The Co-evolution of the US ICT Industries: A Development Bloc Approach

Abstract

This paper examines the co-evolution of the Information and Communication Technology (ICT) industries in the US since 1950s through to the present by taking a development bloc approach. We argue that the co-evolution can take place between industries within a potential ‘development bloc’ and that the co-evolutionary process can essentially be interpreted as the process of ‘bloc building’. We propose a procedure to identify the development bloc, focusing on two key elements of the development bloc concept, viz. transformation and complementarities. We apply the procedure to the US ICT industrial data and our analysis identifies two periods of evolution of US ICT industries: an ICT development bloc forming in the first period and breaking down in the second.

Key words: co-evolution; development bloc; Information and Communication Technology industries; transformation; complementarities.
1. Introduction

The term ‘co-evolution’ can be derived from biology where Ehrlich & Raven (1964) first used the term to refer to evolution of butterflies and plants. In biology, co-evolution can be defined as “the simultaneous evolution of ecologically interacting populations” (Roughgarden, 1983). The interactions are featured with the ‘reciprocal selection’ between interdependent autotrophs and heterotrophs (Odum, 1971). The mutual interdependence, or ‘mutualism’ can be direct or indirect. While species can interact with each other through physical interaction (direct mutualism), they can also benefit other’s presence without direct contact between them (indirect mutualism) (Boucher, James, & Keeler, 1982). As a consequence, traits of one species evolve in response to those of others and the species reciprocally adapt to each other (Futuyma & Slatkin, 1983).

In evolutionary economics, the term ‘co-evolution’ has been adopted for describing the dynamic interrelationships between variables such as knowledge, technology, demand, industrial structure and institution, and the role that the interrelationships play in evolution of industries (McKelvey, 1997; Nelson, 1994). The examination by far is intensively on the ‘techno-economic’ paradigm in one single industry/sector. The co-evolution taking place in a broader environment, e.g. at the multiple-industry level, is yet to be explored.

Without denying the significant implication of the ‘co-evolution’ concept in Nelson (1994; 1995), the term used in this paper differs slightly from its original meaning and turns to the phenomenon of the dynamic interdependence between certain industries. It is commonly recognized that the development of technologies and markets of an industry usually has closer relationship to those of others. Quantitatively, the co-growth of the industries within a certain group, presenting as the co-movement of output of the industries in a long run, can be identified in many occasions. Further, dynamics in one industry such as entry, exit, integration and specialization, and concentration can have substantial impact on that of others through different transmission mechanisms (Arora & Bokhari, 2000; Bonaccorsi & Giuri, 2001).

The central research question that this paper aims to inquire is ‘why some certain industries co-evolve’? Specifically, we are interested in the co-movement between certain industries along their evolution; or why the co-movement in some occasions is much stronger than others.

At the first glance one may allege that the co-movement of outputs of industries results simply from (1) the impact of the aggregate business cycles; and/or (2) the demand of the downstream industry transmitted to the upstream industry. Those are true. However, we suspect that that is only part of the story. Evidences show that the ways that industries respond to an aggregate shock vary (Hornstein, 2000); and the
change of the aggregate economy can only explain a part of industrial cyclical dynamics (Tan & Mathews, 2007). The amount of co-movement indeed depends on the nature and degree of the ‘linkage’ between the industries (Shea, 2002). In respect of the proposition that the co-movement is driven only by demand, we simply note that the downstream industries are not always the ‘leading’ industries and the upstream industries not always ‘lagging’ in the history of industries. Further, the goods/service flows in an economy does not appear sufficient to explain the co-movement we have seen in many industries where there are actually not much input-output relationships between them.

To understand better the phenomenon of co-evolution between industries thus calls for a more sophisticated approach. In this paper, we employ Erik Dahmén’s (1970; 1991c) development bloc approach as a analytic framework. A development bloc is ‘a sequence of complementarities which by way of a series of structural tensions, i.e., disequilibria, may result in a balanced situation’ (Dahmén, 1991a, p.139). Two elements are highlighted in the development bloc concept. First, economic development is carried out through transformation process with which the branches and enterprises that are associated with the ‘positive side’ of economic development supersede those that are associated with the ‘negative side’. According to Dahmén (1970, p.44 )’s definition, “the positive side refers to the introduction of innovations and the negative side to the liquidation of old factor combinations or, better, to the old combinations which are no longer being considered for new investment.” Second, among certain areas/industries, or branches/enterprises as Dahmén labeled them, that are associated with the positive side of economic development, the complementarities will take place due to the constant structural tension between the ‘premature’ areas/industries and the ‘complementary’ areas/industries. Which area/industry is in a premature position and which in the complementary position depend on each other’s development stage and are transferable. A development bloc may emerge as the joint outcome of the transformation and the complementarities.

From the development bloc perspective, we thus argue the co-evolution between certain industries may be interpreted as the formation process of a development bloc; and the research question therefore becomes ‘how to identify development blocs’. The objective of this paper is both methodological and descriptive. At the methodological level, we propose a procedure to identify a development bloc by examining to what extent the industries have experienced the ‘transformation’ (as a group) and the ‘complementarities’ (between the industries) in their evolution. At the descriptive level, we apply the procedure to the US information and communication technology (ICT) industries, and examine the historical production data of the industries over the past five decades. Our analysis identifies two periods of evolution of US ICT industries by far: an ICT development bloc forming in the first period and breaking down in the second.

The paper is organized as follows. The next section discusses the relevant research
traditions to the co-evolution of industries, and explains the particular relevance of the development bloc approach to the phenomena. Following is description of the procedure we propose for identification of a development bloc. Section four applies the procedure to the US ICT industrial data, and presents the findings. We discuss these findings in section five and make remarks concerning the policy and management implications in section six.

2. Understanding the Co-evolutionary Processes of Industries from a Development Bloc Perspective

The industry co-evolution we examine in this paper relates to various lines of inquiries aiming to understand relevant phenomena such as industry co-movement, economic clusters, and transmission of industry dynamics.

A first line of research is conducted by economists who study the short or medium-term industry co-movement at the macro-economic level. Those scholars (e.g. Forni & Reichlin, 1998; Hornstein, 2000; Horvath, 1998; Long & Plosser, 1983; Shea, 2002) are particularly interested in the relationship between the industry co-movement and the business cycles. Co-movement between different industries is regarded as a ‘defining characteristic’ of the business cycles (Hornstein, 2000; Shea, 2002). While common shocks such as monetary policy remain an important source of the interindustry co-movement, many other mechanisms are proposed to be playing substantial roles in the co-movement, such as input-output linkages, consumption complementarities, external economies of scale, trading externalities and aggregate demand spillover (Shea, 2002, p.414). Given that these studies are macro-economic in nature, the co-movement between some certain industries is not the concern, though it is admitted that interindustry patterns of co-movement vary (Shea, 2002). Nor do the studies intend to trace the co-movement over the industries’ life cycle and link the origination and pattern of the co-movement to the nature of the group of industries and their underlying technologies. This line of researches though may provide methodological inputs to the industry co-evolution study.

