase in national income (GDP) for a 10% decline in information input prices.

SINGAPORE INFORMATION SECTOR: A STUDY USING INPUT-OUTPUT TABLES

1. INTRODUCTION

The development and use of Information and Communication Technology (ICT) is one of the main drivers of the 'knowledge economy', which is now closely associated with the idea of the 'new economy'. We have already seen more than three decades of dramatic improvements in the usage and declining cost of IT hardware and software. In fact, the 'IT revolution' has become an important feature of economic dynamism and long-term growth of most economies.

ICT has become pervasive and crucial for the continual growth and development of economies. Indeed, ICT has also played a significant role in globalisation of production and technology transfer. The interaction between the Internet, mobile telecommunications, digital TV, 'bluetooth' technology, e-commerce, and new models of business organisation are creating opportunities in the global economy. Global corporations appear to have been threatened by new start-ups from these new emerging technologies and thus are aligning their marketing strategies to maintain their market share. ICT has enabled small companies to emerge as strong competitors in the global economy in a short span of time. Thus ICT is becoming an essential means for accessing new skills and knowledge, and it has also become a tool for extending the management frontier and marketing space for international corporations. As a general purpose technology (GPT), it is observed that labour productivity and total factor

productivity are high in industries that use ICT intensively (O'Mahony & Van Ark, 2003).

Singapore's remarkable success in hosting more than 6,000 top foreign corporations is largely due to its strategic location, excellent communication infrastructure and an environment that is friendly to new technologies. The strong institutions and public sector have been in the forefront in adopting ICT for its interaction with the private sector. It has made much effort to streamline the policy framework to meet the challenges of the evolving situation and adapt to the 'new economy'. This has enabled ICT to play an important catalytic role in informatising the economy for further growth.

In analysing the economic impact of the ICT, it is therefore important to understand whether the particular technology effect is primarily concerned with production or diffusion. We used two measures to evaluate the impact of ICT on the economy. The success of ICT could be measured by capturing a reasonable share of the world market for a fast-growing, technologically-advanced product, which is primarily concerned with *production*. On the other hand, the success of ICT could also be measured by securing the benefits of lower prices, increased productivity or taking advantage of the opportunities offered by a new product to underpin improved competitiveness in other activities, which is primarily concerned with *diffusion*. We adopt the input-output approach to shed light on both production and diffusion aspects of the Information sector.

After a quick overview of the role of IT in Singapore's economic development, we begin to consider the extent of the informatisation of the Singapore economy during the period from 1990 to 2000. Using the causative matrix approach the information intensities for different industries are measured and analysed. The sources of growth of the Information Sector are identified using a structural decomposition analysis. Finally, the impact of falling prices of ICT products on the GDP of individual sectors and the economy as a whole is evaluated and measured.

2. THE IT STRATEGY & EXTENT OF INFORMATISATION IN SINGAPORE

2.1 Role of IT in Singapore's economic development

By the end of the 1970s, there was a single-minded emphasis among policy makers on escalating the level of technology in order to implement the succeeding phases of Singapore's industrial revolution. They relied on IT as the strategy's principal instrument. The Telecommunications Authority of Singapore (Telecoms) was a key to the strategy because of the high calibre of its services and products and because the telecommunications industry had an important role in the progress of every industry in Singapore. Summary statistics in Table 1 show that the Info-communications sector grew at almost twice as fast as the whole economy between 1980 and 2008. In 1980 it barely contributed 1 per cent of the GDP, and by 2008, its contribution to GDP had expanded to 4.4%.

Table 1: Info-Communications sector and the real economy

	Real GDP at 2000 prices	Manufacturing	Services	Info-Comms Sector	Electronics as % of MFG
	%	%	%	%	%
1980	100.0	27.4	71.6	0.9	20.4
1985	100.0	21.8	76.8	1.4	25.5
1990	100.0	26.3	71.9	1.8	31.1
1995	100.0	25.2	72.4	2.4	40.0
2000	100.0	25.7	70.7	3.6	44.2
2005	100.0	25.6	70.1	4.3	34.0
2008	100.0	24.6	71.0	4.4	26.3
	S$Bill	**S$Bill**	**S$Bill**	**S$Bill**	**S$Bill**
2008	233.5	57.5	165.7	10.3	15.1
Growth(%) 1980-2008	6.5	6.1	6.5	12.1	7.1

A second key was computers and related electronics, which in the late 1980s constituted Singapore's largest industry, measured both in numbers of jobs and in value added by the Manufacturing sector. In 1981 the 65,000 to 70,000 Electronics sector workers comprised about 7 percent of the labour force; gross production of electronics at about S$5.9 billion was about 15 percent of total manufacturing output. By 1990, electronics accounted for 31 percent of manufacturing value added. In the same year, Singapore had become the world's largest producer of disk drives and disk drive parts. Other related products included integrated circuits, data processing equipment, telecommunications equipment, and radio receivers. While the dominance of the Electronics sector has been overtaken by the Biomedical and Pharmaceutical sectors in recent years, it still contributed more than 26 percent of manufacturing value added in 2008.

Aside from producing high value added exports, the Computer and Electronics industries played a vital role in raising manpower productivity in other technology-intensive industries through computerisation and computer communications. The National Computer Board was formed in 1981 to establish Singapore as an international centre for computer services, to reduce the shortage of trained computer professionals, and to assure standards of international calibre at all levels.

The Asian "copyright revolution" is said to have started in Singapore. In early 1980s, copyright and "intellectual property" issues served as an impediment to computer and other industrial development. In joining the international knowledge network as producers as well as consumers, Singapore passed its first copyright law in 1986. There was rigorous enforcement in areas relating to use of computer software, films, and cassette tapes, and book publication. By the mid-1980s, the small but growing printing and publishing industry had entered the high-technology world with computerised typesetting, colour separation, and book binding. Its high quality printing facilities and sophisticated satellite telecommunications network made Singapore a regional publishing and distribution centre in 1990.

