Can we live on services? Exploring manufacturing-services interfaces and their implications for industrial policy design

Antonio Andreoni
University of Cambridge
Centre of Development Studies
aa508@cam.ac.uk

Carlos Lopez Gomez
University of Cambridge
Institute for Manufacturing
cel44@cam.ac.uk

Abstract
Over the last decade, both developed and developing economies have placed renewed attention to the role of manufacturing industries as pressures have mounted up on issues including loss of productive capabilities and competitiveness, loss of production jobs, trade imbalances, deindustrialization. The debate that has recently resurfaced around the role of manufacturing industries vis à vis service activities is extremely polarised due in part to a dominant tendency by analysts and policy makers to consider them as de-linked domains.

The paper aims to fill a gap in the operation management and development economics literature by providing an analytical framework through which symbiotic interdependencies between manufacturing and services can be disentangled. The concept of symbiotic interdependencies stems from the recognition that a set of complementary production and service activities must be performed across a range of functional areas in order to produce given commodities. As a result of outsourcing and fragmentation trends in global industrial systems, production and services activities which used to be performed inside the same production units are increasingly dispersed among a number of manufacturing firms and service providers organised in value chains. Although these production and services activities appear de-linked in terms of ownership boundaries and geographical location, they remain intrinsically interconnected from production, operational and technological perspectives. Understanding to what extent and in which direct and indirect ways manufacturing does contribute to the development of services (and vice versa) in given industrial systems is a fundamental step for moving the policy debate ahead.
Informed by a critical review of the ongoing debate, the paper first discusses the intrinsic limitations of the traditional sectoral approach for analysing interdependencies between manufacturing and services. It argues, instead, that in today’s evolving industrial systems value chains are a more appropriate unit of analysis. Mapping value chains allows for the identification of spaces beyond traditional sectoral boundaries through which manufacturing and services activities interact in processes of value creation. A new taxonomy is proposed which frames the interactions between services and manufacturing across technological and operational interfaces, and discusses their strategic importance in the functioning and upgrading of industrial value chains.

On these bases, the hypothesis according to which countries promoting the interaction between complementary manufacturing and services will progressively experience a process industrial commons development and increasing innovation potential, is tested both on analytical and empirical grounds. A case study of the Singaporean aerospace industry is presented. It is shown how selective industrial policies in this country have aimed at building on their current capabilities on production-related services (i.e. maintenance, repair and overhaul, MRO) for capturing complementary activities of the aerospace value chain. Such policies have played a role in Rolls-Royce decision to establish a wide chord fan blade (WCFB) manufacturing facility and an Advanced Technology Centre (ATC) in Singapore, with an investment expected to exceed £300 million.

The paper provides a rationale for innovative industrial policies. It does so by developing an analytical framework based on the identification of industry-specific complementarities between manufacturing and services. This framework can be used as a focusing device for evaluating policy options and designing selective interventions.
‘Can we live on services?’
Exploring manufacturing-services interfaces and their implications for industrial policy design

Antonio Andreoni* and Carlos López-Gómez**
Centre for Development Studies* and Institute for Manufacturing**
University of Cambridge

Abstract
The paper aims to fill a gap in the operation management and development economics literature by providing an analytical framework through which ‘symbiotic’ interdependencies between manufacturing and services can be disentangled. The concept of symbiotic interdependencies stems from the recognition that a set of complementary production and service activities must be performed across a range of functional areas in order to produce given commodities. As a result of outsourcing and fragmentation trends in global industrial systems, production and services activities which used to be performed ‘inside’ the same production units are increasingly dispersed among a number of manufacturing firms and service providers organised in value chains. Although these production and services activities appear de-linked in terms of ownership boundaries and geographical location, they remain intrinsically interconnected from production, operational and technological perspectives. Mapping value chains allows for the identification of spaces ‘beyond traditional sectoral boundaries’ through which manufacturing and services activities interact in processes of value creation. A new taxonomy is proposed which frames the interactions between services and manufacturing across multiple interfaces, and discusses their strategic importance in the functioning and upgrading of industrial value chains. On these bases, the hypothesis according to which countries promoting the interaction between complementary manufacturing and services will progressively experience a process of industrial commons development and increasing innovation potential, is tested both on analytical and empirical grounds. A case study of the Singaporean aerospace industry is presented. It is shown how selective industrial policies in this country have aimed at building on their current capabilities on production-related services (i.e. maintenance, repair and overhaul, MRO) for capturing complementary activities of the aerospace value chain. The paper provides a rationale for innovative industrial policies. It does so by developing an analytical framework based on the identification of industry-specific complementarities between manufacturing and services. This framework can be used as a focusing device for evaluating policy options and designing selective interventions.

Keywords: manufacturing-services interfaces; global production networks; industrial commons; operation management; industrial policy

JEL codes: L22; L23; L52; L65; L93


Introduction

A view that has held sway for decades among some circles of analysts and policy makers, particularly in developed countries, is that as economies develop the role of the manufacturing activity is destined to lose relevance. As countries grow richer, the argument goes, they shift their resources from agricultural to manufacturing and, then, to service activities. Developed countries specialise in ‘high-value’ services as ‘low-value’ manufacturing activities are moved to cheaper locations. Hence, some believe that governments must proactively facilitate the structural change of their economies to one based on services – a process commonly referred to as tertiarisation. Under this rationale, a number of developed countries have implemented economic policies that favour the promotion of service activities at the expense of manufacturing, contributing to the process of de-industrialisation. Such was the case of the UK, where the vision advocated by Margaret Thatcher’s government in the 1980s has been epitomised with the slogan ‘we can live on services’.

In recent years, however, increased attention has been drawn to manufacturing as pressures have mounted up on issues including the lost of production jobs, decreased competitiveness vis-à-vis foreign competitors, and trade imbalances. Since the early 2000s, a number of countries around the world have published white papers in which the importance of manufacturing is being re-examined. Indeed, an increasing number of analysts have started to question, ‘Has de-industrialisation gone too far?’ The 2008-2009 economic crisis further fuelled this preoccupation, as governments had to step in to avoid the collapse of ‘strategic’ manufacturing firms. The restructuring of the automotive industry, with the subsequent efforts by various governments aimed at keeping production at home, is a striking example.

As a result, the debate on the strategic importance of manufacturing to the national economy has resurfaced. The predominant approach has traditionally been to compare manufacturing and services across a number of variables using standard sectoral classifications that, ipso facto, consider them as de-linked activities. Important insights have been gained about the extent of the interdependencies between manufacturing and services at the national level, for example, through the use of input-output tables1. However, a systematic approach for exploring the nature and the relevance of these manufacturing-services interdependencies, in a more disaggregated

---

1 See, for example, the influential work by Se-Hark Park and Kenneth Chan in Park (1989), Park and Chan (1989) and Park (1994).
manner and beyond the dichotomy given by sectoral classifications, is missing. This
appears as a fundamental omission in the context of today's industrial systems, in which
manufacturers and service providers increasingly perform complementary activities to
jointly produce goods and services – as well as ‘product-service systems’ that integrate
both.

Starting from a critical review of the ‘making’ or ‘doing’ debate (section 1), the
paper aims to move a step forward by focusing on the multifaceted interdependences
existing between manufacturing and services. Although input-output tables are
extremely powerful devices in the identification of linkages and multiplying effects in
terms of employment generation and output increase, they do not provide any specific
information about technological and organizational interdependencies existing between
manufacturing industries and the services sector. The reason is that the unit of analysis
considered, namely sectors, is not adequate for understanding how manufacturing and
services (especially producer services) interact in today’s global production networks
and value chains.

The value chain framework is used to describe the whole range of activities by
which a number of actors gradually add value to a product before it reaches the final
customer (Kaplinsky and Morris, 2001). Because it adopts a holistic view focusing on
processes of value addition without limiting the analysis to sectoral boundaries, the
value chain framework is more appropriate for recognising the interfaces between
manufacturing and service activities at the industry-system level. Embracing this
perspective, the paper proposes a new taxonomy though which complementary
relationships linking manufacturing industries to service activities can be systematically
considered across specific technological and operational interfaces (section 2). An
important distinction made in the taxonomy is the different levels of knowledge-
intensity within producer service industries.

The analysis of manufacturing-services interfaces in a structured way can shed
light into how the outsourcing and off-shoring of manufacturing activities from
developed to developing countries can affect the capacity of the former in maintaining
and reinventing high-value products and services. While recent research has shown that
service industries play an important role in the process of technological upgrading as
‘bridges for innovation’, the paper discusses evidence that this innovative potential can
only be fully exploited by promoting a complementary interacting space with the
manufacturing base.
Following on from that, the paper discusses arguments supporting the hypothesis according to which countries failing to capture *spaces of interaction* between manufacturing and services will progressively experience a process of increasing re-location, industrial commons deterioration, and decreasing innovation capacity (*section 3*). Conversely, a case study on the aerospace industry is used to illustrate the potential of industrial policy to promote the strategic re-linking of manufacturing-services for promoting value chain competitiveness and upgrading (*section 4*). The empirical work has been supported by a review of official policy publications, interviews with policy makers in both developed and developing countries, and interviews with managers in manufacturing and services firms (including fieldwork in Singapore). It has also been enriched by extensive discussions with field practitioners at international development institutions, particularly the United Nations Industrial Development Organisation (UNIDO).

The paper concludes that the competitiveness of economies depends on the existence of spaces of interaction between manufacturing and services. These spaces manifest as industrial commons that can in turn act as drivers of technological dynamism. Modern industrial policymaking must recognise these dynamics if policies are to foster industrial upgrading and provide incentives for innovation.

