CHAPTER 3

Costa Rica in the Electronics Global Value Chain

Opportunities for Upgrading

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Acronyms

E&E	Electronics & Electrical
EMS	Electronics Manufacturing Services
EU	European Union
FDI	Foreign Direct Investment
GPS	Global Positioning System
GVC	Global Value Chain
IC	Integrated Circuit
INTECO	Instituto de Normas Técnicas de Costa Rica
INA	Instituto Nacional de Aprendizaje
ITCR	Instituto Tecnológico de Costa Rica
ODM	Original Design Manufacturer
OEM	Original Equipment Manufacturer
NPD	New Product Development
PC	Personal Computer
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
TAP	Test, Assembly, and Packaging

1. Introduction

The electronics and electrical (E&E) industry in Costa Rica dates back to the 1960s when foreign direct investment (FDI) in the electrical segment first emerged and has continued to experience steady growth over the next two decades. In the 1990s, FDI in the electronic component and parts segment also started entering the overall mix, including the arrival of Intel, the largest firm operating in this industry. Over the last decade, the rate of new entrants into this industry has slowed considerably with the majority of new investments being made in service related fields such as repair and process engineering.[1] In 2011, E&E exports reached $US 2,573 million (nearly double the value of exports in 2002 at $1,173 million), with the vast majority coming from the electronic components segment (84%). The electronics industry has been a steady, top export revenue generator for at least the last 12 years, in 2011 represented 24.5% of Costa Rica's total exports. These industries employ at least 8,800 workers.[2]

Despite the importance of these activities to the Costa Rican economy, there are several hurdles facing future developments, including: (1) the dominance of multinational corporations (MNC) with minimal domestic development; (2) concentration in manufacturing-related activities; and (3) competitiveness of Asian countries. First, growth of the electronics industry in Costa Rica has primarily been driven by MNCs that have branch manufacturing operations in several locations around the world, including Costa Rica. The head offices for these firms, primarily located in the United States (US), are in charge of strategy development as well as sales, sourcing, and new product development (NPD) for these global operations. The facilities in Costa Rica are predominately manufacturing operations focused in the component segment of the chain in which the vast majority of raw material inputs are shipped from the parent company to the facility in Costa Rica to be assembled and are subsequently shipped to another facility owned by the MNC.

This typical operating model of MNCs limits the potential to develop local linkages and the ability of institutional actors to have a direct impact on the development of the sector outside of attracting new FDI and developing domestic companies. Whereas there has been a steady stream of FDI, there have been limited domestic (or foreign-owned) firms that have set up operations in the country to supply or provide subcontractor services to electronics firms in the local, regional, or global markets. Lastly, the core of electronics manufacturing, and increasingly design and NPD as well, are moving to lower cost Asian countries that have large-scale capacities and capabilities that span the entire value chain. The ability of this cluster to provide both low costs and full package capabilities poses a threat to countries that are only competitive in one area.

[1] There have also been a considerable number of investments by electronic companies in business process outsourcing. These are currently covered in the offshore services report.
[2] Around 16% overlaps with the medical device industry and 27% with aerospace. Data is not available for seven firms.

Even though the industry faces several challenges, there are still opportunities for Costa Rica to build on its existing assets in many of the various end markets for electronics components and parts that are more insulated from Asian competition and also build on complementary industries in the country such as medical, automotive, and aerospace.

This report contributes to the formulation of a strategy for the electronics industry by using the global value chain (GVC) framework to understand the complexity of the sector and the numerous subsystems of which it is composed. GVC analysis is particularly useful to inform policy makers as it examines the full range of activities that firms and workers around the globe perform to bring a product from conception to production and end use. It examines the labor inputs, technologies, standards, regulation, products, processes and markets in specific segments and international locations, thus providing a holistic view of the industry both from the top down and the bottom up. In doing so, the analysis allows policy makers to assess where local resources may be invested to gainfully participate in global value chains.

This report has six main sections. First, there is an overview of the electronics and electrical components GVC and a discussion of the key segments of the chain. This section presents the governance structure, upgrading and workforce development aspects of this industry. Understanding the manner in which the industry operates at a global level is essential to be able to determine how Costa Rica may be able to grow in the future. This is followed by an overview of relevant experiences from Malaysia, Israel, and Singapore to identify potential lessons for Costa Rica. The next section provides an analysis of the country's position in the E&E value chain including key challenges the industry may face. Finally, the report offers a set of upgrading trajectories and policy recommendations for the electronics industry.

2. The Electronics Global Value Chain

2.1. The Global Electronics Industry

The electronics industry encompasses a broad range of component, intermediate, and final products that feed into a range of end markets. Total world exports in 2011 of the electronics components market were $457.2 billion, electronics subassemblies were $355.5 billion, and final electronic products were $1.3 trillion (UNComtrade, 2012). The end market for consumer electronics alone was over $526 billion (Euromonitor, 2011).