The second tradition of research is concerned with economic clusters arisen from the network of firms and other strategic alliances such as universities, research institutions, and customers, etc. The interdependence of industries is a salient feature of the cluster research as the interdependent firms in a cluster are usually from a same value-adding production chain (OECD, 1999). The importance of the clusters to economic development and national competitiveness is emphasized in these studies (see e.g. OECD, 1999; Porter, 1990). Most studies in this line however focus on established clusters, with a few exceptions dealing with the formation of new clusters (e.g. Bresnahan, Gambardella, & Saxenian, 2001; Perez-Aleman, 2005). The method for identification of industrial clusters heavily relies on the input-output analysis
which has a clear static flavor because the input-output tables used in the analysis, analogous as ‘snapshots’ of the economic system, provide only information on the linkages of industries at a given point of time.

Finally, co-evolution is an important theme in the evolutionary economics in general, and in the area of industrial dynamics in particular. The basic idea, from an evolutionary economist’s point of view, is that science, technology, business organization, and law etc. are all intertwining aspects of culture; they evolve towards ‘fitness’ through the “selection mechanism” and they are all part of ‘selection environment’ of each other (Nelson, 1995). The co-evolution between variables such as knowledge, technology, demand, industrial structure and institution in one single industry has been empirically examined (McKelvey, 1997; Nelson, 1994; Rosenkopf & Tushman, 1998). At the multi-industry level, the interest has been on the dynamics of vertical integration and specialization as a result of the co-evolutionary processes of firm capabilities, technological change and industry structure in vertically related industries (Arora et al., 2000; Jacobides & Winter, 2005). Bonaccorsi & Giuri (2000; 2001) extend the investigation to the co-evolution of other industrial dynamics such as entry, exit and concentration in vertically related industries. They propose ‘the network of vertical relationship’ as the mechanism to transmit the dynamics from a downstream industry to an upstream industry. Two network configurations, i.e. partitioned and hierarchical, are discussed which result in different transmission effects.

The challenge here, as Malerba (2006, p.18) states, is to “move from the statement that everything is coevolving with everything else to the identification of what is coevolving with what, how intense is this process and whether indeed there is a bi-direction of causality”. As we believe, the co-evolution can occur not only between variables in one single industry or between industries in a same production value chain, but also between industries without salient input-out linkages. In other word, the co-evolution can take place between industries within a potential ‘development bloc’ and the co-evolutionary process can be interpreted as essentially the process of the ‘bloc building’.

The key to understand the development bloc concept and to link the concept with a broader co-evolutionary processes taking place in the economic system is to understand the concept of ‘structural tension’, among others, established by Erik Dahmén. Structural tension often arises when innovations in certain sectors and branches are introduced, but the ‘new combinations’, as Schumpeter called them, have not been reached yet. There would be constant tension between the ‘premature’ areas and other ex post ‘related’ areas as development potentials, or bottleneck, have not been released / overcome. In the situations, entrepreneurs, under conditions of uncertainty, will make investment in those ‘related’ sectors to fill the gaps due to the conceived opportunities. A development bloc may eventually form “through an expansionary process, if complementary new techniques are found and introduced
and/or specific investment are made” (Dahmén, 1991b, p.131). Thus the co-evolution between industries and sectors in this context may be viewed as the result of entrepreneurs’ ‘bloc-building’ activities in the different industries which may have relationships ex post. The relationships can be horizontal or vertical. For example, the co-evolution between the Swedish electrical equipment industry and its downstream industries in the early 1900’s in fact involved the vertical relationship which in fact resulted from the direct engagement of the largest Swedish electrical equipment company at that time, ASEA, into the downstream industries and the creation of demand and application for the equipment via the electrification of the energy-intensive industries. The co-evolution eventually generated a so-called ‘electric development bloc’ in Sweden (Dahmén, 1970; Kaijer, 1992). The co-evolution can also take place between industries with horizontal relationships such as parallel technologies and common customers. Examples of this type include the co-evolution between a transportation industry and the industries grow up in the surrounding territory (Dahmén, 1970); and that between the industry of Internet service providers and the industry of Internet content providers in the early age of Internet.

3 Identification of a Development Bloc

As such, identification of development bloc appears to be the first step toward better understanding the co-evolution between industries. Our research question therefore becomes ‘which industries are likely to form a development bloc?’, or in other words, ‘how to identify a development bloc?’

Several prior studies have made effort toward identification of a development bloc. Erik Dahmén’s own empirical investigation (1970) into Swedish industrial development during the inter-war period involved detailed mapping for more than sixty main branches and more than 200 sub-branches of the economy with firm-level data. The study demonstrated that the economy during the period experienced substantial transformation which resulted in development blocks built around new commodities. In Denmark in early 1980s, a series studies on ‘industrial complexes’ were carried out with the development bloc concept as the theoretical foundation (Drejer, Kristensen, & Laursen, 1999). By primarily relying on the input-output tables of the national economy to analyze vertical linkages between users and producers, the studies identified four ‘complexes’. Recently Enflo et al.(2006) offered a quantitative method to identify a development bloc. Two advanced econometric techniques are used in their study for examining ‘complementarities’ in the process of development bloc formation. First, industries that form a development bloc would be cointegrated, i.e. their long-run growth would be driven by a common stochastic trend. Second, in the short-run, industries that form a development bloc should show reciprocal or ‘bi-directional’ relationships in terms of Granger causality. By conducting the analysis to the Swedish economy from 1900 to 1974, they allege that a bloc around electricity
which consists of five more sectors can be identified.

Those empirical studies are informative; but their analytic processes seem to more or less lean to the examination of either the ‘transformation’ or the ‘complementarities’. As we believe however, the two elements (i.e. transformation and complementarities), are both essential for identification of a development bloc.

Inspired by Schumpeter (1942; 1964), Dahmén sees the transformation analysis is the key for understanding economic development. A development bloc would arise and only arise from the transformation, which can be illustrated with the following cases.