1. ‘Making’ or ‘doing’: moving the debate ahead.

De-industrialisation in advanced economies and service-led processes of catching up recently experienced by some developing countries have reopened one of the age-old debates in political economy: does the wealth of nations, that is, their socio-economic development and technological power, mainly result from superior capacities in manufacturing, that is, in *making* commodities, or in *doing* other activities, namely providing services? Moreover, do different *sectors* and/or *activities* performed within each sector contribute to economic growth in specific or indifferent ways? Finally, to what extent a sustained process of economic growth can rely on the increasing relative expansion of the service sector?

*The pro-manufacturing vision*

For a long time along classical economic lines, the term *industrialization* (meaning manufacturing) was synonymous with development. The participation to the global
industrialization race was regarded has a *conditio sine qua non* for experiencing accelerated economic growth, increasing labour productivity and economic welfare. Historical evidence supported this pro manufacturing vision. At the end of the nineteenth century, the developed world included industrialized parts of Europe and USA, followed by Russia and Japan, while the developing world, with few exceptions, was oriented towards primary production. After the World War II, during the golden age of capitalism, catching-up countries thanks to the increasing advantages of backwardness (Gerschenkron, 1962) and the selective industrial and trade policies implemented by developmental states were able to grow on average three times as fast as USA (Szirmai, 2011; Chang, 1994 and 2002).

During the 1960s, the *pro manufacturing vision* found its theoretical systematization in Albert Hirschman’s and Nicholas Kaldor’s seminal contributions. On the one hand, in Hirschman’s (1958) unbalanced growth model each sector is linked with the rest of the economic system by its direct and indirect intermediate purchase of productive inputs and sales of productive outputs – i.e. backward and forward linkages. According to its system of linkages, each sector exercises on the rest of the economy ‘push’ and ‘pull’ forces. Unlike agriculture, the industrial sector is characterized by both strong backward and forward linkages and, thus, emerges as the main driver of development. On the other hand, building on the classical work on increasing returns by Allyn Young (1928), Kaldor (1966, 1967 and 1981) developed the concept of dynamic economies of scale which captures the idea that the faster the growth of manufacturing output, the faster the growth of manufacturing productivity. The empirical identification of stylized tendencies characterizing the demand and supply conditions in agriculture, manufacturing and services led Kaldor to the formulation of three general laws. In his view, the rate of growth of productivity of the overall economy depends on the expansion of the manufacturing sector as well as the shrinkage of agriculture and other non manufacturing activities such as services which are characterized respectively by decreasing returns and lower productivity growth. Thus, specialization in manufacturing would imply a *double productivity gain*. Although for a

---

2 As recently confirmed in Szirmai (2011), in the long run there is an *empirical correlation* between the dynamic growth of manufacturing output (and manufactured exports) and per capita income. See Szirmai and Verspagen (2010) for a review and test of the empirical evidence collected using growth accounting techniques and econometric analysis.

3 The classical debate on agriculture vs manufacturing development is discussed in Andreoni, 2011.

4 The different sources of increasing returns identified in the classical line of Smith, Babbage, Young and Kaldor are discussed in Andreoni and Scazzieri, 2011. See Toner (1999) for a review of Kaldor’s laws and its contributions to the Cumulative Causation Theory.
long time the validity of Kaldor’s laws was a central object of discussion\(^5\), Kaldor’s views remained extremely influential until the mid 1970s in developing countries but also in UK, as it is testified in the debate hosted in the *Economic Affairs* (1989)\(^6\). The pro manufacturing vision went under attack during the 1980s and was fully reverted in the following decade when the *pro services vision* became dominant.

**The pro-services vision**

This new vision was supported by the fact that *prima facie* in both advanced and developing countries the service sector was taking the role of manufacturing in leading the process of economic growth. Theoretical explanations for the rising share of services associated with economic growth mainly concentrated on final expenditure patterns and prices – i.e. *demand side factors*. The basic intuition was that as people increase their income they begin to demand relatively more services. The falling demand for manufacturing good would naturally lead, the argument goes, to the shrinking of the manufacturing sector which is declassed to a second rate activity (see the seminal work by Fisher, 1939 and Clark, 1940; Bell, 1973 as a classical work on post-industrial society; on income-price linkages see Kravis et. al. 1982; Bhagwati, 1984a; Panagariya, 1988; finally on productivity in services see Baumol et al. 1985).

Empirical evidence seems to support these theoretical arguments. Looking at the figures, as a result of an accelerated process of de-industrialization, in today’s most advanced economies the service sector accounts for over two thirds of GDP (since the 1960s, the most advanced economies have lost on average almost half of their manufacturing sector as a percentage of GDP, see Figure 1). Moreover, in the developing world, we can observe a set of phenomena which seems to run contrary to the historical pattern of structural change followed by today’s advanced countries (Palma, 2005; Dasgupta and Singh, 2005). Firstly, in several developing economies the fall in manufacturing employment, both in relative and absolute terms provide evidence of a form of premature de-industrialisation; secondly the related phenomenon of ‘jobless growth’ even in fast-growing economies such as India is observed; finally, the fact that during the 1990s services often grew at a faster long-term rate than

---

\(^5\) The two main debates were hosted in *Economica* (1968) and in the *Economic Journal* (Rowthorn 1975). See Dasgupta and Singh (2005) for a recent empirical test of Kaldor’s laws.

\(^6\) During the debate at The House of Lords Select Committee on Overseas Trade in April 1984, one commentator’s argued “What will the service industries be servicing when there is no hardware, no wealth actually being produced. We will be servicing, presumably, the product of wealth by others… We will supply the Changing of the Guard, we will supply the Beefeaters around the Tower of London, we will become a curiosity. I don’t think that is what Britain is about. I think that is rubbish” (Liston, 1989).
manufacturing, as for example in India, has suggested the idea that actually services can substitute manufacturing as engines of growth.

Figure 1: Structure of production, 1950 – 2005 (GVA as a % of GDP at current prices)

The pro services vision has been translated in a new policy package which is well summarized in the OECD Growth in Services Report (2005). Here, the following set of policies is recommended with the explicit aim of strengthening the potential of services to foster employment, productivity and innovation:

[1] Open domestic services markets to create new job opportunities and foster innovation and productivity.
[2] Take unilateral and multilateral steps to open international markets to trade and investment in services.
[3] Reform labour markets to enable employment creation and adjustment to a growing services economy.
[4] Adapt education and training policies to rapidly changing requirements for new skills.
[5] Adapt innovation policies to the growing importance of services innovation.

Source: Szirmai (2011)

---

* Earliest year for which data are available: 1950, except for Morocco, Taiwan and Thailand, 1951; China and Tanzania, 1952; South Korea, 1953; Malaysia and Zambia, 1956; Ghana, Hong Kong, Israel, 1960; Belgium, 1965; West Germany, Italy and Norway, 1951; Japan, 1952

* China, 1962, proportions for 1960 not representative due to collapse of agriculture in great leap forward 58–60; Morocco, 1965, manufacturing share

* Tanzania, 1963.


* Bangladesh 1950–1959, same data as Pakistan.

* Australia, Austria, Belgium, Canada, Denmark, Finland, France, (West) Germany, Italy, Japan, The Netherlands, Norway, Sweden, Switzerland, UK, USA.

[6] Remove impediments that prevent services firms from seizing the benefits of ICT. 
[7] Provide a fiscal environment which is conducive to the growth of services.  
Countries such as Australia, Canada, Luxembourg, the Slovak Republic and the United States are offered as successful examples of the huge potential contribution that the service sector can have in both employment creation (high-skilled workers in particular in finance, business services, education and health) and in productivity growth. Evidence of that is provided for the 1980s and the 1990s (see figures 2 and 3 below).

As for developing countries, the idea that industrialisation is no more synonymous of development has also taken pace. It is suggested that developing countries are experiencing a historical unusual pattern of structural change which is determined by a new technological paradigm. According to this explanation, services such as ICT, business services and finance are replacing (this would be argued by the pro services visionaries) or complementing manufacturing in a pro-growth way. Less emphasis is given to the fact that developing countries may be running the risk of a premature de-industrialization which would undermine their capacities to satisfy future changes in consumer demand or to accumulate/build those production capacities and institutions.

---

7 It is interesting to note that, on the contrary, in the late 1960s Kaldor as an economic adviser to the British government proposed a selective employment tax to promote manufacturing in Britain.
which characterize a manufacturing-led pattern of growth (see Cohen and Zysman, 1987; Rowhtorn and Coutts, 2004).

While the pro services vision has convinced many that we are leaving in a post-industrial society, increased attention has been drawn to manufacturing over the last decade as pressures have mounted up on issues including lost of production jobs, lost of competitiveness vis-à-vis foreign competitors, and trade imbalances. Indeed, an increasing number of analysts have started to question, ‘Has de-industrialisation gone too far?’; and also ‘Are we really living in a post-industrial society?’

Sources of de-industrialisation and statistical illusions
The first issue that must be addressed for properly answering the above questions is to investigate the sources of de-industrialisation. As demonstrated by Robert Rowthorn and his affiliates (1987 and 1999), the rapid process of de-industrialisation experienced by most industrialised countries (in particular the EU and UK) as well as by many medium- and high-income developing countries is the ‘natural consequence of the industrial dynamism in an already developed economy’ while ‘the pattern of trade specialization among the advanced economies explains the differences in the structure of employment among them’. In other words, the main explanation of deindustrialization has to be found in the ‘systematic tendency of productivity in manufacturing to grow faster than in services’ (Rowthorn and Ramaswamy, 1999: 1-7, italics added). A recent work by Tregenna (2009: 433) confirms this thesis by empirically demonstrating that the decline in manufacturing employment is ‘associated primarily with falling labour intensity of manufacturing rather than an overall decline in the size or share of the manufacturing sector’.