The electronics segment in particular is characterized by rapid technological change and large investments in research and development (R&D). Manufacturing processes are highly automated and quality standards are demanding. Many key manufacturing and business processes in the electronics industry have been formalized, codified, standardized, and computerized including product design (e.g., computer aided design), production planning, inventory and logistics control (e.g., enterprise resource planning), as well as various aspects of production (e.g., assembly, test and inspection, materials handling).

This combination of standardization and automation has created a recipe for 'value chain modularity' in which multiple firms participate in the chain, assembly operations can easily be separated from technology development, and basic, high-volume components can be substituted with relative ease (Sturgeon & Kawakami, 2010). This, coupled by narrowing profit margins in the manufacturing segments, has made it difficult to remain profitable and an expert at everything and has led to a high degree of offshoring and outsourcing throughout the value chain (van Liemt, 2007).

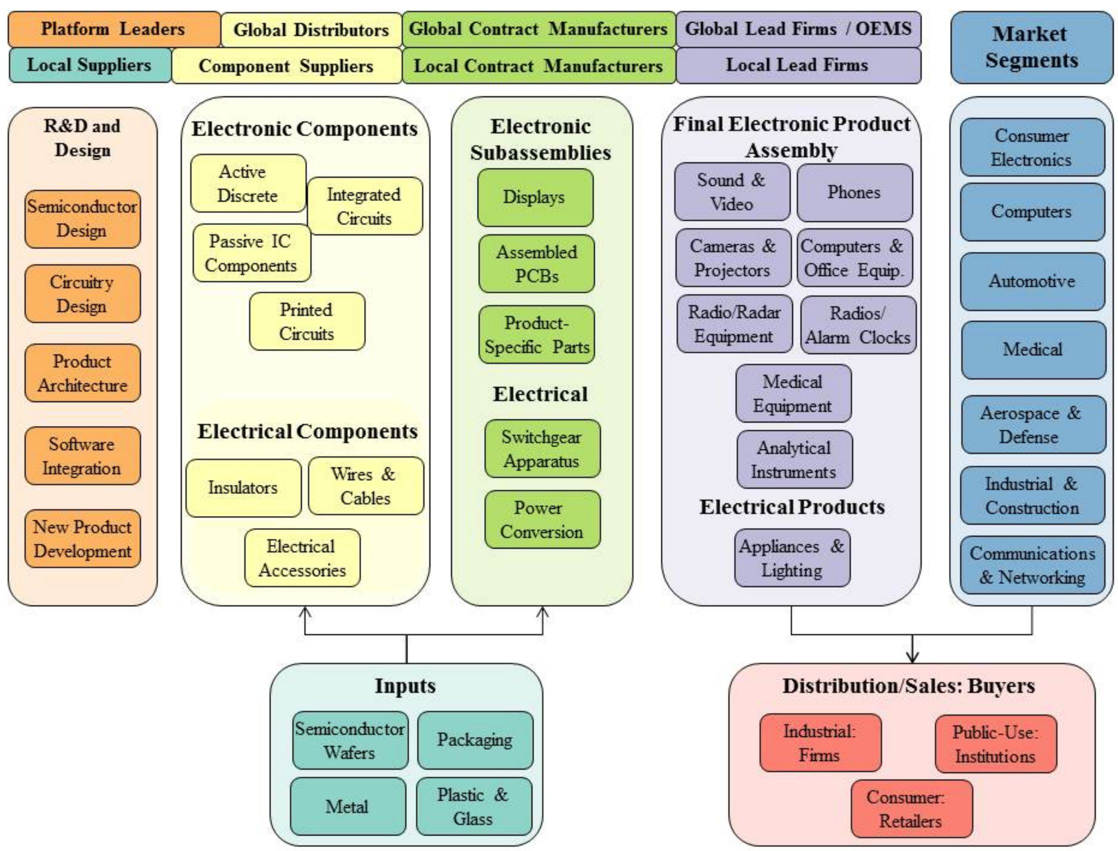
Lead firms now focus on their core competencies, which also happen to be the most profitable segments of the chain (e.g., product development, consumer research, branding and marketing), and rely on contract manufacturers to do the rest. Farther upstream, this presents both challenges and opportunities for component suppliers. On one hand, competition in the production of standard, high volume components is very price sensitive. On the other hand, the relative level of standardization has allowed electronics to be embedded in a wide range of final products, offering a range of opportunities for customized components that have the same fundamental architecture.

The following sections present the global value chain, discuss the global geographic distribution of demand and supply, examine the key actors in the chain and how the chain is impacted by public and private institutions, provide an overview of the human capital requirements for the various activities in the chain, and identify typical upgrading trajectories. Analyzing the global dynamics of this industry provides important insight for developing an upgrading strategy for future growth in Costa Rica.

2.2. Mapping the Electronics Global Value Chain

This section provides a review of the electronics global value chain. The 'electronics industry' can refer to intermediate products (electronic components, parts or subassemblies), final products (consumer and industrial electronics), or both. This paper will consider both of these segments as well as the tangential field of electrical components and subassemblies.[3] Given the vast scope of the electronic and electrical industries (see the Appendix for a full range of HS codes), there have been no previous known attempts to map the entire value chain of the combined E&E industries. Therefore, for the purpose of this report, a comprehensive map of the electronics value chain was created (Figure 1).