“-Introduction of new methods of production and marketing.
- Appearance of new and marketable products and services.
- Opening up of new markets.
- Exploitation new sources of raw materials and energy.
- Scrapping of ‘old’ method of producing and marketing products and services.
- Disappearance of ‘old’ products and services.
- Decline and fall of ‘old’ products and services.
- Closing of ‘old sources of raw material and energy

(Dahmén, 1991a, p.137)

The complementarities are another feature of formation of a development bloc. While complementarities in a broad sense take place among technological, economic, and other related factors (Dahmén, 1989, p.138), here we focus on complementarities between industries/areas. Imagine at a stage the innovations are generated but can not be fully utilized due to, for example, lack of downstream applications, upstream supplies or surrounding support technologies. Perceiving the profit associated with the would-be ‘new combinations’, entrepreneurial activities will be performed on those ‘lagged’ areas. However, the gap-filling activities will by no mean synchronous and new gaps will emerge from time to time, until an ‘equilibrium’, i.e. a relative balanced situation, is reached.

To operationalize the two elements of the development bloc, we suggest that first the degree of the ‘transformation’ by a certain group of industries in an economy can be revealed by examining its relative importance to the economy over time, primarily measured with the workforce statistics, production share and their contribution to the productivity growth. Second, following Enflo et al.(2006) we believe the degree of ‘complementarities’ between certain industries can be examined via the cointegration and Granger causality tests. We will explain the advantage of this method in more details below.
4 Applying the Development Bloc Approach to the Co-evolution of the US ICT Industries

In order to empirically examine the co-evolution of industries, our next task is to select a group of industries, and apply the procedure suggested above to the industries. The principle for selecting the industries is based on both our intuition as well as the current industry classification systems. While the ‘boundary’ of a potential development bloc may seem arbitrarily defined with this method, to start with a category such as ‘ICT’ in the classification system seems to be the only feasible ways given that there are infinite possibilities for choosing the industries. In this section we examine the co-evolution of the US ICT industries. ICT or IT (information technology) sector “incorporates the whole of the computing and telecommunication technologies and major parts of consumer electronics and broadcasting” (Grauer, 2002)\(^1\). The US has been a leading country since the beginning of the so-called ‘ICT revolution’\(^2\). By examining the pattern of the ‘transformation’ and the ‘complementarities’ of the US ICT industries over their history, we intend to find out whether or not a development bloc has been formed.

4.1 Data

Our data are from the published materials of the US Census Bureau, the US Bureau of Labor Statistics, the US Department of Labor and other secondary sources. The primary source of the data in this study is the US M3 survey which is conducted by the US Census Bureau and generates monthly shipment data of manufacturing industries in the US. Since the survey shifted from Standard Industrial Classification (SIC) to North American Industry Classification System (NAICS) in 2001, two groups of time series are available, one with the SIC covering the period 1958-2001 (“the SIC series” or “the earlier series” hereafter) and another with NAICS covering the period from 1992 through the present (“the NAICS series” or “the later series” hereafter). While the two groups of series are based on different classification systems, comparison is possible between the corresponding series and we then are able to investigate the historical development of the ICT industries as well as their recent

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\(^1\) According to OECD’s definition OECD. 2002a. Measuring the Information Economy. Paris: Organisation for Economic Co-operation and Development., for a manufacturing industry to be within the category of the ICT industries, its products (1) must be intended to fulfill the function of information processing and communication including transmission and display; and (2) must use electronic processing to detect, measure, and/or record physical phenomena or to control a physical process. For the ICT service industries, their products must be intended to enable the function of information processing and communication by electronic means. In this paper we focus on investigation of ICT manufacturing industries due to data availability; and select the time series composing the ‘Information Technology Industries’ category in the NAICS system and the corresponding time series in the SIC system (see the data section below for more details).

\(^2\) By 2001 based in the US are five of the top 10 communication equipment and systems firms, seven of the top 10 IT equipment and systems firms, nine of the top ten IT services firms, eight of the top ten software firms and five of the top ten telecommunications firms (OECD, 2002b).
trend (see the table 4 below).

The following eight SIC-based time series are used as the first group of data and the six industry series are plotted in the figure 1.

Aggregated series:
1. ITI: Seasonally Adjusted Value of Shipment, Information Technology Industries
2. TCG: Seasonally Adjusted Value of Shipment, Total Capital Goods

Main Group series:
3. 35H: Seasonally Adjusted Value of Shipment, Computer and Office Equipment
4. 36E: Seasonally Adjusted Value of Shipment, Household Audio and Video Equipment
5. 36X: Seasonally Adjusted Value of Shipment, Communication Equipment
6. 36H: Seasonally Adjusted Value of Shipment, Electronic Components and Accessories
7. 38X: Seasonally Adjusted Value of Shipment, Search and Navigation Equipment
8. 38C: Seasonally Adjusted Value of Shipment, Measuring and Controlling Devices

(Source: US Census Bureau (2006))

The second group of series we use is NAICS-based and covers the period from 1992 through the present. In the NAICS system the category of ‘Information Technology Industries’ consists of twelve series, including

33G Photographic equipment manufacturing
34A Electronic computer manufacturing
34B Computer storage device manufacturing
34C Other computer peripheral equipment manufacturing
34D Communications equipment manufacturing, nondefense
34E Communications equipment manufacturing, defense
34F Audio and video equipment
34I Search and navigation equipment, nondefense
34J Search and navigation equipment, defense
34K Electromedical, measuring, and control instrument manufacturing
34L Manufacturing and reproducing magnetic and optical media
35E Other electrical equipment, appliance, and component manufacturing

(Source: US Census Bureau (2006))
Among these twelve series, the data of series of 34L and 35E are not available. Since another two series, i.e. ‘Semiconductor and related device manufacturing’ (Code: 34G) and ‘Other electronic component manufacturing’ (Code: 34H), are included in the category of ‘Computer and Electronic Products’ and closely relevant to the so-called IT sector, we include those two industries into our analysis. The twelve time series are plotted in the figure 2.

Insert Figure 2 about here

The percent dispersement of SIC Categories to the currently used NAICS Categories are given in the table 1 below, revealing the consistence of the two systems.

Insert Table 1 about here

4.2 Transformation of US ICT

We first examine whether the US ICT industries as whole show significantly increasing importance by looking at the workforce data, the production data and the productivity data. It is not difficult to believe that the landscape of the US economy has drastically changed with the rapid growth of ICT sector in the US in the second half of the last century. In terms of employment, the workforce employed in information sector continually increasing until 2000 while the workforce in the total manufacturing sector remained flat and that in agriculture fell, as shown in the figure 3.