Secondly, the decreasing relative importance of manufacturing measured as a percentage of total employment seems the result of a ‘statistical illusion’ mainly determined by the fact that a number of activities from design and data processing to transport, cleaning and security have been contracted out by manufacturing firms to

---

8 As we will argue later developed countries may be running the same risk of losing those manufacturing capacities which are vital even for the development of their service sector (see section 3).
9 De-industrialisation is registered as a decline in manufacturing employment first in relative terms and then, at least in some countries, also in absolute terms.
10 Most industrialised countries reached this phase of de-industrialisation around the end of the 1960s and the beginning of the 1970s, while some high-income DCs (such as the rapidly industrialising countries of East Asia) began this phase in the 1980s. The empirical analysis in Palma (2005) confirms the ‘inverted-U’-type of trajectory of manufacturing employment with respect to income per capita. Moreover, four different sources of deindustrialization are identified.
specialist service providers (Bhagwati’s 1984b idea of splintering). Actually, looking at the figures provided by Pilat et. al. (2006), not only we discover that most OECD countries have indeed experienced a steady decline in the share of manufacturing in total employment but also that employment losses have involved different industries and countries in different ways (with no exception for high tech manufacturing).

Figure 3: Decline in manufacturing employment across developed countries

Notwithstanding, manufacturing production and value added have continued to experience strong growth; demand of manufacturing goods is still sustained; finally, productivity growth in manufacturing remains high in many OECD countries and there is evidence that the manufacturing sector is still driving the process of innovation and technological change. Although the growing investments in innovative services and the outsourcing of R&D to specialised labs (counted as services) have reduced business investments in manufacturing’s R&D, the latter sector still accounts for the bulk of spending on technological innovation and development. The recent analysis of the structural evolution of the USA economy provided in Spence and Hlatshwayo (2011) confirms these general trends.
**Intersectoral linkages and symbiotic interdependencies**

The statistical illusion above mentioned is partially determined by the fact that the traditional distinction between services and manufacturing is *blurring* and, as a result, measuring intersectoral interactions is extremely complex (Pilat and Wolfl, 2005). The bundle of interactions which connects manufacturing and services is becoming increasingly denser given the outsourcing of services activities from manufacturing firms to services providers. The existence of strong intersectoral interactions and interdependencies is something that was originally revealed by input – output analyses performed by Park (1989), Park and Chan (1989) and Park (1994). Focusing our attention on the ‘symbiotic’ interdependencies between manufacturing and services leads to the consideration of a fundamental question, which has been very often under evaluated in the polarized debate between manufacturing and services, between ‘making’ or ‘doing’. Namely, *to what extent and in which direct and indirect ways does manufacturing contribute to the development of services (and viceversa)?* The influential work by Se-Hark Park and Kenneth Chan addressed this issue by examining

---

11 Building on the work of Alfred Chandler, the historical analysis developed by Schmenner (2008) has shown how servitization has antecedents that go back 150 years. At that time, the bundling of manufactured goods to downstream-available services was a business strategy adopted by companies with not great manufacturing strengths in order to establish barriers to entry for potential competitors.

12 Interestingly Damesick (1986)’s analysis of Britain transformation during the 1970s and early 1980s stressed the idea of a symbiotic relationship between manufacturing and services development (the same intuition has been empirically tested by Park, 1989).

13 As it has been stressed by Francois and Reinert (1996: 2) ‘While emphasis in the services literature has been placed on final expenditure patterns and prices, some of the most striking aspects of service sector growth relate instead to the relationship of services to the production structure of economies, particularly the relationship of the service sector to manufacturing’.
separately the linkages existing between disaggregated groups of services and various manufacturing industries\textsuperscript{14}. Their analysis was based on the classification proposed by Gershuny and Miles (1983), which divides service activities into two major groups: marketed services and non-marketed services, and further break them down into subcategories (see Figure 5 below). An important distinction made in this classification is that of \textit{producer services}, which include specialised technical services supporting production processes.

\textbf{Figure 5: Gershuny and Miles’ division of services}

\begin{table}[h]
\begin{tabular}{|l|l|}
\hline
1. Marketed services & 2. Nonmarketed services \\
\hline
(a) \textit{Producer services} & (a) \textit{Social services} \\
(i) finance, banking, credit, insurance, real estate & (i) health, medicine, hospitals \\
(ii) professional services: engineering, architectural, legal & (ii) education \\
(iii) other services: cleaning, maintenance, security & (iii) welfare \\
\hline
(b) \textit{Distributive services} & (iv) public administration, legal, military services \\
(i) transport and storage & \\
(ii) communications & \\
(iii) wholesale and retail trade & \\
\hline
(c) \textit{Personnel services} & \\
(i) domestic services: laundry, barbershops, etc. & \\
(ii) hotel, restaurant and catering, etc. & \\
(iii) repairs & \\
(iv) entertainment and recreation & \\
\hline
\end{tabular}
\end{table}

\textit{Source:} Gershuny and Miles (1983)

Park and Chan’s empirical analysis conducted on 26 countries selected in the UNIDO databank confirmed Hirschman’s intuition according to which the manufacturing sector has larger multiplier effects (specifically tends to generate a two to threefold greater output impact on the economy) in comparison to services. This is explained by the denser backward and forward linkages formed within and around the manufacturing sector\textsuperscript{15}. Moreover, their data showed the ‘catalytic role’ that industry could play in

\textsuperscript{14} Empirical studies in regional income and employment multiplier analysis (Stewart and Streeten, 1971) had previously shown using input-output techniques that the ‘the direct employment effect of industrial investment is small relative to its indirect effects resulting from the interindustry purchases of inputs and income induced effects of private consumption’ Also ‘as the industrial base broadens and becomes more integrated, both horizontally and vertically, the employment impact of industrial activities should also increase substantially’ (Park and Chan, 1989: 201). This scenario is consistent with the ‘macro-economic’ effects observed by A.Young (1928) and later discussed in Kaldor (see above).

\textsuperscript{15} The input-output analysis conducted by Pilat and Wolf 2005 reached the same conclusion stating that ‘Manufacturing industries interact much more strongly with other industries, both as providers and as users of intermediate inputs. Even though services now contribute as providers of intermediate input to
fostering employment opportunities in the services sector – i.e. indirect employment effect. At the same time this study explicitly stressed that ‘the evolution of the intersectoral relationship between services and manufacturing in the course of development is symbiotic, in the sense that the growth of the service sector depends not only on that of the manufacturing sector, but also structural change of the former is bound to affect that of the latter’ (Park and Chan, 1989: 212). These results have been recently confirmed by Guerrieri and Meliciani (2005). Their analysis has shown firstly that a country’s capacity to develop its services sector is depended on the specific structure of its manufacturing sector. This is because manufacturing industries require different producers services and tend to use them with different degrees of intensity. Secondly, their analysis has highlighted how the cumulative expansion of services can follow both intersectoral and intrasectoral patterns as the same service producers are also intensive users of these producer services.

Although input-output tables are extremely powerful devices in the identification of linkages and multiplying effects in terms of employment generation and output increase, they do not provide any specific information about technological and organizational interdependencies existing between manufacturing industries and the services sector at the level of production processes. The reason is that the unit of analysis considered, namely sectors, is not adequate for understanding how manufacturing and services (especially producer services) interact in today’s global production networks and value chains (see figure 6). As a matter of fact, sectoral divisions are too aggregate for understanding the way in which industrial systems operate. The reason is that what is commonly referred to as a ‘sector’ may actually involve a range of very diverse firms related with the production process in different ways. Indeed interdependencies between manufacturing and services are technology and operation specific, as well as dependent on the scale and time/sequence arrangements of production and on the specific configurations of productive capabilities required at each stage of value adding.

the performance of other industries, their role remains more limited than that of the manufacturing sector’.
### Figure 6: Generic division of economic sectors and industries*

<table>
<thead>
<tr>
<th>SECTORS</th>
<th>PRIMARY SECTOR (Agriculture)</th>
<th>SECONDARY SECTOR (Industry)</th>
<th>TERTIARY SECTOR (Services)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agriculture, forestry and fishing</td>
<td>Manufacturing</td>
<td>- Wholesale and retail trade; repair of motor vehicles and motorcycles</td>
</tr>
<tr>
<td></td>
<td>- Crop and animal production, hunting and related service activities</td>
<td>- Manufacture of food products</td>
<td>- Transportation and storage</td>
</tr>
<tr>
<td></td>
<td>- Forestry and logging</td>
<td>- Manufacture of beverages</td>
<td>- Accommodation and food service activities</td>
</tr>
<tr>
<td></td>
<td>- Fishing and aquaculture</td>
<td>- Manufacture of tobacco products</td>
<td>- Information and communication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of textiles</td>
<td>- Financial and insurance activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of wearing apparel</td>
<td>- Real estate activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of leather and related products</td>
<td>- Professional, scientific and technical activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials</td>
<td>- Administrative and support service activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of paper and paper products</td>
<td>- Public administration and defence; compulsory social security</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Printing and reproduction of recorded media</td>
<td>- Education</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of coke and refined petroleum products</td>
<td>- Human health and social work activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of chemicals and chemical products</td>
<td>- Arts, entertainment and recreation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of basic pharmaceutical products and pharmaceutical preparations</td>
<td>- Other service activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of rubber and plastics products</td>
<td>- Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of other non-metallic mineral products</td>
<td>- Activities of extraterritorial organizations and bodies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of basic metals</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of fabricated metal products, except machinery and equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of computer, electronic and optical products</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of electrical equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of machinery and equipment n.e.c.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of motor vehicles, trailers and semi-trailers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of other transport equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Manufacture of furniture</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Other manufacturing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Repair and installation of machinery and equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mining and quarrying Utilities</td>
<td>- Electricity, gas, steam and air conditioning supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Water supply; sewerage, waste management and remediation activities</td>
<td></td>
</tr>
</tbody>
</table>

*Based on ISIC Rev. 4*
Thus, instead of capturing flows of raw materials and intermediate commodities between and within sectors as input-output analysis does, by looking at the interfaces between manufacturing and services we aim at capturing how structural features of specific activities performed in each sector interact and influence the development of other activities in the other sector.