Table 2: National IT plans in Singapore

	National IT Plans	Focus	Government IT Plans
1980-1985	National Computerisation Plan	ICT Infrastructure; Business Sector Usage; HRD	Civil Service Computerisation Program
1986-1991	National IT Plan	+Industry Collaboration+ IT Culture	
1992-2000	IT 2000: Intelligent Island	+Pervasive IT Connectivity & Services +IP thru R&D Activities	
2000-2003	Infocomm21: Infocomm Capital	+E-Society: Govt; IT Industry; Manpower	e-Government Action Plan I
2003-2006	Connected Singapore	+ Enhanced Connectivity + Innovation	e-Government Action Plan II
2006-2015	Intelligent Nation 2015	+Entrepreneurship	iGov2010

In guiding the implementation of the IT strategies, policy makers in Singapore prepared several plans and road maps over the years (Table 2). The IT movement was jump-started with the National Computerisation Plan in 1980 with the Civil Service Sector taking the lead. Subsequently, plans were drawn up to enhance usage of IT in both private and public sectors. At each stage, pertinent infrastructure and institutions were built and established to support the informatisation and digitalisation of the economy and the community.

2.2 The extent of informatisation

To study the extent of the informatisation of the Singapore economy during 1990 to 2000, the left causative matrix model has been employed. In a model suggested by Lipstein (1968) causative matrix C maps or transforms one transition probability matrix into the next.

$$P_{t+1} = C.P_t$$

$$\rightarrow \quad C = P_{t+1}P_t^{-1}$$

Obviously, if the matrix C is an identity matrix, it will connote that the transition probability matrix has remain unchanged during the two periods. In general, C is not an identity matrix, and the element c_{ij} represents the influence of state i on the changing probabilities of transition to state j, relative to the influences of any other state.

To operationalise the use of causative matrix for input-output analysis, in place of the transition probability matrix, the standardised Leontief inverse matrix is used. The elements of each column of the Leontief inverse are normalised (which yields the matrix L) by their respective column sums. This standardises for change in magnitudes of the output multipliers and focuses the analysis upon the relative effects upon one and another (Jackson et.al, 1990; Roy et.al, 2002).

Thus, the model is written as: $L^{t+1} = C.L^t$. A typical element of L^{t+1} is written as

$$l_{ij}{}^{t+1} = c_{i1}l_{1j} + c_{i2}l_{2j} + \ldots + c_{in}l_{nj}$$

where the ts have been dropped on the right hand side for expositional clarity. Sector *i*'s contribution to sector *j*'s output multiplier in the next period is a linear function of all sectors' previous contributions to sector *j*'s output multiplier. A negative c_{ik} implies a reduction in sector *i*'s contribution to *j*'s output multiplier due to the presence of sector k. Element c_{ik} is, therefore, interpreted as sector k's influence on sector *i*'s ability to contribute to the output multipliers of other sectors. All column sums of C equal 1.

The sum of the elements in each row of the causative matrix is interpretable as a sort of final demand multiplier. When the sum is greater than unity, it indicates greater contributions to output multiplier. This indicates that the sector experienced greater output changes influence by the changes in the final demand of other sectors. Row sums less than one indicate that impacts from final demand changes are weakening. Negative deviations of the diagonal elements of the sectors from unity imply decreased relative internalisation of their own final demand output impacts. The causative matrix approach has the advantage of capturing both the direct changes in interactions and the relative changes due to the presence of other sectors.

2.3 Data

The basic data used in our study are from the three input-output tables of the Singapore economy for the years 1990, 1995 and 2000 prepared by the Department of Statistics, Singapore. The input-output tables are made

manageable and comparable by suitable aggregation to 39 sectors. The 39 sectors are grouped into two broad categories: information and non-information. The Information sector is defined as those activities that intrinsically convey information process, produce or distribute information. The Information sector, therefore, includes publishing (34), computer and computer peripherals (35), electronics and communication products (36), communications (37) information technology services (38), education & training (39). Those activities that do not satisfy the above criteria are termed as non-information. The list of sectors is provided in Appendix A.

2.4 Results

The causative matrix is computed for the period 1990 to 1995 and also for the period 1995 to 2000. The table in Appendix B presents relevant statistics extracted from the causative matrix for the two periods. The tables show that the row sum corresponding to the Information sector is larger than one for both periods. This implies that the final demand in other sectors has generated increased impacts on the Information sector. Furthermore, the row sum in the second period (1995 – 2000) is larger than that in the first sub-period, substantiating the observation of rising informatising intensity during the decade of 1990s.

For the Information sector, we find that the diagonal element $c_{34,34}$ exceeds unity for both sub-periods. Hence, relative to the impacts on the other sectors, the final

demand of the Information sector has stimulated an enhanced output impact on the Information sector itself throughout the 1990s. The impact is greater in the second sub-period as compared to the first. This implies that the sector was in a phase of expansion and relative endogenisation of its impacts. It reflects the rapid expansion of the Information cluster, entrenching the electronic value chain in Singapore.

Following Roy et. al. (2002), sectors are classified according to (a) the deviation of their diagonal elements from one, with positive deviation indicating increased relative indigenisation of their own final demand output impacts, and (b) the deviation from zero of the sums their respective off-diagonal elements, with positive deviation reflecting increased relative output impacts on the sector engendered by final demand in all other sectors. Table 3 shows that industries classified according to the above criteria for the sub period 1990-1995. Table 4 presents similar information for the second sub period, 1995 to 2000.