Insert Figure 3 about here

We can also detect the transformation by examining the share of ICT industries’ output in the economy and comparing that with those of non-ICT sectors. We use two aggregate time series in the US M3 survey for this investigation, i.e. ITI (Information

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3 The information sector defined by the US Department of Labor is slightly different from that discussed in this paper. The main components of the sector are the publishing industries, including software publishing, and both traditional publishing and publishing exclusively on the Internet; the motion picture and sound recording industries; the broadcasting industries, including traditional broadcasting and those broadcasting exclusively over the Internet; the telecommunications industries; the industries known as Internet service providers and web search portals, data processing industries, and the information services industries. For more details see http://www.bls.gov/iag/information.htm
Technology Industries) and TCG (Capital Goods). The category of capital goods is comprised of both IT industries and non-IT industries such as farm machinery and equipment manufacturing; construction machinery manufacturing; mining, oil, and gas field machinery manufacturing; industrial machinery manufacturing; and so on. We compare both ICT and TCG output in percent of the GDP from 1968 to 2001, as shown in the figure 4.

The manufacturing sector in the US in general shows a declining trend as the percentage of production of TCG industries to the GDP fell for most time before 2000. Against the trend however, the percentage of production of ICT industries to the GDP continually increased during the same period. It should be noted the figure 2 may even substantially under-represent the pace of the rise of the ICT sector in the economy given that the ICT technologies change over time with usually rapidly declining prices and improving performance. The sharply falling trend of the prices of some major ICT products in the ‘constant quality index’ can be found in the figure 5.

The transformation process experienced by the US ICT sector can be even better revealed with the historical data on the contribution of the ICT sector to productivity improvement. As the so-called ‘IT productivity paradox’ or the ‘Solow computer paradox’, the initial performance of ICT sector in terms of its contribution to measured productivity was disappointing before 1990s. As Robert Solow claimed, “We see the computers everywhere but in the productivity statistics” (David, 1990, p.355). However, this notion was soon found not valid. Against the initial observations, the studies on the ICT industries in 1990s confirm that ICT did improve US’s productivity substantially. Many even attribute the resurgence of the US economy since 1995 to the development of the ICT sector. For example, according to Jorgenson (2001)’s calculation based on a constant-quality price index, the share of ICT industries in the overall GDP growth rate rose from 0.20% in 1948-1973 to 1.18% in 1995-1999 which was almost responsible for half of the growth of the economy; by contrast the contribution of noninformation industries fell from 3.79% in 1948-1973 to 2.91% in 1995-1999. Further, the contribution of ICT industries to the growth of total factor productivity (TFP) rose from 0.06% in 1948-1973 to 0.5% in 1995-1999 which is twice the contribution of non-information to TFP during the

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4 A full list of the industries composing TCG (‘Total Capital Goods’) can be found in www.census.gov/m3
5 The US M3 survey which generates the data discontinued with SIC classification system in 2001. For more detailed description of the time series used in this paper from the M3 survey can be found in the next section.
same period. These results are reported in the table 2. In fact, the ‘lag’ in productivity confronted by the information technology is very similar with that confronted by electric technology introduced around 1900 and vividly illustrates a transformation process (David, 1990). Both technologies could not be fully utilized and explicitly shown in productivity statistics until other ‘things’ happened. In the case of the latter they are the spread of factory electrification; and in the case of the former they include the development of software and the introduction of Internet. In sum, the historical statistics of the workforce, production and productivity seems to support that the development of the US ICT industries before 2000 was featured with the ‘transformation’, one of the two key characters of a development bloc.

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Insert Table 2 about here
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4.3 Complementarities of US ICT

4.3.1 Method
In business cluster research, the ‘linkages’, a counterpart of the concept of ‘complementarities’ we discuss here, is usually identified via input-output analysis (Drejer, 2002; Lodh & Lewis, 1976; Wixted, Yamano, & Webb, 2006). In an input-output table used in such an analysis, the horizontal rows report how the output of a sector/industry is distributed among others; conversely the vertical columns show how much each sector/industry takes from others as inputs (Leontief, 1966). Thus the inter-industry relationships may be detected by examining how much goods and services in monetary values flow between industries. Apparently the industries with larger transactions between them in form of input/output would have stronger linkages than others.

Although the input-output tables provides an easy solution for detecting static ‘linkages’ among industries, such a method may cause some suspicions if used for identifying the dynamic ‘complementarities’, leaving the usually poor data availability alone. An input-output analysis touches only the ‘production linkages’; the latent or ex post relationships between sectors/industries, such as those resulted from parallel technologies or common customers, can hardly be demonstrated in an input-output table. Moreover, the input-output analysis tells little about the dynamics of the interdependences of industries over the evolution. An important variable, time, is missed in such an analysis.

For these reason, we decide to follow Enflo et al.(2006) and turn to time series analysis. Two techniques are used in Enflo et al.(2006), i.e. the cointegration analysis for detecting the long-run relationships between time series; and the Granger causality tests for the short-term relationships. The degree of complementarities then depends
on the cointegration as well as mutually Granger causal relationships between the industries.

Two or more series are regarded as being cointegrated if they individually are non-stationary\(^6\) but a linear combination of them is stationary. Suppose that two time series, \(X_t\) and \(Y_t\), are nonstationary and we regress \(Y_t\) on \(X_t\), i.e.
\[
Y_t = \beta_1 + \beta_2 * X_t + u_t;
\]

Or:
\[
u_t = Y_t - \beta_1 - \beta_2 * X_t;
\]

where The stochastic trends of the two variables would be cancelled out if \(u_t\) is found to be stationary. In such a situation, the two variables would have an equilibrium relationship in the long run. Cointegration can be tested via Johanson Cointegration Test or Augmented Engle-Granger (AEG) Test.

On the other hand, the Granger test can help determine the causality between two co-moved time series. The philosophy of using this analysis to identifying causality of two time series is that “if the past values of one time series did not posses incremental forecasting ability for a second time series that was above and beyond the forecasting ability in that second time series’ own past values, then the first time series was not a cause of the second” (Thies, 1997, p.1566).\(^7\)

### 4.3.2 Unit Root Test

The tests for stationarity of each time series are essential before we can perform the cointegration analysis and Granger causality tests. Cointegration analysis is only valid for non-stationary series; otherwise the conventional regression analysis can be employed. By contrast, Granger causality tests require stationary time series data as non-stationary series will lead to a problem of spurious regression.

The unit root test is the formal method for testing stationarity. Several procedures are available for the unit root test and we adopted two of the most common procedures, i.e. Augmented Dickey Fuller (ADF) test and Phillips Perron (PP) test. We perform the two tests respectively for each time series in both level form and in first differences of the data. The results of those tests are reported in the table 3.