2. Interfaces between manufacturing and services from a value chain perspective

In today’s industrial context, firms do not operate in isolation. Rather, competition increasingly occurs between interrelated firms or groups of firms that collaborate with one another performing complementary activities to produce goods and services. In order to capture the evolving interdependencies between manufacturing and services and the implications of de-linking the ‘making’ and the ‘doing’ in production, it is necessary to decompose the process of value adding in production and to analyse how specific manufacturing processes may be complemented by a bundle of services at each stage of value adding. Different actors – i.e. both manufacturers and service providers – are generally involved in the process of value adding and may be structurally organised in complex production networks. Each actor contributes to the process of value adding by performing productive tasks and/or complementing production with the provision of different services.

The production network and value chain approaches have become intensively used over the past decade to describe such dynamics. They focus on the dynamics of interlinkages between related firms within industrial systems. A production network is defined as ‘a set of inter-firm relationships that bind a group of firms into a larger economic unit concept’ (Sturgeon, 2001). While having elements in common, the value chain approach has been used with a broader scope to describe the whole range of activities by which a number of actors gradually add value to a product before it reaches the final customer. It overcomes important weaknesses of the sectoral unit of analysis because it adopts a holistic view focusing on processes of value addition and dynamic interlinkages between the diverse actors. This enables it to deal with linkages that go beyond particular sectors, whether they are inter-sectoral or between formal and informal sector activities (Kaplinsky and Morris, 2001). Therefore, the value chain
approach enables the analysis of the interdependencies realised at the interfaces between manufacturing and services.

From a practical perspective, adopting a value chain perspective allows framing the analysis of the evolving structure of industrial systems in today’s era of rapid change. This is in turn essential in order to gain insights into how manufacturing-services interfaces interrelate in contemporary industrial systems. Indeed, over the last couple of decades, major forces, both economy-wide and industry-specific in nature, have driven rapid structural change in the global industrial activity, dramatically changing the way in which value chains operate. Among them, those particularly affecting the way in which manufacturing and service activities interrelate include globalisation, fragmentation, commoditisation, changing consumer demand, servitisation and rapid technological change. These driving forces and the resulting structural changes in global value chains and in manufacturing-services interfaces are discussed in more detail later below. This analysis will set the ground for defining some basic building blocks of a taxonomy for characterising the interfaces between manufacturing and services, which will be discussed at the end of this section.

2.1 Manufacturing-services interfaces in today’s industrial systems: driving forces and structural changes

The global manufacturing activity has experienced unprecedented change over the last couple of decades. Major forces affecting today’s competitive landscape have resulted in global value systems that are increasingly fragmented and geographically dispersed (Martinez et al., 2008). The way in which manufacturing and service activities interact in global value chains has also evolved as a consequence. Although a detailed review of these forces is outside the scope of this paper, we briefly discuss the most relevant to our discussion, focusing on how they have affected the evolving linkages and interfaces between manufacturing and services.

Centrifugal forces: fragmentation, commoditisation and outsourcing

As production systems have become more sophisticated and the world more globalised, firms have adopted new strategies involving fragmentation and reorganisation of their activities, both in terms of ownership boundaries and in terms of the location for production. As a result, the manufacturing activity has become increasingly fragmented. Goods are created in a number of stages that increasingly
occur across different locations in different countries. Raw materials are obtained in one location, intermediate inputs such as parts and components produced in another, and then exported to yet a different one for further processing and/or assembly in final products. Production-related activities such as R&D, design and professional services are also part of these organisational structures and have also experienced similar fragmentation trends (OECD, 2007).

Thus, production of intermediate and final commodities in GVCs is realised through the complex integration (both upstream and downstream) of interdependent manufacturing and service activities performed respectively by specialised firms and providers. In particular, production related services (PRSs) are either undertaken within manufacturing or outsourced to external providers. In the latter case, they can be collocated within the same national boundaries – i.e. outsourcing, or re-located in other countries – i.e. off-shoring. The Figure 7 below shows the growth of global demand for offshore services from 2005 to 2010.

**Figure 7: Global demand for offshore services, by activity, 2005-2010**

![Figure 7: Global demand for offshore services, by activity, 2005-2010](image)

Note: BPO = business process outsourcing; CAGR = compound annual growth rate; IT = information technology; ITO = information technology outsourcing; KPO = knowledge process outsourcing; R&D = research and development.

Thus, manufacturing-services interfaces may involve different producers and providers which integrate their activities according to multiple patterns of interaction, each of them implying different degrees of proximity and distance\textsuperscript{16}. The management of these \textit{spaces of interaction} requires a continuous process of organisational restructuring and coordination at the global value chain architectural level which would not be possible without the massive utilization of ICTs and the direct development (or indirect access) to appropriate capabilities (Andreoni, 2010).

Fragmentation and outsourcing trends are reinforced by the ubiquitous process of \textit{commoditisation} experienced in industrial systems (Martinez et al., 2008). The concept explains that as some industries go through different stages in their lifecycle, the difficulty to produce a product or service profitably varies significantly. At early stages, there are only one or a few producers with the productive capabilities necessary to deliver the commodity or service. As time goes on, other firms catch up and what it was once as a cutting-edge, innovative product can be produced anywhere by many firms (i.e. barriers to entry decrease with time). For example, some US firms where once the leading producers of many types of electronic equipment. Today most of the production has now shifted to Asia, though firms in many counties are able to produce most of these products at the same level of sophistication. A key consequence of the commoditisation phenomenon is that manufacturers in advanced countries have tended to outsource production to developing countries in order to exploit cost advantages. Conversely, in advanced countries there is a “general shift to knowledge-intensive services” (OECD, 2007, p. 33).

Outsourcing, in particular off-shoring, have a profound impact on both companies as well as countries experiencing processes of relocation. Supporters of these trends have been arguing that outsourcing, especially in its international form has long term economic benefits, namely increasing productivity effects and reductions in factor costs. According to them ‘outsourcing is fundamentally just a trade phenomenon; that is, subject to the usual theoretical caveats and practical responses, outsourcing leads to gains from trade, and its effects on jobs and wages are not qualitatively different from those of conventional trade in goods’ (Bhagwati et al. 2004, p.94). Unfortunately, the empirical literature on offshore outsourcing and its productivity effects (e.g. skill

\textsuperscript{16} Pilat and Wolfl (2005) document the growing trend towards the outsourcing of business-related services, such as research and development, financing or logistics instead of having these functions done in-house.
upgrading) does not univocally support the idea of a positive causal link between the two phenomena. Provided that much depends on both sector and firm-specific characteristics, Olsen (2006) reports that productivity enhancing effects for outsourcing companies (and, thus, for their respective countries) are small in manufacturing while relatively more significant for firms in services.

Though recognising variations between industries, Gage and Lasher (2005) argue that the ability to focus on core competences has become the most prevalent motive for which value chains fragment—or firms engage in vertical specialisation. This allows firms to take advantage of cost savings or productivity enhancements gained from externally supplied components (outsourcing) or from abroad (off-shoring, see Figure 8 below). Other motivations cited include the desire to enter new emerging markets and gain access to strategic assets that can help tap into foreign knowledge, risk sharing, cash injections and the introduction of leaner management schemes.

![Figure 8: Sourcing strategies: interactions between location and ownership](image_url)

Columns indicate the location of production and rows indicate the boundaries of the firm. Vertical arrows represent a change in the boundaries of the firm. Horizontal arrows represent a change in the location of production. Dashed lines correspond to vertical FDI.  
*Source:* (Miroudot, Lanz, & Ragoussis, 2009)

As part of these restructuring in the global industrial activity, trade in intermediate inputs has been steadily growing over the last decade. A study recently conducted by
the OECD (Miroudot et al., 2009) combined trade data and input-output tables to study bilateral trade in intermediate goods and services. It estimated according to the industry of origin and the using industry for the period 1995-2005. It was found that intermediate inputs represent 56% of goods trade and 73% of services trade. This means that trade flows are dominated by products that are not consumed but further used in other stages of the value chain. The authors explain some differences in the dynamics of services and goods intermediate trade, with the trade of intermediate services trade exhibiting a slightly bigger relative growth than that of intermediate goods:

With the fragmentation of production and the increasing importance of outsourcing, trade in intermediate inputs has been steadily growing between 1995 and 2006 at an average annual growth rate of 6.2% for goods and 7% for services (in volume terms). However, trade in final goods and services has increased at the same pace and as a consequence the share of intermediate goods trade has remained constant while the share of intermediate services trade has slightly increased.