Table 3: Typology of structural change during 1990 to 1995, based on the left causative matrix method

	ODE < 0	ODE > 0
Cii > 1	**IV** 5 Leather & Leather Products 12 Plastics & Plastic Products 22 Gas and Water Supply 23 Construction 28 Banking & Insurance 29 Business Services	**I** 2 Processed Food 3 Beverage & Tobacco 6 Wood & Wood Products 11 Rubber & Rubber Products 13 Non-Metallic Products 18 Transport Equipment 27 Port Operation Services 34 INFORMATION
Cii < 1	**III** 1 Agri, Forest, Fish & Quarry 7 Paper & Paper Products 8 Printing 10 Chemicals 14 Metals & Metal Products 15 Non-Electrical Machinery 16 Electrical Industrial Machine 17 Electrical Appliance & Eqpt 25 Hotel & Restaurant 30 Medical & Health 32 Personal Services	**II** 4 Textiles & Apparel 9 Petroleum & Petrol Products 19 Precision Instruments 20 Misc. Manufacturing 21 Electricity 24 Wholesale & Retail 26 Transportation Services 31 Recreational Services 33 Other Services

Note: * ODE = sum of off-diagonal elements in each row

The Information sector falls in the Type I category for both sub-periods. The expansion and growth of the Information sector was very much demand-driven during the 1990s. It also reflects the widespread adoption of ICT by other sectors generating demand for products from the Information sector.

Table 4: Typology of structural change during 1995 to 2000, based on the left causative matrix method

	ODE < 0	ODE > 0
Cii > 1	**IV** 1 Agri, Forest, Fish & Quarry 3 Beverage & Tobacco 4 Textiles & Apparel 5 Leather & Leather Products 7 Paper & Paper Products 14 Metals & Metal Products 15 Non-Electrical Machinery 16 Electrical Industrial Machine 18 Transport Equipment 19 Precision Instruments 20 Misc. Manufacturing 24 Wholesale & Retail	**I** 10 Chemicals 17 Electrical Appliance & Eqpt 21 Electricity 26 Transportation Services 34 INFORMATION
Cii < 1	**III** 2 Processed Food 6 Wood & Wood Products 8 Printing 9 Petroleum & Petrol Products 11 Rubber & Rubber Products 13 Non-Metallic Products 27 Port Operation Services 28 Banking & Insurance 32 Personal Services	**II** 12 Plastics & Plastic Products 22 Gas and Water Supply 23 Construction 25 Hotel & Restaurant 29 Business Services 30 Medical & Health 31 Recreational Services 33 Other Services

Note: * ODE = sum of off-diagonal elements in each row

3. INFORMATION INTENSITY OF THE SINGAPORE ECONOMY

In the previous section, we established that the Information sector had increased its endogenisation during the 1990s and it is enjoying increased output impact arising from growth in the final demand of other sectors. In this section, we attempt to measure the information intensity of various sectors and their changes over the two sub-periods.

The first intensity measure is the ratio of the amount if information products used per unit of output. Denoting this ratio for sector i by h_i, we can proceed to obtain a second measure (h_i*) that account for both direct and indirect use of information products. In matrix form,

$$H^{*\prime} = H'(I-A)^{-1}$$

where $H^{*\prime}$ is the row vector with element h_i*, and H' is the row vector with element h_i; and $(I-A)^{-1}$ is the standard Leontief inverse matrix.

The vector H and H* have been calculated for the years 1990, 1995 and 2000, and the results are presented in Table 5.

Table 5A: Information coefficients of various sectors for 1990, 1995 and 2000

		Direct Info Used				
	Industry	**2000**	**1995**	**1990**	**Change: 1990-95**	**Change: 1995-00**
1	Agri, Forest, Fish & Quarry	0.0128	0.0057	0.0036	0.0020	0.0071
2	Processed Food	0.0072	0.0038	0.0048	-0.0009	0.0034
3	Beverage & Tobacco	0.0137	0.0068	0.0180	-0.0112	0.0069
4	Textiles & Apparel	0.0072	0.0053	0.0047	0.0006	0.0019
5	Leather & Leather Products	0.0046	0.0033	0.0035	-0.0002	0.0013
6	Wood & Wood Products	0.0097	0.0054	0.0051	0.0003	0.0043
7	Paper & Paper Products	0.0080	0.0049	0.0044	0.0005	0.0031
8	Printing	0.0181	0.0077	0.0151	-0.0074	0.0104
9	Petroleum & Petrol Products	0.0043	0.0019	0.0009	0.0011	0.0023
10	Chemicals	0.0063	0.0057	0.0062	-0.0005	0.0005
11	Rubber & Rubber Products	0.0061	0.0047	0.0043	0.0004	0.0014
12	Plastics & Plastic Products	0.0072	0.0068	0.0038	0.0030	0.0004
13	Non-Metallic Products	0.0076	0.0042	0.0102	-0.0061	0.0034
14	Metals & Metal Products	0.0124	0.0194	0.0049	0.0144	-0.0069
15	Non-Electrical Machinery	0.0115	0.0107	0.0120	-0.0013	0.0008
16	Electrical Industrial Machine	0.0227	0.0198	0.0183	0.0015	0.0028
17	Electrical Appliance & Eqpt	0.0376	0.0312	0.0107	0.0205	0.0064
18	Transport Equipment	0.0134	0.0107	0.0063	0.0044	0.0028
19	Precision Instruments	0.0169	0.0137	0.0087	0.0050	0.0032
20	Misc. Manufacturing	0.0054	0.0069	0.0054	0.0016	-0.0015
21	Electricity	0.0012	0.0029	0.0070	-0.0041	-0.0016
22	Gas and Water Supply	0.0111	0.0121	0.0054	0.0067	-0.0010
23	Construction	0.0057	0.0022	0.0020	0.0002	0.0035
24	Wholesale & Retail	0.0336	0.0294	0.0255	0.0040	0.0041
25	Hotel & Restaurant	0.0146	0.0130	0.0160	-0.0030	0.0016
26	Transportation Services	0.0235	0.0095	0.0118	-0.0023	0.0140
27	Port Operation Services	0.0211	0.0086	0.0148	-0.0062	0.0125
28	Banking & Insurance	0.0444	0.0216	0.0221	-0.0005	0.0228
29	Other Business Services	0.0496	0.0234	0.0324	-0.0091	0.0262
30	Medical & Health	0.0255	0.0149	0.0123	0.0026	0.0106
31	Recreational Services	0.0338	0.0135	0.0142	-0.0007	0.0203
32	Personal Services	0.0177	0.0106	0.0089	0.0017	0.0070
33	Other Services	0.0435	0.0154	0.0092	0.0062	0.0281
34	INFORMATION	0.0530	0.0260	0.0431	-0.0170	0.0270