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In both ADF tests and PP tests, the null hypothesis of unit root is not rejected for all series in level form, but is rejected for all series in first-differenced form, inferring that all the time series of interest are first-difference stationary (i.e. \(I(1)\)). Thus they

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\(^7\) As above
are eligible for cointegration analysis. Those series however have to be transformed into stationary series before Granger causality tests can be applied.

The same test is applied to the NAICS series as well, resulting all but 34I are $I(1)$. Thus the series of 34I was excluded in our cointegration analysis later to the NAICS series.

4.3.3 Results
We then conduct cointegration analysis to investigate whether any long-run relationships exist between pairs of the industries by performing the Johansen test, a standard procedure in modern econometric computer programs such as the Eviews 5.0. The cointegration relationships between the pairs are summarized in the table 4.

Out of the fifteen pairs, nine show cointegration and six do not show cointegration. In particular, Measuring and Controlling Devices (38C) is cointegrated with all the other five industries; and communication industry (36X) is cointegrated with all the other industries except Electronic Components and Accessories (36H).

Our next task is to run Granger tests on all pairs of the same series. Given that all our time series are nonstationary, or first-difference stationary (i.e. $I(1)$), we use the (log) first-differenced form of data in our Granger causality models. Since the number of lags in the causality models are arbitrary, we run the regression for each pair of series four times with the order of lags = 3, 4, 5, and 6 respectively. These tests show that the result are not very sensitive to the choice of lag length. Figure 6 summarizes the Granger causal relationships between the series with the lag length of six, at the significance level of 5%.

The results suggest that among the fifteen pairs of variables, six of them have mutual Granger causal relationships at 5% significance level. If we choose the significance level of 5%.

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8 The Johansen test requires estimation beforehand regarding the means and the trend of data. Eviews 5.0 provides five assumptions for choice. Practically the final decision was usually made between two options: the ‘Assumption Three’ (i.e. all trends are stochastic) and the ‘Assumption Four’ (i.e. some of the series are trend stationary), as none of the Assumption One, Two and Five seem to suit our data. The Assumption One would be chosen when all series have zero mean. The Assumption Two would suit the cases where none of the series appear to have a trend. The Assumption Five “may provide a good fit in-sample but will produce implausible forecasts out-of-sample” (Quantitative Micro Software, 2005, p.741). The detailed results of the cointegration tests on all fifteen pairs of our time series with all five trend assumptions are available from the authors by request.

9 The detailed results of these tests are available from the authors by request.
level of 10%, there would be three more Granger mutually causal relationships.

In sum, our analysis reveals that with the decreasing importance of other manufacturing industries the share of the ICT industries in the US grow rapidly since 1950s until late 1990s, which hints for an underlying transformation process. Also, the complementarities between the ICT industries during the same period are confirmed by the cointegration analysis and the Granger causality tests. As such we suggest that an US ICT development bloc forms in the second half of the last century.

4.4 What happened since late 1990s?

While the feature of ‘transformation’ and ‘complementarities’ can somehow be tracked in the US ICT sector after later 1990s, the tendency seems to start changing. The ICT output in percent of GDP along with capital goods production in percent of GDP covering the period from 1992 through the present is plotted in the figure 7. A turning point can be detected around 1997, after which the share of ICT industries in the economy in terms of output started falling, a tendency now converging with that of the general manufacturing sector.

Internationally, the ICT share of the growth in the US economy has been outperformed by those of many other economies (Jorgenson & Vu, 2005). While ICT investment is still making an increasing contribution to the US economy growth, the contribution to the economy growth increased only by 4.6% from the period 1989-1995 to the period 1995-2003, which is smaller than not only the average of the G7 countries whose ICT contribution to the economy growth rose from 17.4% to 27%; but also those of the developing countries such as Brazil (from 4.57% to 23.71%), China (from 1.7% to 8.8%) and South Korea (from 3.9% to 11.2%) during the same periods. The details can be found in the table 5.

We also apply the same analysis procedure as we did above to the recent time series (i.e. the NAICS series) for detecting the pattern of complementarities. First we perform cointegration analysis for each pair of the NAICS series 1992-2006. Totally 66 cointegration tests were performed. With the similar criteria applying to the results of the Johansen Cointegration tests, only six pairs of series at most out of the totally 66 pairs of series are cointegrated or nearly cointegrated, depending on the
assumption made regarding the patterns of the series 10.

We then again perform Granger causality test to the twelve NAICS series. Out of all the 66 pairs of industries are only four pairs found to be mutually Granger cause each other with the lag length of six. Only two pair showing mutual Granger causation when the lag length = 5 and none with the lag length = 4 or less 11. In sum, the two key conditions of a development bloc are rejected with the later series of ICT industries, which suggests that the US ICT development bloc, if one did exist, starts breaking down since late 1990s.

5 Discussion: The Formation and the Breakdown of the US ICT Development Bloc

Based on the above, we propose the co-evolution of the US ICT industries results in a ‘ICT development bloc’ during the second half of the last century. The co-evolution of the US ICT industries can be further illustrated with the development of the two key ICT industries in the USA12, i.e. semiconductor and computer13.

Before 1960 computers could barely be called an industry. The first-generation computers, equipped with the electronic tubes, were designed primarily for military purposes such as calculating ballistic trajectories and testing theories behind the hydrogen bomb.

A revolutionary event for ICT in general and for computers in particular was the invention of the transistor in 1947 at Bell Labs. The development and commercialization of the transistors marked the birth of the semiconductor industry and led to the entry of a number of start-up companies such as Fairchild, Motorola, Texas Instruments and RCA. While the development of the semiconductor industry opened up a mass of potential application in different areas, the most significant impact might be on computers, where the second-generation computers, replacing vacuum tubes with solid-state transistors, made commercial usage feasible. Although only the largest companies could afford those computers, the market attracted a number of players including IBM, Burroughs, UNIVAC, NCR, CDC and Honeywell. The markets of both computer and semiconductor grew rapidly, with the value of the former rising from $0.3 billion to $2.7 billion during the period between 1962 and 1969 (Jorgenson, 2001), and the value of the latter rising from $4 million to $413 million during the same period of time (Langlois & Steinmueller, 1999)14. Along with

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10 The detailed results of these cointegration tests are available from the authors by request.
11 The detailed results of these Granger tests with different lag lengths are available from the authors by request.
12 Apparently the observation is also applied to the ICT industries at the global level.
13 The discussion of this part draws materials from, among other sources, Jackson, Mandeville, & Potts (2002), Jorgenson (2001), and Langlois & Steinmueller (1999).
14 The values of computers are in billions of current dollars; price are normalized to one in 1996.
the booming markets was the closer link between the two sectors. Before 1962 one hundreds percent of integrated circuits went to government users and none of them were used by computer producers. By contraries, by 1969 the share of integrated circuits used by computer producers jumped to 44 percent; and the figure for government users fell to 36 percent, as shown in the table 6.