This study also found that most of intermediate trade still occurs in developed countries. It also highlighted that activities of multinational enterprises can be associated with higher trade flows of intermediate inputs and with a higher ratio of foreign to domestic inputs in using industries. As a result, the ratio of global imports and exports per unit of output has increased. This is confirmed by (Sturgeon & Kawakami, 2010), who found a 10-fold increase of world imports of intermediate goods in the last four decades (constant price data). In 2006, this represented more than 56% of total world imports.

**Centripetal forces: consolidation and servicisation**

Meanwhile, global value chains are experiencing processes of geographical consolidation. There is a tendency by lead firms to prefer larger, more capable globally operating, first-tier suppliers (Cattaneo, Gereffi, & Staritz, 2010). The level varies from industry to industry, and within each industry, depending on the structure of production and trade. Consolidation is taking place not only at the country level, but also at the firm level. Milberg & Winkler (2010) found that consolidation is most pronounced in textiles, iron and steel, machinery, and transportation. In some sectors, including handbags, apparel, and footwear, consolidation began in the 1990s. (Sturgeon & Kawakami, 2010) argue that the 2008-2009 crisis sped up a process of consolidation in

---

17 An intermediate good can be defined as an input to the production process that has itself been produced and, unlike capital, is used up in production (Miroudot et al., 2009)
the electronics industry that had however been under way since the bursting of the
technology bubble in 2001. Gereffi & Frederick, 2010 also document a consolidation
process in the apparel industry ‘spurred by the phaseout of the Multi-Fibre
Arrangement’s quotas at the end of 2004’. Van Biesebroeck & Sturgeon (2010) observe
the beginning of a historic market shift in the automotive industry to large developing
countries, most likely accelerated by the 2008-2009 crisis.

A broader perspective to industrial systems also allows recognising that the
distinction between manufacturing and services is blurring. They have traditionally been
considered as separate entities, with analysts debating which one is more important to
the national economy for decades (see also section 1). But the manufacturing-services
dichotomy disregards the fact the emergence of new business models has meant that
many firms are increasingly becoming both producers of goods and providers of
services. Similarly, corporations increasingly split their operations into manufacturing
and service units for organisational or accountancy reasons but without a significant
change in their core activities. Notably, the servicisation phenomenon has attracted
attention in the literature over the last years. Manufacturing firms are increasingly
adding services to their value proposition, as customers demand for more and better
services. Servicisation involves ‘the innovation of an organisation’s capabilities and
processes so that it can better create mutual value through a shift from selling product to
selling product-service systems’ (Neely, 2008). A product-service system is defined as
an ‘integrated product and service offering that delivers value in use’. Such systems
offering are expected to allow firms to differentiate from competitors and to achieve
revenue and profit growth. Rolls-Royce’s “Power-by-the-hour” scheme (a marketing
concept based on flight hours instead of maintenance hours) is a typical example of
servicisation. Service contracts represent a move from the break-and-fix services model
into a performance based contracting model. From the customer’s perspective product-
services systems can help reduce maintenance spending and ensure product availability.
To the manufacturer, it allows a predictable revenue stream and proactive capacity
planning.

2.2 Towards a taxonomy of manufacturing-services interfaces
The preceding section has offered valuable insights into how the interfaces between
manufacturing and services are realised in today’s global value chains. From the
insights gained a number of conceptual building blocks have been drawn towards a
taxonomy for characterising the extent and the nature of relationships between manufacturing and services (see Figure 9 below).

**Figure 9: Building blocks of a taxonomy for the analysis of manufacturing-services interfaces**

As a starting point, an overarching distinction can be made between those services that interact with the production process (either as inputs of the process or as an integral part of it) and those who do not. We call the former *production related services* (PRSs) and the latter *non-production related services* (NPRSs). The key differentiating factor between PRSs and NPRs is the extent to which the service provider needs to possess technical knowledge about the production process involved. This distinction is useful, for example, for establishing what kind of services might be more affected by the relocation of the production process. Indeed providers of PRSs such as design, technical and engineering services develop their specific capabilities in different functional areas through continuous interactions with manufacturers. In particular, PRSs providers need to be continuously exposed to the emerging productive needs, bottlenecks and complexities of production processes if they want to provide effective responses in time. This is the reason why PRSs providers tend to maintain a certain degree of proximity with manufacturers and tend to co-locate, thus, generating economies of agglomeration (see section 4 for a detailed example).

As stressed previously, manufacturing and services exhibit linkages of various forms that can take place at different stages of the value chain. Manufacturing firms use
service inputs \textit{upstream} and \textit{downstream} the production process: they commission marketing studies that inform product design; outsource technical testing and certifications of components; hire firms to transport raw materials, components and finished products; employ cleaning services; consult specialists to upgrade their production process technology; use marketing specialists to promote their products in the market; and partner with maintenance firms to offer after-sales services. Therefore, following on from the overarching distinction presented above, we distinguish between interfaces occurring at different stages of the value chain. Although we broadly divide them into upstream and downstream the production stage, they could be further subdivided according to the different stages identified in the value chain of interest. Indeed, each link in the GVC involving manufacturers and service providers (in particular PRSs) constitutes an interface in which the service provider’s value adding is determined by its capacity to match/respond to the specific productive needs arising at that specific stage of the manufacturing process.

Evidently, \textit{services are different in nature}. This means that inside the two broader sample of PRSs and NPRs (entering both upstream and downstream) we can distinguish different sets of services according to the different functional areas they interact with. Inside the first group of PRSs we can distinguish between technological and operational services, also adding one residual category of other services (see Figure 10 for a full list based on ISIC Rev 4 Classification); similarly, inside the NPRSs group we can distinguish financial and distributive services, also adding a residual category (see Figure 11 for a full list based on ISIC Rev 4 Classification). For the purposes of the taxonomy proposed here, we focus on production-related services and introduce a discussion of their main features.

\textbf{Technological services} include specialised technical services that influence the technological sophistication of the production system through which goods are produced. They include specialised engineering, scientific and other professional services. Specific examples include specialised manufacturing resource planning solutions such as MRP and MRPII (downstream) and the refurbishing of products and repair of components already in the market (upstream). According to the Gage and Lesher (2005, p. 20) radio frequency identification (distribution services), enhanced CAD software (pattern making, grading, and nesting and marking services), and the increased capacity of the internet (all services) “are playing a role in the increased use and tradability of services related to the apparel value chain”.
As discussed earlier the globalisation of the value chain has been driven by companies’ desire to increase efficiency, as growing competition in domestic and international markets forces them to become more efficient and lower costs. Notably, manufacturing firms are increasingly interacting with providers with production-related operational services who carry out non-core activities on their behalf that however are indispensable for the daily operation of the production system. A number of activities that related to the so-called information technology outsourcing (ITO) and business process outsourcing (BPO) fall under this category. They include business functions, such as network management, application integration, management consultancy, and human resources.

Besides technological and operational services, there are a number of other services that while not interacting directly with the production process, enable its functioning in various ways. They include services such as rental of machinery and leasing of intellectual property.

Thereafter, building on this classification and the consideration of knowledge intensity in service industries (Andersson, 2006), it is possible to establish some distinctions between the strategic relevance of some type of services compared to others. This is an important consideration because it implies that some services are more strategic than others to manufacturing firms, i.e. the capabilities of certain services providers are more crucial to the value offering of the manufactured product. For example, the capabilities of providers of technical engineering services (e.g. used to improve the accuracy of certain machining or casting processes) and research services may have a higher strategic weight than that of firms specialising in facilities cleaning and human resource administration. Related to this point is the analysis of the value chain governance – formal and informal systems of coordination (Gereffi et al., 2005) – which can support the discussion on power relationships between actors of the chain.

The taxonomy of manufacturing services-interfaces introduced in figure 9 is detailed in the following figures 10 and 11 by firstly listing the specific typologies of services entering the broader categories of technological, operational, financial, distributive and other services; secondly, by considering the ‘knowledge intensity’ of the services involved.
Figure 10: A taxonomy of manufacturing services-interfaces (production related services)

<table>
<thead>
<tr>
<th>TYPE</th>
<th>UPSTREAM</th>
<th>DOWNSTREAM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Code</td>
<td>Description</td>
</tr>
<tr>
<td>TECHNOCALOGICAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Computer programming, consultancy and related activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>J6201 Computer programming activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>J6202 Computer consultancy and computer facilities management activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>J6209 Other information technology and computer service activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Engineering and scientific services</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M71 Architectural and engineering activities; technical testing and analysis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M71 Research and experimental development on natural sciences and engineering</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Market research</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M732 Market research and public opinion polling (for informing product design)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Design services</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M741 Specialised design activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M749 Other professional, scientific and technical activities n.e.c.</td>
<td></td>
</tr>
<tr>
<td>OPERATIONAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Telecommunications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>J61 Telecommunications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Management services</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M70 Activities of head offices; management consultancy activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Employment activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M78 Employment activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Business support activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N82 Office administrative, office support and other business support activities</td>
<td></td>
</tr>
<tr>
<td>OTHER</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Legal and accounting services</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M69 Legal and accounting services</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Renting and leasing activities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N771 Rental and leasing of motor vehicles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M773 Renting and leasing of other machinery, equipment and tangible goods</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M774 Leasing of intellectual property and similar products, except copyrighted works</td>
<td></td>
</tr>
</tbody>
</table>

Notes: “●” = Low knowledge intensity; “■” = Medium knowledge intensity; “■ ■” = High knowledge intensity.
Based on ISIC Rev.4
Figure 11: A taxonomy of manufacturing services-interfaces (non-production related services)