Table 5B: Information coefficients of various sectors for 1990, 1995 and 2000

	Industry	Total Information Used				
		2000	1995	1990	Change: 1990-95	Change: 1995-00
1	Agri, Forest, Fish & Quarry	0.0276	0.0142	0.0114	0.0028	0.0135
2	Processed Food	0.0174	0.0105	0.0110	-0.0005	0.0069
3	Beverage & Tobacco	0.0282	0.0197	0.0267	-0.0070	0.0085
4	Textiles & Apparel	0.0149	0.0108	0.0091	0.0017	0.0041
5	Leather & Leather Products	0.0121	0.0092	0.0090	0.0003	0.0029
6	Wood & Wood Products	0.0218	0.0120	0.0117	0.0003	0.0099
7	Paper & Paper Products	0.0144	0.0097	0.0085	0.0013	0.0047
8	Printing	0.0281	0.0129	0.0210	-0.0081	0.0152
9	Petroleum & Petrol Products	0.0068	0.0036	0.0022	0.0014	0.0032
10	Chemicals	0.0113	0.0111	0.0110	0.0001	0.0001
11	Rubber & Rubber Products	0.0127	0.0098	0.0103	-0.0006	0.0029
12	Plastics & Plastic Products	0.0131	0.0113	0.0087	0.0025	0.0018
13	Non-Metallic Products	0.0157	0.0102	0.0177	-0.0075	0.0055
14	Metals & Metal Products	0.0212	0.0267	0.0102	0.0165	-0.0055
15	Non-Electrical Machinery	0.0201	0.0175	0.0180	-0.0005	0.0026
16	Electrical Industrial Machine	0.0292	0.0248	0.0231	0.0017	0.0045
17	Electrical Appliance & Eqpt	0.0468	0.0389	0.0147	0.0242	0.0079
18	Transport Equipment	0.0249	0.0193	0.0128	0.0064	0.0056
19	Precision Instruments	0.0230	0.0189	0.0132	0.0057	0.0040
20	Misc. Manufacturing	0.0139	0.0146	0.0112	0.0034	-0.0007
21	Electricity	0.0050	0.0058	0.0103	-0.0045	-0.0008
22	Gas and Water Supply	0.0189	0.0145	0.0092	0.0053	0.0045
23	Construction	0.0178	0.0087	0.0091	-0.0004	0.0091
24	Wholesale & Retail	0.0518	0.0404	0.0377	0.0027	0.0114
25	Hotel & Restaurant	0.0317	0.0215	0.0253	-0.0037	0.0102
26	Transportation Services	0.0325	0.0152	0.0173	-0.0021	0.0173
27	Port Operation Services	0.0314	0.0132	0.0224	-0.0092	0.0182
28	Banking & Insurance	0.0585	0.0281	0.0314	-0.0034	0.0304
29	Other Business Services	0.0648	0.0304	0.0421	-0.0117	0.0344
30	Medical & Health	0.0383	0.0211	0.0231	-0.0020	0.0173
31	Recreational Services	0.0552	0.0229	0.0238	-0.0008	0.0323
32	Personal Services	0.0341	0.0198	0.0186	0.0012	0.0143
33	Other Services	0.0571	0.0218	0.0146	0.0072	0.0354
34	INFORMATION	0.0598	0.0294	0.0481	-0.0187	0.0303

With the exception of three industries, metal and metal products (14), miscellaneous manufacturing (20) and electricity (21), all industries had shown continual increase in information intensities in the second half of the 1990s. As shown in Table 6, 16 industries which had positive increase in their information intensity during 1990 to 1995, continued to record positive change during 1995 to 2000. Meanwhile, 15 industries had reversed their negative change in information intensity during the first half of 1990s to positive change during the second half of the 1990s.

Table 6: Changing information intensities during the two sub-periods

	Increase from 1995 to 2000	Decrease from 1995 to 2000
Increase from 1990 to 1995	1 Agri, Forest, Fish & Quarry 4 Textiles & Apparel 5 Leather & Leather Products 6 Wood & Wood Products 7 Paper & Paper Products 9 Petroleum & Petrol Products 10 Chemicals 12 Plastics & Plastic Products 16 Electrical Industrial Machine 17 Electrical Appliance & Eqpt 18 Transport Equipment 19 Precision Instruments 22 Gas and Water Supply 24 Wholesale & Retail 32 Personal Services 33 Other Services	14 Metals & Metal Products 20 Misc. Manufacturing
Decrease from 1990 to 1995	2 Processed Food 3 Beverage & Tobacco 8 Printing 11 Rubber & Rubber Products 13 Non-Metallic Products 15 Non-Electrical Machinery 23 Construction 25 Hotel & Restaurant 26 Transportation Services 27 Port Operation Services 28 Banking & Insurance 29 Business Services 30 Medical & Health 31 Recreational Services 34 INFORMATION	21 Electricity

4. SOURCES OF GROWTH OF INFORMATION SECTORS

For the purpose of identifying the sources of growth in the Information sector, a model based on structural decomposition analysis is used. Following Roy et.al. (2002), the change in output ($X_1 - X_o$) between two time points can be written as[1]:

$(X_1 - X_o) =$	$R_1\Sigma_h(\lambda-1)d_o^h$	Effect of growth in domestic final demand
	$+ R_1\Sigma_h(d_1^h - \lambda d_o^h)$	Effect of mix in domestic final demand
	$+ R_1(e_1 - e_o)$	Effect of change in export
	$+R_1 (A_1^I - A_o^I)X_o$	Technical coefficient effect: Information input
	$+ R_1 (A_1^N - A_o^N)X_o$	Technical coefficient effect: Non-Information input

where X_t = vector of output at time t; t =0, 1

R_1 = Leontief Inverse Matrix = $(I-A)^{-1}$ at time period 1

d^h = vector of domestic final demand of type h; domestic final demand includes consumption, government final demand expenditure, and gross capital formation.

e_t = vector of export at time t

A^I = technical coefficient matrix with entries equal zero except for the row and column corresponding to the Information sector.