The third-generation computers in 1970s were triggered by the introduction of integrated circuits (ICs). Although ICs at that stage were with “Small-Scale Integration” (SSI) which contains only a few transistors, they had considerable advantages over discrete circuits. The cost of ICs was much lower because the chips, with all their components, are printed by photolithography at a time. The performance was higher because the components switch quickly and consume little power. As a result, new markets for computers emerged, such as the minicomputers to address the increasing demand for the scientific and engineering use.

The fourth-generation computers were characterized by microprocessors which were introduced around 1969. The development of microprocessors has driven the generation of the microcomputers in the mid-1970s and Personal Computers in 1980s. On the other hand, these new computer market segments have also created huge demand for the upstream industries.

The brief review of development of generations of computers with their featured chips reveals the dynamic interaction between, in this case, two vertically related industries. The technological breakthroughs and market expansion in both industries created ‘tension’ as well as opportunities for each other. Visually, the co-evolution of industries can present as the cyclical co-movement of the industrial outputs, as illustrated in the figure 8 \(^\text{15}\). Such a cyclical co-movement might be interpreted as driven only by business cycles or demand. However, we believe a deep reason for such cyclical co-movement lies in the nature of the dynamical interdependence of the two technologies/industries which belong to a same ‘bloc’ and can potentially create a ‘new combination’, which could be the decisive force behind the transmission of the cyclical dynamics transmits across the industries.

\(^\text{15}\) Given that the semiconductor industrial output data are not available from the US M3, we use the output data at the global level instead. For more details about the data for plotting the figure 8, please refer to Tan & Mathews (2007).
Then why did the pattern of the co-evolution change, and the US ICT development bloc start breaking down from late 1990s, as our data suggest? We propose that the globalization in ICT sector, especially the establishment and spread of global production networks (GPNs) may be one of the main causes. ICT sector “has been, and remains, at the forefront of industrial globalization” (OECD, 2002b). On the three measures of globalization, not only has the international trade of ICT products grown at a much faster pace than that of the total merchandise trade, but also have international activities of foreign direct investment (FDI) and international alliance in ICT sector shown much stronger patterns than those in other sectors (OECD, 2002b).

Traditionally multinational corporations (MNCs) are keen to offshore production for two main reasons: market access and cost reduction. However, as Ernst & Kim (2002) suggest, while these motivations remain valid, three major driving forces are now responsible for the recent emergence of GPNs, including liberalization across the world, enhanced mobility of firm and the growing complexity of global competition.

Now value chains of ICT industries are much more specialized, modularized and distributed globally than ever. As illustrated in IC sector which has experienced continuing structural change toward disintegration and international production over the last two decades (as shown in the figure 8), while many semiconductor design activities are still carried out in the US, semiconductor manufacturing has largely been moving to other regions, especially in Southeast Asia, as shown in the figure 9 and figure 10 (Macher et al., 2002).

The establishment of GPN and the relocation of production activities are not limited within the IC sector, but appear in almost every ICT industry. First Japan, then Korea, Taiwan and Singapore as well-known as Asian Tigers, and now other emerging economies such as China and India have appeared as new preferable locations for the specialized IT clusters. For example, Japan, Korea, Taiwan and Singapore become the major sources of memory devices and displays (Ernst et al., 2002); most hard disk drives in the world are now made in Singapore-centered area in Southeast Asia; Taiwan supplies more than 70 percent of foundry service in the world (Chen, 2002); and the exports of high-technology products in China, most of which are under the category of IT products, rose from US$ 7681 millions in 1993 to US$ 37,040 millions in 2000, with the average annual growth rate of 52 percent (UNCTAD, 2001).

The knowledge diffusion seems inevitable as a result of the shift of ICT production

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16 According to OECD (2002b), trade in ICT (Information and Communication Technology) products in OECD countries showed a compound annual growth rate of 13.8% over the period 1990-2000, twice of that in total merchandise trade
from its original countries such as the US to others. This diffusion has been enabled by not only formal mechanisms such as FDI and technical consultancies (Ernst et al., 2002) but also informal mechanisms such as original equipment manufacturing (OEM), or even through technically skilled immigrants who link their home countries with the world’s technology centers (Saxenian, 2002). Eventually, local capability can be formed and the gaps between ‘giving’ countries and ‘receiving’ countries are closing, as illustrated with the development of the technology capability in Taiwan’s semiconductor industry (see the figure 12).

It should be noted that by ‘breakdown’ of the development bloc, it does not necessarily mean a weakening position of US firms in ICT sector. Rather, we are expecting the diffusion of the bloc from one specific country to a wider area; and the currently leading firms would be likely to serve as ‘carriers’ of such diffusion.

6 A Final Remark

According to many economic historians (Edquist & Henrekson, 2006; Greenwood, 1997; Schön, 2006), we are experiencing the third industrial revolution in the human history, i.e. the information and communication technology (ICT) revolution. Similarly with the first industrial revolution (i.e. the steam power revolution) and the second industrial revolution (i.e. the electrification revolution), the ICT revolution is featured with economic transformation with the rising importance of ‘new’ industries and meanwhile the falling share of others, co-evolution between those new industries and finally diffusion of production, technology and knowledge across countries.

During the process, some countries become leaders and some followers. But eventually the gap may become closer due to the diffusion of knowledge, especially under the background of globalization. As Schön (2006, p.4) notes,

“In such period of more rapid transformation, regions and nations react differently. Evidently, there are leading regions and nations, since innovations appear in specific circumstances and from the existence of geographically confined complementarities and externalities. Diffusion is more rapid to regions and nations that are favoured by new demands – due to their resource endowments, their institutional characteristics and their social capability…. Over time however (due to investments) competencies, infrastructures and institutions [of the lagging countries] will be more generally adapted to the new complementarities. Hence the development blocs will be more widely diffused.”
The formation and diffusion of the development bloc thus present huge opportunities for countries and regions. However, the opportunities are not taken-for-granted. As Eliasson, Johansson, & Taymaz (2004) point out, “It all depends on the local receiver competence to build industry on the new technology.”