<table>
<thead>
<tr>
<th>TYPE</th>
<th>UPSTREAM</th>
<th>Code</th>
<th>Description</th>
<th>Knowledge intensity</th>
<th>Code</th>
<th>Description</th>
<th>Knowledge intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FINANCIAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial and insurance activities</td>
<td></td>
<td>K64</td>
<td>Other monetary intermediation</td>
<td>▼</td>
<td>K64</td>
<td>Other monetary intermediation</td>
<td>▼</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K642</td>
<td>Activities of holding companies</td>
<td></td>
<td>K642</td>
<td>Activities of holding companies</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>K643</td>
<td>Trusts, funds and similar entities</td>
<td></td>
<td>K643</td>
<td>Trusts, funds and similar entities</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>K649</td>
<td>Other financial service activities, except insurance and pension financing activities</td>
<td>▼■■</td>
<td>K649</td>
<td>Other financial service activities, except insurance and pension financing activities</td>
<td>▼■■</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K65</td>
<td>Insurance, reinsurance and pension financing, except compulsory social security</td>
<td></td>
<td>K65</td>
<td>Insurance, reinsurance and pension financing, except compulsory social security</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>K66</td>
<td>Activities auxiliary to financial service and insurance activities</td>
<td></td>
<td>K66</td>
<td>Activities auxiliary to financial service and insurance activities</td>
<td></td>
</tr>
<tr>
<td><strong>DISTRIBUTIVE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retail trade of intermediate goods and components</td>
<td></td>
<td>G46</td>
<td>Wholesale trade, except of motor vehicles and motorcycles</td>
<td>■</td>
<td>G46</td>
<td>Wholesale trade, except of motor vehicles and motorcycles</td>
<td>■</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G453</td>
<td>Sale of motor vehicle parts and accessories</td>
<td></td>
<td>G451</td>
<td>Sale of motor vehicles parts and accessories</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation and storage</td>
<td></td>
<td>H4912</td>
<td>Freight rail transport</td>
<td>▼</td>
<td>H4912</td>
<td>Freight rail transport</td>
<td>▼</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H4923</td>
<td>Freight transport by road</td>
<td></td>
<td>H4923</td>
<td>Freight transport by road</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>H4930</td>
<td>Transport via pipeline</td>
<td></td>
<td>H4930</td>
<td>Transport via pipeline</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>H5012</td>
<td>Sea and coastal freight water transport</td>
<td></td>
<td>H5012</td>
<td>Sea and coastal freight water transport</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>H5022</td>
<td>Inland freight water transport</td>
<td></td>
<td>H5022</td>
<td>Inland freight water transport</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>H512</td>
<td>Air freight transport</td>
<td></td>
<td>H512</td>
<td>Air freight transport</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>H52</td>
<td>Warehousing and support activities for transportation</td>
<td></td>
<td>H52</td>
<td>Warehousing and support activities for transportation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>H53</td>
<td>Postal and courier activities</td>
<td></td>
<td>H53</td>
<td>Postal and courier activities</td>
<td></td>
</tr>
<tr>
<td><strong>OTHER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Security services</td>
<td></td>
<td>N80</td>
<td>Security services</td>
<td>▼■■</td>
<td>N80</td>
<td>Security services</td>
<td>▼■■</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N81</td>
<td>Services to buildings and landscape activities</td>
<td></td>
<td>N81</td>
<td>Services to buildings and landscape activities</td>
<td></td>
</tr>
<tr>
<td>Information service activities</td>
<td></td>
<td>JG31</td>
<td>Data processing, hosting and related activities; web portals</td>
<td>▼■■</td>
<td>JG31</td>
<td>Data processing, hosting and related activities; web portals</td>
<td>▼■■</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Notes: “■” = Low knowledge intensity; ”■■” = Medium knowledge intensity; “■■■” = High knowledge intensity. Based on ISIC Rev.4
3. De-linking manufacturing and services in GVCs: industrial commons deterioration and technological lock-in

After a couple of decades (from the 1980s to the late 1990s) in which farming out/abroad in-house operations was a religion, recently more cautious and sometimes alarming perspectives have been emerging. The dominant view implied that ‘by shedding assets, companies can be born again as product designers, solutions providers, industry innovators, or supply chain integrators’ and, thus, that they can ‘dump operational headaches and bottlenecks downstream, often capture immediate cost savings, and avoid labor conflicts and management deficiencies’ (Doig et al. 2001, p. 24). However, in many industries such as the automotive, electronics and the software ones it has been observed that in the outsourcing race companies increasingly run the risk of ceding and, sometimes, even destroying those capabilities and processes that have constituted their competitive advantages. Moreover, outsourcing companies increasingly fail to capture the innovation opportunities which reside especially in the spaces of interaction and interfaces between manufacturing production and PRSs (Quinn and Hilmer, 1995). In sum, there is evidence that many companies have overestimated the advantages of outsourcing and offshoring while underestimated problems such as dealing with inventory, obsolescence, organizational traumas, reaching quality standards, maintaining in house technological capabilities (Ritter and Sternfels, 2004).

As suggested by the taxonomy developed here (see section 2), the existence of multiple interdependencies among manufacturing and services activities in GVCs calls for a comprehensive assessment of the effects arising from outsourcing, especially the impact of de-linking manufacturing and services (especially PRSs) through offshoring. Few contributions have identified the dynamic and interlocking effects of offshoring for countries ‘losing’ manufacturing firms (or service providers) on the one side, and those ‘acquiring’ the same manufacturing firms (or service providers) on the other. The relocation of manufacturing firms and/or service providers in other countries triggers two simultaneous transformational processes which affect the productive and technological structures of countries. Specifically, countries relocating big junk of their manufacturing activities tend to experience a process of industrial commons deterioration, increasing relocation of PRSs and technological lock-in; on the contrary,

---

18 According to The 1999 Outsourcing Trends Report, the outsourcing of operations and facilities across industries rose by 18 percent only in the period from 1999 to 2000.
in those countries in which production is relocated, an expansion of the manufacturing sector and an increasing co-location of other manufacturing firms (as well as production related services providers) are observed. The transformation in the US software industry elucidates this point. Initially, in order to lower software development costs US companies started outsourcing mundane code-writing projects to Indian firms\(^{19}\). However, as soon as Indian companies have developed their technological capabilities in software engineering, they have been increasingly able to attract more complex manufacturing and services activities such as developing architectural specifications and writing sophisticated firmware and device drivers (Pisano and Shih, 2009). The opposite trend, namely technological capabilities decumulation has been observed in US software companies. Of course, processes of relocation and colocation may be triggered by initially offshoring services providers as well as manufacturing firms. However, given the multiplying effects which characterizes the expansion of the manufacturing basis (see section 1) and the fact that certain services (in particular PRSs) have to remain proximate to production, it seems that offshoring manufacturing activities is strategically more damaging than losing services providers.

These cumulative processes of relocation and colocation are responsible for the transformation of the productive and technological structures of countries (that is, their specialization in GVCs) and for the present and future prospects of innovation and specialization of private companies. For example, as a result of outsourcing, the U.S. industrial structure is no more able to manufacture many of the cutting-edge products it invented. As it has been documented ‘[a]mong these are such critical components as light-emitting diodes for the next generation of energy-efficient illumination; advanced displays for mobile phones and new consumer electronics products like Amazon’s Kindle e-reader; the batteries that power electric and hybrid cars; flat-panel displays for TVs, computers, and handheld devices; and many of the carbon fiber components for Boeing’s new 787 Dreamliner (Pisano and Shy, 2009, p. 116). On the contrary, there is evidence that countries acquiring manufacturing production and PRSs activities are accumulating technological capabilities and increasingly benefitting from the relocation and colocation of companies at all stages of GVCs. By 2010 Fortune 500 companies have 98 R&D centers in China and 63 in India; IBM employs more people in the

\(^{19}\) Apple is a well known exception. Although it has outsourced the manufacture of its notebooks, iPod, and iPhone, Apple has preserved in-house technological capabilities by remaining involved in key phases of the production process such as the selection of components, industrial design, software development as well as direct interaction with users – i.e. learning by using.
developing world than in America; in 2008, the Chinese telecom giant Huawei applied for more international patents than any other firm in the world (see Cataneo et al. 2010); and, by some estimates, as much as 90% of electronics research and development now takes place in Asia (McCormack, 2009).

For capturing the interlocking dynamics described above, two processes deserve more attention. The following case study analysis (section 4) will elucidate their implications in the specific context of the aerospace industry.

**Co-location and Industrial commons**

Pisano and Shih (2009) research on the semiconductor, electronics, pharmaceutical and biotech industries have revealed how the production and innovation capacities of a given economic system depend on the presence of multiple resources such as R&D know-how, engineering skills, technological capabilities and specific manufacturing and prototyping competences. These resources are embedded in a large number of manufacturing and services companies as well as other institutions, typically universities and vocational schools. The co-location of these actors and, thus, the possibility for the same companies and institutions to have access to their resources is at the roots of the industrial commons phenomenon. Indeed, as in almost all high-tech industries product and process innovations are strongly intertwined, the fact that manufacturing firms can locally undertake daily interactions with other manufacturers and PRSs constitutes a competitive advantage which benefits all actors involved – i.e. industrial commons. With this respect, it is worth to stress that even the development of cutting-edge high-tech products often depend, among the others, on the commons of a mature manufacturing industry.