A^N = technical coefficient matrix with entries equal zero except for the rows and columns corresponding to the non-Information sectors.

Λ = ratio of domestic final demand between any two periods.

[1] The decomposition formula presented is slightly different from that of Roy et.al.(2000). The import substitution effect is absent because import demand for each industry and final demand components is presented as entries in a row in the input-output table. Technically, the domestic supply ratio (u) takes the value of unity in every sector. The change in import demand is considered later in the section.

Table 7 presents the results of the decomposition exercise for the Information sector. During the first half of the 1990s, while there was an overwhelming growth in the Information sector due to the export expansion, the technical coefficient effects were relatively miniscule. However, in the second half of the 1990s, while export expansion effect was still dominant, domestic final demand effect (14%) played a more significant role relative to that (5.6%) of the previous sub-period. Concurrently, the technical coefficient effect had also become significant in the second half of the 1990s. In particular, the change in the technical coefficients of the Information sector was responsible for the bulk of the technical effect.

Table 7: Sources of growth for the Information Sector, 1990 - 2000

	1990 - 1995		1995 - 2000	
	S$m	%	S$m	%
Change in information output	43549.3	100.0	35729.6	100.0
Effect of growth in final demand	1827.2	4.2	2677.9	7.5
Effect of mix in final demand	626.4	1.4	2327.1	6.5
Export effect	41217.5	94.6	26499.4	74.2
Technical coefficient effect: Information	-199.3	-0.5	4387.9	12.3
Technical coefficient effect: Non-Information	77.5	0.2	-162.7	-0.5
Change in Import Requirement in Information Sector	29920.4	100.0	21097.7	100.0
Effect of change in output	25762.4	86.1	22434.4	106.3
Effect of change in import coefficients	4158.0	13.9	-1336.7	-6.3

Changes in output will lead to changes in the level of import demand. Of particular interest is whether import substitution is experienced in the Information sector. To check this effect, we decomposed the change in import requirement into two components: one due to the change in the information output, and the

other to the change in the import requirement per unit of information output. Symbolically, the change in import during two time periods is given as:

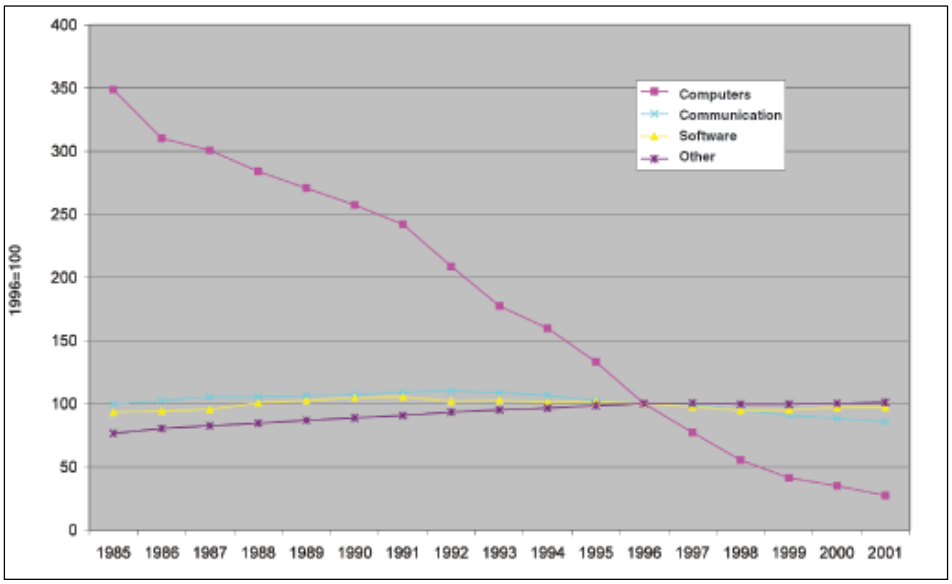
$$M_1 - M_o = m_1X_1 - m_oX_o$$

$$= [(m_1+m_o)/2](X_1 - X_o) + [(X_1+X_o)/2](m_1 - m_o)$$

where M_t = import at time t, and m = M/X

The decomposition of change in import requirement for the Information sector during the two sub-periods of the 1990s is shown in the last three rows of Table 7. During the first sub-period, 1990 to 1995, the increase in import requirement in the information is partly due to the increase in the import coefficient. However, in the second half of the 1990s, the import coefficient for the Information sector has declined, reflecting that some degree of import substitution had occurred.

Figure 1: Prices of ICT related products



Source: Tuomi, I. (July 2004), *Realising the Productivity Potential of ICTs*. Institute of Prospective Technological Studies (IPTS) Report, Issue 85.

5. IMPACT OF FALLING PRICES OF INFORMATION PRODUCTS

It is well known that the prices of information products have experienced a secular decline in their prices. This can be seen in Figure 1, which shows the price indices for computers, communications, software, and other products using 1996 prices as the base year. The product life cycles of such products are apparently shorter with new versions coming into the market in relatively short time. Concurrently, prices of such products exhibit tendency to decline due to firstly, need to dispose of older versions and stocks; secondly, rapid innovation and new products introduced into the market; and thirdly, keen global competition.