On the management front, the co-evolution of industries, and the dynamics of development blocs would has substantial impacts on firms’ ‘selection environment’ (Nelson & Winter, 1982). New skills and strengths have to be built when the old ones are not relevant any more. The ‘inertia of success’, as Andy Grove (1996) calls it, however is not unusual but may have very dangerous consequences on the firm.
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Figure 1: SIC series used in the study

Source of primary data: US M3 survey

Figure 2: NAICS time series used in this study

Source of primary data: The US M3 survey
Figure 3: Structural change in the workforce employed in the sectors of information, agriculture and manufacturing


Figure 4: Output of ICT industries and Capital Goods industries in Percent of GDP 1968-2001

Source of primary data: US M3 survey
Figure 5: Constant Quality Index of Prices of Computers, Communications, Software, and Services, 1948-99

Source: Adapted from Jorgenson (2001, p.6)

Figure 6: Granger causal relationships among industries, at 5% significance level
Figure 7: Output of ICT industries and Capital Goods industries in Percent of GDP 1992-2005

Output of ICT industries and Capital Goods industries in GDP, 1992-2005

Source of primary data: US M3 survey

Figure 8: Co-movement of PCs and Semiconductors

Source: IDC; Semiconductor
Figure 9: Disintegration of the IC Industry

Source: TSMC (2001); Adapted from Chen (2002)

Figure 10 Fabrication capacity by region of location

Source: Leachman & Leachman (2001); adapted from Macher (2002)
Figure 11 Fabrication capacity by region of ownership

Source: Leachman & Leachman (2001); adapted from Macher et al.(2002)

Figure 12: Closing the technology gap in semiconductors in Taiwan

Source: Adapted from Mathews (2006)
<table>
<thead>
<tr>
<th>M3 SIC Category</th>
<th>M3 NAICS Category</th>
<th>Percent Dispersement of M3 SIC Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>35H</td>
<td>Computer and Office Equipment</td>
<td></td>
</tr>
<tr>
<td>33G</td>
<td>Photographic Equipment Manufacturing</td>
<td>2.8</td>
</tr>
<tr>
<td>34A</td>
<td>Electronic Computer Manufacturing</td>
<td>59</td>
</tr>
<tr>
<td>34B</td>
<td>Computer Storage Device Manufacturing</td>
<td>12.4</td>
</tr>
<tr>
<td>34C</td>
<td>Other Computer Peripheral Equipment</td>
<td>25.4</td>
</tr>
<tr>
<td>34K</td>
<td>Electromedical, Measuring, and Control Instrument Manufacturing</td>
<td>0.2</td>
</tr>
<tr>
<td>39C</td>
<td>Office Supplies (Except Paper) Manufacturing</td>
<td>0.2</td>
</tr>
<tr>
<td>36E</td>
<td>Household Audio and Video Equipment</td>
<td></td>
</tr>
<tr>
<td>34F</td>
<td>Audio and Video Equipment Manufacturing</td>
<td>79</td>
</tr>
<tr>
<td>34L</td>
<td>Manufacturing and Reproducing Magnetic and Optical Media</td>
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</tr>
<tr>
<td>36F/G</td>
<td>Communication Equipment</td>
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<td>34D/E</td>
<td>Communications Equipment Manufacturing</td>
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</tr>
<tr>
<td>34H</td>
<td>Other Electronic Component Manufacturing</td>
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</tr>
<tr>
<td>36H</td>
<td>Electronic Components and Accessories</td>
<td></td>
</tr>
<tr>
<td>34D/E</td>
<td>Communications Equipment Manufacturing</td>
<td>1.8</td>
</tr>
<tr>
<td>34G</td>
<td>Semiconductor and Related Device Manufacturing</td>
<td>55.3</td>
</tr>
<tr>
<td>34H</td>
<td>Other Electronic Component Manufacturing</td>
<td>42.6</td>
</tr>
<tr>
<td>36E</td>
<td>Motor Vehicle Parts Manufacturing</td>
<td>0.3</td>
</tr>
<tr>
<td>38A/B</td>
<td>Search and Navigation Equipment</td>
<td></td>
</tr>
<tr>
<td>34I/J</td>
<td>Search and Navigation Equipment Manufacturing</td>
<td>100</td>
</tr>
<tr>
<td>38C</td>
<td>Measuring and Controlling Devices</td>
<td></td>
</tr>
<tr>
<td>33G</td>
<td>Photographic Equipment Manufacturing</td>
<td>6.9</td>
</tr>
<tr>
<td>34K</td>
<td>Electromedical, Measuring, and Control Instrument Manufacturing</td>
<td>86.2</td>
</tr>
<tr>
<td>39A</td>
<td>Medical Equipment and Supplies Manufacturing</td>
<td>6.9</td>
</tr>
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Source: US Census Bureau (2005)

Table 2: Source of Gross Domestic Product Growth

<table>
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<th></th>
<th></th>
<th></th>
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<tr>
<td></td>
<td>Output</td>
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<tr>
<td>Gross domestic product</td>
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<td>3.99</td>
<td>2.86</td>
<td>2.36</td>
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<td>Contribution of IT</td>
<td>0.40</td>
<td>0.20</td>
<td>0.46</td>
<td>0.57</td>
<td>1.18</td>
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<td>Computer</td>
<td>0.12</td>
<td>0.04</td>
<td>0.16</td>
<td>0.18</td>
<td>0.36</td>
</tr>
<tr>
<td>Software</td>
<td>0.08</td>
<td>0.02</td>
<td>0.09</td>
<td>0.15</td>
<td>0.39</td>
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<tr>
<td>Communication equipment</td>
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<td>0.10</td>
<td>0.10</td>
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<td>IT service</td>
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<td>0.06</td>
<td>0.10</td>
<td>0.15</td>
<td>0.25</td>
</tr>
<tr>
<td>Contribution of Non-IT</td>
<td>3.06</td>
<td>3.79</td>
<td>2.40</td>
<td>1.79</td>
<td>2.91</td>
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<tr>
<td>Contribution of Non-IT investment</td>
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<td>1.06</td>
<td>0.34</td>
<td>0.23</td>
<td>0.83</td>
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<tr>
<td>Contribution of Non-IT consumption</td>
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<td>2.73</td>
<td>2.06</td>
<td>1.56</td>
<td>2.08</td>
</tr>
<tr>
<td></td>
<td>Input</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross domestic income</td>
<td>2.84</td>
<td>3.07</td>
<td>2.61</td>
<td>2.13</td>
<td>3.33</td>
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<tr>
<td>Contribution of IT capital service</td>
<td>0.34</td>
<td>0.16</td>
<td>0.40</td>
<td>0.48</td>
<td>0.99</td>
</tr>
<tr>
<td>Computer</td>
<td>0.15</td>
<td>0.04</td>
<td>0.20</td>
<td>0.22</td>
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<tr>
<td>Software</td>
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<td>0.02</td>
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<td>0.16</td>
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<td>Communication equipment</td>
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<td>0.10</td>
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<tr>
<td>Contribution of Non-IT capital service</td>
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<td>1.77</td>
<td>1.05</td>
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<td>1.07</td>
</tr>
<tr>
<td>Contribution of labor service</td>
<td>1.14</td>
<td>1.13</td>
<td>1.16</td>
<td>1.03</td>
<td>1.27</td>
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<tr>
<td>Total factor productivity</td>
<td>0.61</td>
<td>0.92</td>
<td>0.25</td>
<td>0.24</td>
<td>0.75</td>
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Source: Adapted from Table 6, Jorgenson (2001)
Table 3: Results of unit root tests on SIC series