It is evident how outsourcing, especially offshoring, tends to de-link manufacturing and services and to affect their possibilities to conduct research and experiment new products and process technologies. In sum, the deterioration of industrial commons caused by outsourcing can in the long run affect the ability of a given economic system to introduce new products, as the suppliers, skills and services required to set up a new enterprise are no longer available locally. On the contrary, those countries in which manufacturing and services activities co-locate according to

---

20 The idea of industrial commons is rooted in the classical work on industrial districts (Marshall, 1920).
21 Coffey and Bailly (1991, p.109) emphasize the role of co-location stressing how ‘it is the cost of maintaining face-to-face contacts between the producer on the one hand, and their inputs and markets, on the other hand, that is potentially the most expensive element of intermediate-demand service production’.
different patterns of complementarity, experience processes of industrial commons development and benefit from innovation opportunities arising at the manufacturing-services interfaces.

**Re-location and Technological lock-in**

The second dynamic related to the de-linking of manufacturing and services in GVCs is that of technological lock-in. This refers to macro level forces that create systematic barriers to the diffusion and adoption of efficient technologies (Arthur, 1989). One of the major factors associated with technological lock-in is the idea of increasing returns to adoption. Early adoption of a technological solution might give it enough edge to secure its dominance in the market. Even if an improved technology (e.g. more environmentally efficient) is developed, such increasing returns may keep them locked-out of the market (i.e. it doesn’t pay off to produce it anymore). These technological lock-in dynamics explain the eventual dominance of the QWERTY keyboard over the Dvorak Simplified Keyboard (David, 1985), and the VHS video cassette recorder standard over Betamax (Arthur, 1994).

Recent work has shown that manufacturing offshore can lead to technological lock-in effects. Fuchs and Kirchain (2010) explain that as production in the optoelectronics industry has been outsourced to East Asia, emerging, the manufacture of better performing designs developed in the US no longer pay off. “Production characteristics are different abroad, and the prevailing design can be more cost-effective in developing country production environments” (Fuchs & Kirchain, 2010). Therefore, they conclude that offshoring reduces incentives to innovation can therefore lead to an erosion of technological competitiveness.

The potential consequences of technological lock-in have been increasingly attracting attention among academics and policymakers. Such concerns not only focus on the potential adverse consequences in advanced countries given the lost of production capacity, but also on the potential loss of technology dynamisms and competitiveness in global industrial systems as a whole.
4. Re-linking manufacturing and services: the case of the Singaporean aerospace industry

The civil aerospace industry is selected to illustrate some of the main ideas put forward in previous sections. These include ideas on the benefits of the value chain approach and a taxonomic reference for identifying and characterising the interfaces between manufacturing and services in a given industrial system; the relationship between manufacturing-services spaces of interaction and industrial competitiveness; and the potential for co-location between certain type of services and the production process. Sources of information used for this analysis include reports by industry association, consultancies, and governmental agencies; company webpages; and interviews with academics and policymakers.

The aerospace industry: the traditional approach

The aerospace industry has recently attracted the interest of policymakers both in developed and developing countries. The OECD has traditionally classified it as a high-tech industry (Hatzichronoglou, 1997) mainly based on research intensity indicators (other industries in this category include pharmaceuticals; medical, precision and optical instruments; radio, television and communication equipment; and office, accounting and computing machinery). The United Nations (UN) offers a classification of the aerospace industry both in terms of activities and products, which are the basis of most economic analyses (see Figure below). However, as per the limitations discussed earlier, these standard industry classifications have limited use for recognising the interfaces between manufacturing and services. Although the activity classification in the Figure 12 below includes one service, overhaul and conversion of aircraft or aircraft engines, as part of the broader aerospace category, UN databases do not actually provide disaggregated data for it and it is therefore difficult to establish its relative relevance within the whole value chain.
### Figure 12: Standard classifications of the aerospace industry

<table>
<thead>
<tr>
<th>Activity classification</th>
<th>Product Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ISIC Rev.4 code 3030</strong> - Manufacture of air and spacecraft and related machinery</td>
<td><strong>SITC Rev.4 code 792</strong> - Aircraft and associated equipment; spacecraft (including satellites) and spacecraft launch vehicles; parts thereof</td>
</tr>
</tbody>
</table>

**This class includes:**
- manufacture of airplanes for the transport of goods or passengers, for use by the defence forces, for sport or other purposes
- manufacture of helicopters
- manufacture of gliders, hang-gliders
- manufacture of dirigibles and hot air balloons
- manufacture of parts and accessories of the aircraft of this class:
  - major assemblies such as fuselages, wings, doors, control surfaces, landing gear, fuel tanks, nacelles etc.
  - airscrews, helicopter rotors and propelled rotor blades
  - motors and engines of a kind typically found on aircraft
  - parts of turbojets and turboprops for aircraft
  - manufacture of ground flying trainers
  - manufacture of spacecraft and launch vehicles, satellites, planetary probes, orbital stations, shuttles
  - manufacture of intercontinental ballistic missiles (ICBM)

**This class also includes:**
- overhaul and conversion of aircraft or aircraft engines
- manufacture of aircraft seats

**Source:** (UN, 2011)

The production of aircrafts involves very complex structures. An airplane can consist of up to six million parts, compared to some 7,000 parts contained in a car (AT Kearney, 2003). The industry’s supply chain is dominated by a few large companies, notably final assemblers such as Boeing and Airbus. A vast and global supplier base supports these firms, including fairly large and sophisticated engine and avionics manufacturers. These include firms like General Electric Aircraft Engines (GEAE), Rolls-Royce, Honeywell and Pratt & Whitney. They are referred to as tier-one suppliers – and increasingly “system integrators” – and play a significant role in the aerospace industry (BNDES, 2009). Tier I suppliers are further supplied by a large base of tier 2 and tier 3 suppliers, which may serve multiple industries (including automotive). Tier 2 suppliers include companies such as L-3 Communications, Harris and Parker-Hannifin. They are followed by tier 3 suppliers, which include suppliers of machined components such as castings and raw materials suppliers of metals, plastics and rubber. Except for the first level of the supply chain (aircraft manufacturers such as Boeing and Airbus), companies actively trade between them. Honeywell and Rolls-Royce are competitors but often
collaborate and trade between themselves too. Therefore, the industry is characterised by collaborative programs and equity cross holdings between aircraft manufacturers (Boeing and Airbus) and its tier 1 suppliers. At tier 2, 3 and 4 levels, there is a large and diversified manufacturing base, which is often shared by the firms in tiers above it (BNDES, 2009).

The traditional approach has been to organise this vast range of actors into broadly defined categories that include leading firms, system integrators, and tier 1 and tier 2 suppliers. Figure 13 describes the typical representation of the structure and major actors of the aircraft manufacturing supply chain. It can be observed that the focus is solely on production-related firms. This type of information can be obtained from publicly available industry and market reports from a range of sources including industry associations and consultancies.

Figure 13. Actors and architecture of the aircraft manufacturing supply chain

Source: Based on (BNDES, 2009)

**Manufacturing-services interfaces in the aerospace value chain**

From a value chain perspective, however, it is necessary to recognise actors beyond the supply chains that affect processes of value creation in the aerospace industry. As expected, this includes a range of both manufacturing and service activities related to
the production of aircrafts. Based on the key dimensions illustrated in Figure 9 (see section 2), we analyse upstream and downstream services related to the production of aircrafts, and find that what is traditionally considered as aerospace is closely related to the aviation industry and to the space industry. The aviation industry includes airports, airlines, general aviation, air navigation service providers and those activities directly serving passengers or providing airfreight services. The space industry includes space-enabled products and services such as launch vehicles, satellites, and ground stations. For the purposes of this investigation, the extended civil aerospace value chain shown in Figure 14 below will be considered:

(a) Aircraft assembly and sales
(b) On-board avionics
(c) Propulsion systems
(d) Aerostructures
(e) Airlines
(f) Maintenance repair and overhaul (MRO)
(g) Training and simulation services

Figure 14. Extended aerospace value chain

Source: Authors

Having identified relevant actors and relationships, it is possible to analyse how value is distributed along the value chain. This is helpful in order to observe the co-creation of value between manufacturing and service activities encompassed in the aerospace industry. Due to data availability, revenue and employment are chosen for analysis in this exercise. These are some of the most common concerns expressed in national manufacturing strategy documents, along with tax-related measures. The results are shown in Figure 15. Data to populate the framework is difficult to get at the required

---

22 Space industry actors are not included as this segment is highly dependent on government expenditure on space programmes, and our focus here is on commercial civil activities.
level of disaggregation. However, having a clear structure based on value chain relationships is useful in deducing data from available sources. In some cases, a small number of firms are the only participants in that part of the chain, so figures can be obtained adding up data from individual annual corporate reports. It is necessary to triangulate diverse sources of information in order to make sure data is reliable and comparable. Qualitative inputs are necessary to interpret and structure the data. Another element included in the value distribution mapping is the type of activities more relevant to the operation of the different types of firms. This is relevant, for example, because R&D intensity is often a concern to the government.

Figure 15 - Value distribution mapping in the aerospace value chain

Source: López-Gómez, O’Sullivan and Gregory (2011)
One of the main findings of the mapping exercise was the realisation that although often disregarded in aerospace industry studies, the MRO service segment provides a significant contribution in terms of revenue (and therefore it can be implied that in tax contributions) but mainly in terms of employment. If airlines are excluded, it represents around 25-30% of the value chain employment\textsuperscript{23}. MRO is estimated to account for $45-50 billion\textsuperscript{24}, and is expected to grow to $61-70 billion by 2017 (Deloitte, 2010). The relatively large cumulative value captured by MRO is largely explained by the long lifetime of aircrafts, and by a shift towards integrated products and services in the aerospace sector. Moreover, since deregulation in the 1970s, there has been a sustained trend for MRO outsourcing, as airlines have tended to focus on their core business of passenger and freight transportation (Johnstone, Dainty, & Wilkinson, 2009). This is a trend consistent with the discussion presented in Section 2 on the changing fragmented nature of industrial value chains.