We note that the GDP of a given production sector can be measured as:

GDP = Gross Output – Intermediate Inputs – Primary Inputs

Symbolically:

$$GDP = P_yY = P_QQ – P_NN – P_ZZ - P_FF$$

where P_y denotes the price of Y, and Y is in real (quantity) value. Similar representations apply for the other inputs. Q is the gross output, N is quantity of information product, Z is non-information input, and F is for primary input like labour (L) and capital (K). Assuming that transaction is conducted in a competitive environment and enterprises maximise their profit subject to given technology, factor endowment and relative input prices, then Kohli (1978) and Woodland (1982) have shown that the GDP is the solution of the following optimisation problem:

$$GDP(P_Q, P_N, P_Z, F) = \max_{Q, J, Z}\{ P_QQ – P_NN – P_ZZ - P_FF : f(N, Z, F) \geqslant Q\}$$

The GDP function (national revenue function) is a function of prices of inputs, output and factor endowment. By invoking Duality Theory in Economics, the Sheppard Lemma indicates that the profit maximising demand for information products (N) can be obtained by the differentiation of the GDP function with respect to the price of information input:

$$\partial(\text{GDP})/\partial P_N = N(P_Q, P_N, P_Z, F)$$

Multiplying both sides of the equation by P_N/GDP, we have:

$$[\partial(\text{GDP})/\partial P_N](P_N/\text{GDP}) = N.P_N/\text{GDP}$$

➔ Elasticity of GDP with respect to price of information
= Ratio of Expenditure on information input to GDP

The ratio of expenditure in information input to GDP for each industry and for the whole economy can be estimated from the input-output table. In other words, the sensitivity of sectoral GDP to price of information input can be measured by the ratio of expenditure on information input to nominal GDP (not output) of the industry.

The economy-wide elasticity of GDP with respect to the price of information input is simply the weighted average of the information input price elasticities for the industries.

A graphical presentation of the results for the year 2000 and 1995 is shown in Figure 2 and Figure 3. For both years, three industries top the list of having the largest impact from a price decrease in information input: Information sector,

electrical appliances and equipment, and business services. The impact in 2000 was generally larger than that in 1995. More than half of the industries have GDP (positive) impact of less than 0.5% for a 10% decrease in the price of information input. The Information sector has the largest impact of 2.2% increase in the sector's GDP; followed by the electrical appliance and equipment sector with 1.3% increase in its GDP.

Using GDP shares as weight, the impact on the national GDP can be derived the respective years. For the year 2000, a 10% decrease in information input prices can lead to an increase of the national GDP by 0.84%. This is almost twice of that estimated for the year 1995 and 1990.

Figure 2: Impact on industry GDP of a 10% decrease in the price of information input, 2000

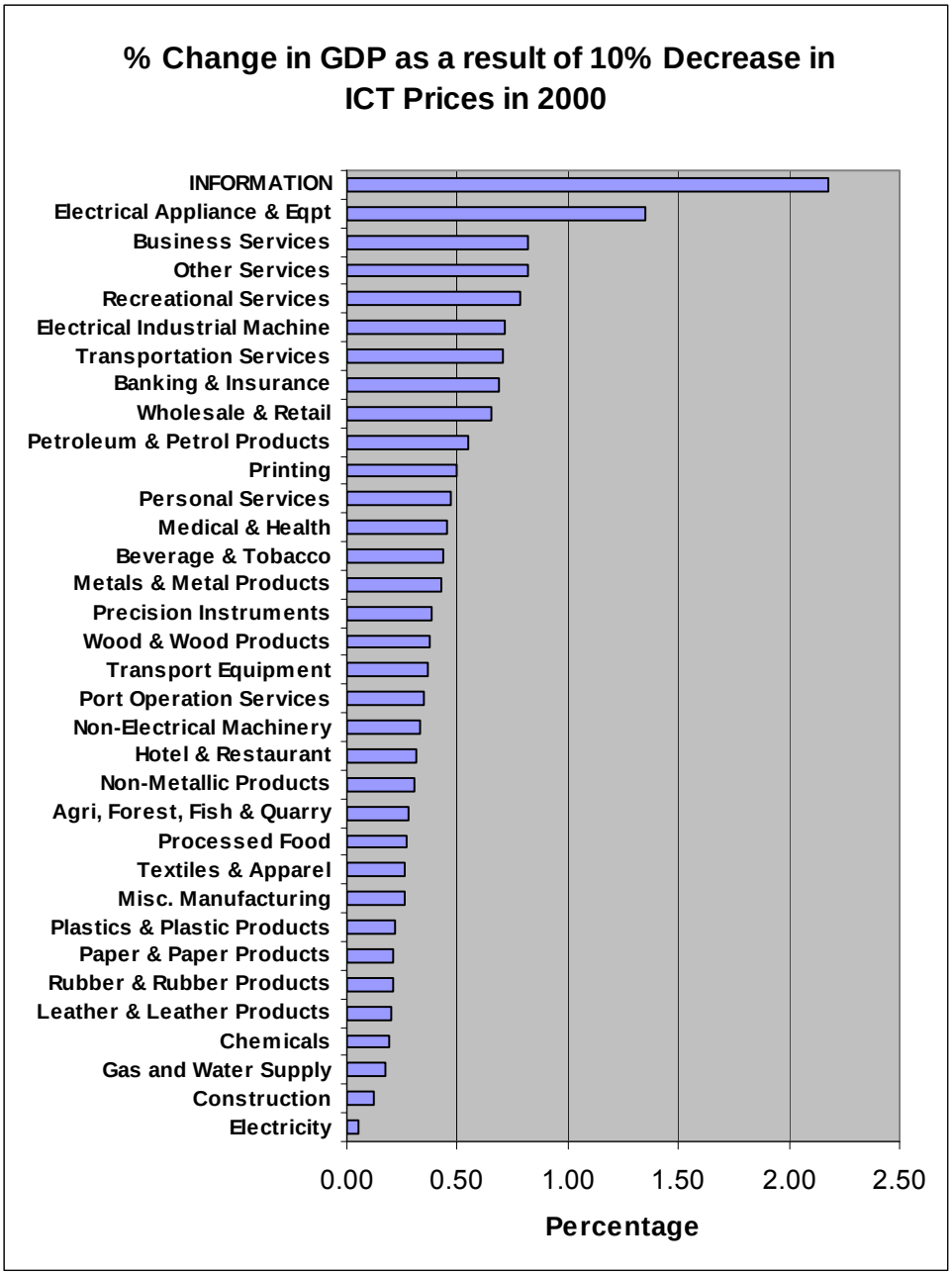
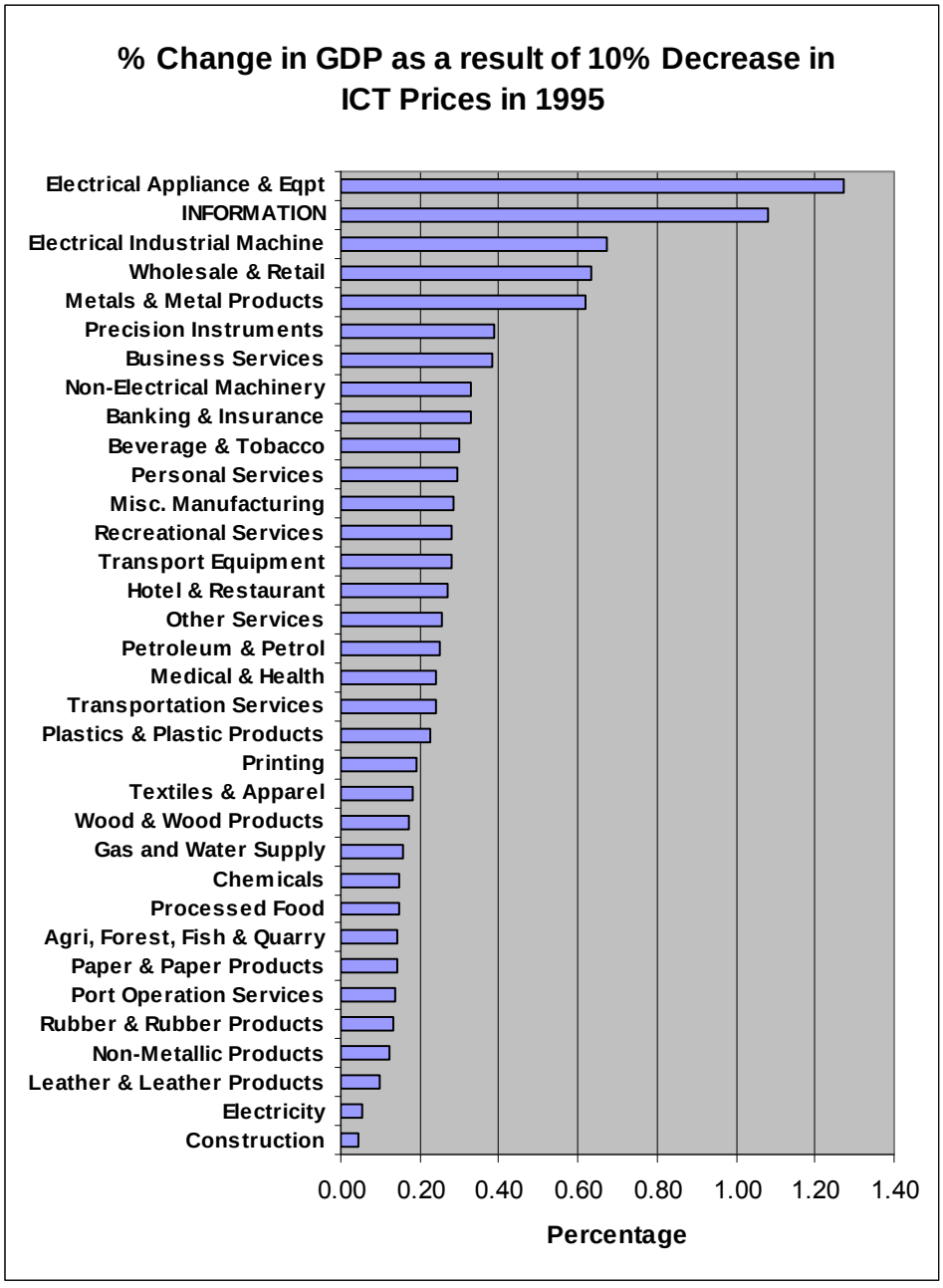