<table>
<thead>
<tr>
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<th>Series</th>
<th>Prob.</th>
<th>Lag</th>
<th>Max Lag</th>
<th>Obs</th>
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<td>35H</td>
<td>1.0000</td>
<td>3</td>
<td>18</td>
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<td>36H</td>
<td>1.0000</td>
<td>3</td>
<td>18</td>
<td>515</td>
<td></td>
</tr>
<tr>
<td>36X</td>
<td>1.0000</td>
<td>2</td>
<td>18</td>
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<td>38C</td>
<td>1.0000</td>
<td>4</td>
<td>18</td>
<td>514</td>
<td></td>
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<tr>
<td>38X</td>
<td>0.9385</td>
<td>2</td>
<td>18</td>
<td>516</td>
<td></td>
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<tr>
<td>36E</td>
<td>0.7962</td>
<td>2</td>
<td>18</td>
<td>516</td>
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<table>
<thead>
<tr>
<th>ADF test in first difference</th>
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<th>Prob.</th>
<th>Lag</th>
<th>Max Lag</th>
<th>Obs</th>
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</thead>
<tbody>
<tr>
<td>D(35H)</td>
<td>0.0000</td>
<td>2</td>
<td>18</td>
<td>515</td>
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<td>D(36H)</td>
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<td>18</td>
<td>512</td>
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</tr>
<tr>
<td>D(36X)</td>
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<td>1</td>
<td>18</td>
<td>516</td>
<td></td>
</tr>
<tr>
<td>D(38C)</td>
<td>0.0000</td>
<td>5</td>
<td>18</td>
<td>512</td>
<td></td>
</tr>
<tr>
<td>D(38X)</td>
<td>0.0000</td>
<td>1</td>
<td>18</td>
<td>516</td>
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</tr>
<tr>
<td>D(36E)</td>
<td>0.0000</td>
<td>8</td>
<td>18</td>
<td>516</td>
<td></td>
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</table>

<table>
<thead>
<tr>
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<th>Series</th>
<th>Prob.</th>
<th>Bandwidth</th>
<th>Obs</th>
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<tr>
<td>35H</td>
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<th>Prob.</th>
<th>Bandwidth</th>
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<tr>
<td>D(38X)</td>
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<td>2.0</td>
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</tr>
<tr>
<td>D(36E)</td>
<td>0.0000</td>
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Table 4 Results of Cointegration Test to the SIC Series

<table>
<thead>
<tr>
<th></th>
<th>35H</th>
<th>36E</th>
<th>36H</th>
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<th>38X</th>
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<td>N</td>
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<td>Y</td>
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<td>Y</td>
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<td>36H</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>36X</td>
<td>Y</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td></td>
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<tr>
<td>38C</td>
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<tr>
<td>38X</td>
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Note: Y = the two series are cointegrated; N = the two series are not cointegrated
Table 5: Sources of output growth: 1995-2003 vs. 1989-1995

<table>
<thead>
<tr>
<th>Source of growth (% points per annum)</th>
<th>Source of growth (% points per annum)</th>
</tr>
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<tbody>
<tr>
<td>GDP Growth</td>
<td>GDP Growth</td>
</tr>
<tr>
<td>ICT</td>
<td>%ICT/GDP</td>
</tr>
<tr>
<td>Non-ICT</td>
<td>%Non-ICT/GDP</td>
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<td>GDP Growth</td>
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<tr>
<td>ICT</td>
<td>%ICT/GDP</td>
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<tr>
<td>Non-ICT</td>
<td>%Non-ICT/GDP</td>
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</tbody>
</table>

<table>
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<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>GDP Growth</td>
<td>ICT</td>
</tr>
<tr>
<td>Canada</td>
<td>1.39</td>
<td>0.49</td>
</tr>
<tr>
<td>France</td>
<td>1.3</td>
<td>0.19</td>
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<tr>
<td>Germany</td>
<td>2.34</td>
<td>0.26</td>
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<tr>
<td>Italy</td>
<td>1.52</td>
<td>0.26</td>
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<tr>
<td>Japan</td>
<td>2.56</td>
<td>0.31</td>
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<tr>
<td>United Kingdom</td>
<td>1.62</td>
<td>0.27</td>
</tr>
<tr>
<td>United States</td>
<td>2.43</td>
<td>0.49</td>
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<tr>
<td>All G7</td>
<td>2.18</td>
<td>0.38</td>
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<td>Brazil</td>
<td>1.97</td>
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<tr>
<td>China</td>
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<tr>
<td>India</td>
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<td>0.09</td>
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<td>Indonesia</td>
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<td>0.1</td>
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<td>Mexico</td>
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<td>Russian Federation</td>
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<td>0.07</td>
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<td>South Korea</td>
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<tr>
<td>All GD7</td>
<td>3.45</td>
<td>0.13</td>
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</table>

Source: Based on Table 2, Jorgenson & Vu (2005)
Table 6: End-Use Share of Total U.S. Sales of Integrated Circuits and Total Market Value 1962-1978

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Government</td>
<td>100%</td>
<td>55%</td>
<td>36%</td>
<td>20%</td>
<td>10%</td>
</tr>
<tr>
<td>Computer</td>
<td>0</td>
<td>35</td>
<td>44</td>
<td>36</td>
<td>38</td>
</tr>
<tr>
<td>Industrial</td>
<td>0</td>
<td>9</td>
<td>16</td>
<td>30</td>
<td>38</td>
</tr>
<tr>
<td>Consumer</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Total U.S. domestic shipments (millions)</td>
<td>$4</td>
<td>$79</td>
<td>$413</td>
<td>$1204</td>
<td>$2080</td>
</tr>
</tbody>
</table>

Source: Borress, Millstein, & Zysman (1983); adapted from Table 2.7 Langlois et al. (1999, p.37)