\textbf{The MRO segment: a service linked with manufacturing}

By taking a closer look at the activities involved in MRO, it is possible to recognise its close linkages with other parts of the value chain. The civil MRO market is segmented into four markets: airframe heavy maintenance, engine overhaul, component MRO and line maintenance. As it can be observed in the figure below, MRO interacts with manufacturing activities in various ways. Namely, manufactured components are used to replace some of the aging ones. Additionally, a number of manufacturing processes are employed for the repair and overhaul of some other components (e.g. coating processes in the maintenance of engine blades). Therefore, the interfaces between services and manufacturing are clearly evident in the operations of MRO providers.

Nevertheless, MRO has been largely disregarded in aerospace industry analyses, which tend to focus on final assemblers and manufacturers of parts and components. For example, a key concern expressed in initiatives in countries with an established aerospace industrial base is to increase local production of components. MRO is not included in policy-related industry analysis because its considered as an activity not related to manufacturing. Moreover, as discussed earlier, it is difficult to analyse MRO using available international trade databases, as its exports are not recorded in custom databases.

\textsuperscript{23} Jobs in MRO might require a lower skill level than in other parts of the value chain, but this is an issue that requires further investigation.

Table 16: MRO segments

<table>
<thead>
<tr>
<th>Segment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Airframe Heavy Maintenance</strong></td>
<td>Detailed inspection and repair of the airframe and components, performed at specified time intervals. These intervals are specified by the aircraft manufacturer, national aviation authority (eg FAA, EASA), and further refined by the airline/operator. AHM include any applicable corrosion prevention programs and comprehensive structural inspection and overhaul of the aircraft.</td>
</tr>
<tr>
<td><strong>Engine Overhaul:</strong></td>
<td>Off-wing repair and replacement of parts to restore the engine to designed operational condition, to guidelines established by the engine manufacturer. Typically, the engine is disassembled, inspected, and parts are repaired or replaced as necessary. The engine is then re-assembled and tested before being reinstalled on the aircraft.</td>
</tr>
<tr>
<td><strong>Component MRO:</strong></td>
<td>Maintenance, including repair and overhaul of aircraft components which provide the basic functionality for aircraft flight including aircraft control and navigation, communications, control surface movements, cabin air conditioning, electrical power, and braking.</td>
</tr>
<tr>
<td><strong>Line Maintenance:</strong></td>
<td>Light, regular maintenance checks that are carried out to ensure that the aircraft is fit for flight—including troubleshooting, defect rectification, overnight maintenance and component replacement. There are three principal activity categories: Transit checks, daily/weekly checks and A-checks. B-checks rarely exist these days since its related activities are captured in A and/or weekly checks.</td>
</tr>
</tbody>
</table>

*Source: (AeroStrategy, 2009)*

**Manufacturing-services co-location: the case of Singapore**

When analysing the MRO industry, Singapore appears as a natural case study. Since 1990, the country’s aerospace industry has grown at an average rate of 13.3%. MRO dominates 90% of industry output (US$4.67 billion). Singapore is now considered the most comprehensive MRO hub in Asia Pacific, capturing 25% share of Asian market & 6% share of the global market (UKTI, 2011).

Building on this strong position, in 2006, Singapore unveiled plans for a dedicated 300-hectare aerospace park to host a wide range of aerospace-related activities. The government expect the park to be fully operational by 2018 and by then it is expected to contribute $3.3 billion annually in value-add and to create 10,000 new aerospace-related jobs (predominantly skilled and technical positions). The aerospace park will host the following activities (EDB, 2006):

- Maintenance, Repair & Overhaul (MRO)
- Design and manufacture of aircraft systems, components and potentially light aircraft
- Business and general aviation activities
- Regional aerospace campus, which will house educational and training institutes and research facilities

According to the government, the second of three phases of the Seletar aerospace park had already been completed by the first half of 2011. Key tenants that have been attracted to the park include Pratt & Whitney, Rolls-Royce and ST Aerospace. Industry bulletins report that investments are continuing to pour in (EDB, 2008).
MRO and the aerospace industrial commons

Rolls-Royce is particularly receiving attention due to its commitment to build state-of-the-art assembly facilities for its Trent 900 and Trent 1000 engines. It is also building the most advanced regional training centre for civil and marine applications. The start of production of engines and blades is planned for mid-2012 in its “Facility of the Future”—the firm’s first facility to implement a full moving line engine assembly and test capability. Total investment in the Rolls-Royce Seletar Campus is expected to exceed £300 million (Rolls-Royce, 2009).

Figure 17: Seletar Aerospace Park: exploiting the co-location potential

What is evident from the Singaporean government’s approach to the development of Selectar is its recognition of the linkages between MRO (services) and other parts of the value chain, both manufacturing and services (e.g. production and R&D). From the outset, the plant was to build on the country’s current MRO capabilities not only to increase them, but also to develop other activities such as production of components and R&D. For example, as part of their activities in the country, Rolls-Royce and Boeing have entered into partnerships with Singapore universities and research institutes to further their research in areas like advanced materials, repair technologies, predictive maintenance and fuel-cells (EDB, 2008).

Perhaps most importantly, anecdotal evidence suggest that Rolls-Royce played a pivotal role the in the Singaporean government’s deliberate attempt to build industrial commons. Rolls-Royce was not only important for its individual contribution, but for the spill over effects in building a conducive environment in the Seletar aerospace park.
According to government sources, there are a number of benefits related to the existence of local competences in Seletar (EDB, 2009):

Companies that site themselves at the Seletar Aerospace Park stand to reap the many synergies from being in an integrated environment. The benefits include economies of scale and increased efficiency. There is also significant scope for new industry collaborations through the park’s shared infrastructure, and close proximity of suppliers, customers and partners within a tightly-knit aerospace business community.

**Future prospects in global MRO**

Since the cost structure of many MRO operations is strongly dependant on labour costs, developing countries have the potential to capture the ‘flying geese’. With growing fuel prices and increasing concerns to reduce maintenance-related transport times and aircraft downtimes, locations near areas of high air traffic are—literally and figuratively—better positioned. As observed in the map below, a number of Latin American, North African, South East Asian and Middle Eastern countries are located within 2,000 miles of the busiest airports in the world. Countries interested in promoting aerospace would be better positioned by having MRO under their radar.

![Figure 18: MRO potential growth locations (and nearby developing countries)](image)

*Source: Compiled from the Airport Council International webpage and individual airport webpages.*

---

20 busiest airports by aircraft movement, 2009
5. Concluding Remarks

This paper argues that the current dominant approaches for the analysis of industrial systems – sectoral analyses based on aggregate international trade data and static industry classifications – have led to a limited understanding of today’s industrial realities and, in particular, of manufacturing-services interfaces. Global value chains increasingly involve firms from different areas of specialisation that go beyond traditional sectoral and geographical boundaries. The paper has provided the building blocks for the analysis of manufacturing-services interfaces and, thus, of what we have defined as ‘symbiotic’ interdependencies between manufacturing and services in global value adding processes. The concept of symbiotic interdependencies stems from the recognition that a set of complementary production and service activities must be performed across a range of functional areas in order to produce given commodities. As a result of outsourcing and fragmentation trends in global industrial systems, production and services activities which used to be performed ‘inside’ the same production units are increasingly dispersed among a number of manufacturing firms and service providers organised in value chains. Although these production and services activities appear de-linked in terms of ownership boundaries and geographical location, they remain intrinsically interconnected from production, operational and technological perspectives. Mapping value chains has allowed for the identification of spaces ‘beyond traditional sectoral boundaries’ through which manufacturing and services activities interact in processes of value creation.

The new taxonomy proposed in the paper frames the interactions between services and manufacturing across multiple interfaces. Firstly, it does so by distinguishing between production related services (PRSs) and non-production related services which enter both upstream and downstream the global value adding process. As a second step, the above mentioned broader classification has been disaggregated by considering specific services according to different functional areas involved and on the basis of the knowledge intensity involved in their provision. On these bases, the hypothesis according to which countries promoting the interaction between complementary manufacturing and services will progressively experience a process of industrial commons development and increasing innovation potential, has been tested both on analytical and empirical grounds. The Singaporean aerospace case study has shown how traditional sectoral analyses based on standard industrial classifications have
largely disregarded maintenance, repair and overhaul (MRO) services, which
nevertheless captures a very significant contribution in terms of employment and output
of the whole value chain. Most importantly, the case study has shown that the
recognition of the linkages between MRO (services) and other parts of the value chain,
both manufacturing and services (e.g. production and R&D) have led the Singaporean
government to adopt selective policies aimed at building on their current capabilities on
services to promote competitiveness in the whole aerospace value chain.

This has important implications for industrial policy design more in general. Firms classified in one sector may be closely dependant on the inputs of firms in a
different one; for support programmes to work, the inclusion of both types of firms
might be essential. Furthermore, the nature and sophistication of the competences
required to carry out different types of activities involved in an industrial value chain
vary significantly. A country might be able to capture some, but not all of them.
Competitiveness of economic systems depends on the existence of spaces of interaction
between manufacturing and services. These spaces manifest as industrial commons that
can in turn act as drivers of technological dynamism. Modern industrial policymaking
must recognise these dynamics if policies are to foster industrial upgrading and
providing incentives for innovation.
References