Figure 3: Impact on industry GDP of a 10% decrease in the price of information input, 1995



6. CONCLUSION

A vibrant Information sector will play an important catalytic role in developing Singapore into a knowledge-based economy. The analysis provided in the paper supports the assertion that the information economy will be a precursor to a knowledge-based economy. The Information sector grew in tandem with the expansion of export in the first half of the 1990s. By the second half of the 1990s, it developed sufficient momentum and capability to expand domestically as a cluster. While the external demand increases, export will continue to be a driving force of growth for the Information sector, our domestic demand has also grown in importance. The use of ICT was found to be generally pervasive in the economy.

The paper also investigated the impact of falling prices of information input on sectoral GDP. It is found that for a 10% decrease in information input prices, the sector GDPs would increase by 0.05% to 2.2%. The overall impact for the economy is a positive 0.84% increase in national income (GDP) for a 10% decline in information input prices.

References

Jackson R. W., Rogerson P. and Plane D. (1990). A causative matrix approach to interpreting structural change, *Economic Systems Research* 2, 259–269

Kohli, U. (1978). A Gross national Product function and the derived demand for import and supply of export. *Canadian Journal of Economics*, 11, 167-182.

Lipstein, B. (1968). Test marketing: a perturbation in the market place, *Management Science*, Series B, 14, 437-48.

O'Mahony and Van Ark (2003). *EU Productivity and Competitiveness: An Industry Perspective. Can Europe Resume the Catching up process?* Luxembourg: European Commission/Enterprise publications.

Roy S., Das T., & Chakraborty D. (2002). A Study on the Indian Information Sector: an Experiment with Input-Output Techniques. *Economic System Research,* 14(2), 107-130.

Shepard, R. W. (1970). *Theory of Cost and Production Function*, Princeton, NJ: Princeton University Press.

Tuomi, I. (2004). Realising the Productivity Potential of ICTs. Institute of Prospective Technological Studies (IPTS) Report. Issue 85.

Woodland, A. D. (1982). *International Trade and Resource Allocation,* Amsterdam: North Holland.

Appendix A

Table A1: Classification of industries into Information and Non-Information Sector

Sectors	Industry	Sectors	Industry
Non-Information	1 Agri, Forest, Fish & Quarry 2 Processed Food 3 Beverage & Tobacco 4 Textiles & Apparel 5 Leather & Leather Products 6 Wood & Wood Products 7 Paper & Paper Products 8 Printing 9 Petroleum & Petrol Products 10 Chemicals 11 Rubber & Rubber Products 12 Plastics & Plastic Products 13 Non-Metallic Products 14 Metals & Metal Products 15 Non-Electrical Machinery 16 Electrical Industrial Machine 17 Electrical Appliance & Eqpt 18 Transport Equipment 19 Precision Instruments 20 Misc. Manufacturing		21 Electricity 22 Gas and Water Supply 23 Construction 24 Wholesale & Retail 25 Hotel & Restaurant 26 Transportation Services 27 Port Operation Services 28 Banking & Insurance 29 *Business Services* 30 Medical & Health 31 Recreational Services 32 Personal Services 33 Other Services
		Information	34 Publishing 35 Computers & Comp Eqpt 36 Electronics & Comms Prdts 37 Communications 38 Information Technology Svc 39 Education

Appendix B

Table B1: Statistics from the computed left causative matrices

		1990 – 1995			1995 - 2000		
	Industry	**Row SUM**	**Cii**	**ODE**	**Row SUM**	**Cii**	**ODE**
1	Agri, Forest, Fish & Quarry	0.8804	0.9424	-0.0620	1.0053	1.0206	-0.0153
2	Processed Food	1.0211	1.0006	0.0204	0.8151	0.9592	-0.1442
3	Beverage & Tobacco	1.0596	1.0144	0.0452	0.9679	1.0203	-0.0525
4	Textiles & Apparel	0.9732	0.9632	0.0099	0.9814	1.0040	-0.0226
5	Leather & Leather Products	0.9994	1.0006	-0.0013	1.0639	1.0649	-0.0010
6	Wood & Wood Products	1.0372	1.0138	0.0234	0.9865	0.9896	-0.0030
7	Paper & Paper Products	0.9205	0.9577	-0.0372	0.9698	1.0166	-0.0468
8	Printing	0.9801	0.9872	-0.0071	0.9355	0.9559	-0.0204
9	Petroleum & Petrol Products	1.2218	0.9877	0.2341	0.7144	0.9965	-0.2821
10	Chemicals	0.9338	0.9488	-0.0150	1.2335	1.0904	0.1431
11	Rubber & Rubber Products	1.0399	1.0186	0.0213	0.9308	0.9437	-0.0128
12	Plastics & Plastic Products	1.0034	1.0420	-0.0386	1.0747	0.9998	0.0749
13	Non-Metallic Products	1.0857	1.0650	0.0207	0.8845	0.9713	-0.0868
14	Metals & Metal Products	0.9090	0.9488	-0.0398	0.9423	1.0332	-0.0909
15	Non-Electrical Machinery	0.9682	0.9788	-0.0107	1.0063	1.0234	-0.0171
16	Electrical Industrial Machine	0.9547	0.9778	-0.0231	1.0187	1.0250	-0.0063
17	Electrical Appliance & Eqpt	0.8749	0.8877	-0.0127	1.0573	1.0371	0.0201
18	Transport Equipment	1.0666	1.0119	0.0546	1.0229	1.0385	-0.0157
19	Precision Instruments	0.9760	0.9713	0.0048	1.0457	1.0464	-0.0007
20	Misc. Manufacturing	1.0071	0.9902	0.0168	1.0497	1.0678	-0.0181
21	Electricity	0.9407	0.9039	0.0368	1.6347	1.2801	0.3546
22	Gas and Water Supply	1.0085	1.0148	-0.0063	0.8891	0.8687	0.0204
23	Construction	0.9965	1.0135	-0.0171	0.9840	0.9816	0.0025
24	Wholesale & Retail	1.3180	0.9853	0.3327	0.4687	1.0105	-0.5418
25	Hotel & Restaurant	0.9073	0.9459	-0.0386	1.0095	0.9980	0.0115
26	Transportation Services	1.0030	0.9545	0.0485	1.0737	1.0420	0.0317
27	Port Operation Services	1.1231	1.0110	0.1121	0.9149	0.9699	-0.0550
28	Banking & Insurance	1.0036	1.0542	-0.0506	0.9580	0.9866	-0.0286
29	Business Services	0.8717	1.0051	-0.1334	1.1728	0.9921	0.1806
30	Medical & Health	0.9248	0.9839	-0.0590	0.9847	0.9650	0.0198
31	Recreational Services	0.9737	0.9560	0.0177	0.9922	0.9677	0.0245
32	Personal Services	0.9530	0.9683	-0.0153	0.9900	0.9954	-0.0054
33	Other Services	1.0231	0.9571	0.0660	1.0001	0.9644	0.0357
34	INFORMATION	1.0263	1.0132	0.0131	1.2214	1.0167	0.2047

Notes: ODE = sum of off-diagonal elements in each row
Cii = the ith diagonal element in the left causative matrix

About IPS Working Paper Series

The IPS Working Papers Series is published in-house for early dissemination of works-in-progress. This may be research carried out by IPS researchers, work commissioned by the Institute or work submitted to the Institute for publication.

The views expressed in the Working Papers are strictly those of the author(s) alone and do not necessarily reflect the views of the IPS.

Comments on the Working Papers are invited. Please direct your comments and queries to the author(s).

IPS Working Papers are available from the IPS at $7.00 each (before GST). Postage and handling charges will be added for mail orders.

For more information, please visit www.lkyspp.nus.edu.sg/ips or
contact email: ips@nus.edu.sg or tel: 6516-8388 or fax: 6777-0700.

Institute of Policy Studies
Lee Kuan Yew School of Public Policy
National University of Singapore
1C Cluny Road House 5
Singapore 259599

Tel: (65) 6516 8388 Fax: (65) 6777 0700
Web: www.lkyspp.nus.edu.sg/ips
Registration Number: 200604346E