Figure 1. The Electronics Global Value Chain



Source: Author

The electronics GVC is composed of raw materials and inputs to electronic components, electronic components, subassemblies, final product assembly for a variety of end market segments, and the ultimate buyers of final products. The value chain also includes several

[3] This report does not directly include final electrical products such as appliances, nor does it include final products that incorporate electronic components, but the final product itself is outside the scope of the typical definition of electronics (e.g., automobiles, aircraft, industrial machinery, etc.).

activities that add value to final products outside of the manufacturing process related to research, product and process development, design, marketing and after-sales services. Given the breadth of products covered in this report, there is a wide range of **value-adding activities**, however the main activities that cut across several sectors include: new product development, circuitry and semiconductor design, software integration, and overall product architecture development. These activities are the most profitable in the chain and predominately controlled by original equipment manufacturers (OEM) or leading component suppliers. These are the last activities and the least likely to be performed in offshore locations or outsourced to other facilities, but this is starting to occur in some countries with large agglomerations of manufacturing facilities in Asia (see Box 1).

Box 1. Offshoring New Product Development in the Electronics Value Chain

In 2010, a survey on the drivers and obstacles of offshoring NPD activities was conducted with 405 US electronic device manufacturers. Of the firms sampled, 43% stated they had at least some offshore product development. The researchers identified several characteristics of firms that engaged in offshore NPD compared to those that did not: (1) they also outsource and offshore a larger share of manufacturing, (2) they earn more revenue from sales outside of the US and (3) they have more overall employees and a larger staff dedicated to NPD. Over 50 percent of the respondents engaged in offshore NPD stated that increasing revenues and reducing labor costs were important drivers to offshore NPD whereas only 20 percent stated that being close to manufacturing facilities was an important driver. The average cost savings from offshore NPD was 14 percent with a median of 10 percent. Other reasons for offshoring NPD that were considered 'important' or 'somewhat important' by over half of the firms included (in order of decreasing importance): access to skilled workers, reducing NPD time, need to be close to customers, need for labor force flexibility, improving product quality and gaining access to local markets. The obstacle to offshore NPD cited as important by the largest share of firms was intellectual property protection, however the strategic importance of NPD was considered at least somewhat important by 70 percent of firms.

The most common locations for offshore NPD were the Asia Pacific region (lead by China and India) followed by Western Europe in which 44-60 percent of respondents had offshore NPD. Only around 13 and 8 percent of firms had in-house or outsourced NPD activities in Latin America respectively. These figures were most similar to Eastern Europe (12 and 11 percent) and Canada (12 and 4 percent).

The NPD activities most likely to occur offshore were the intermediate processes including physical development, test and validation, process and sustaining engineering. The most strategic activities, concept generation, concept design and R&D, were the least likely to occur offshore.

Source: (Kraemer et al., 2010)

The **inputs and raw materials** required to make electronic components vary by the component. The key component in active elements is the semiconductor substrate or wafer. These are produced in foundries or fabs. The materials used in semiconductor fabrication include silicon and silicon chips (for wafers), plastic, ceramics, various metals (mainly aluminum and copper), and doped chemicals and other doped materials. Elements boron, gallium, phosphorus and arsenic are used in doping silicon chips, which turns a silicon crystal from a good insulator into a viable conductor (IBISWorld, 2012b). Key inputs to other electronic and electrical components include various quantities of metals such as aluminum, copper, gold, and silver. Glass and glass products are a key input for displays (IBISWorld, 2012b). A key input for circuit boards is fabricated plastic products to form the layers of the board (Waterman, 2012a).

The next stage in the value chain is **components.** There are numerous steps in the component manufacturing process, including molding, stamping, precision machining, and finishing. These specific steps in the component manufacturing segment of the value chain can be (1) performed by multiple facilities in more than one country in which semi-finished products are exported from one facility to another, (2) in the same facility in the same country, (3) or in multiple facilities owned by different firms in the same country in which one firms uses a subcontractor to perform certain steps. These subcontractors can be separate foreign-owned companies, or they can be locally-owned. Conducting more production activities is beneficial at the country level because it increases the range of skills available in the country's workforce.

Electronic components are basic electronic elements with two or more connecting leads or metallic pads intended to be connected together, usually by soldering to a printed circuit board, to create an electronic (integrated) circuit (IBISWorld, 2012b). They can be categorized as active or passive, where active components amplify voltage and control the flow of electric current in a circuit (Freedonia, 2012c).[4] Semiconductors and passives are usually configured together in an electronic subsystem (the most common type being a printed circuit board assembly) for incorporation into a complete electronic system (Freedonia, 2012a).

- **Passive electronic circuit components** are used to store, filter or regulate electric energy, and do not require power to operate (Waterman, 2012a). They interrupt, resist or otherwise influence current flow, but cannot control it and possess no signal amplification capability (Freedonia, 2012a). Examples of passive electronic IC components include capacitors, resistors and varistors.
- **Discretes** contain only one device per chip and are designed to perform a single electrical function. These nonintegrated devices can be used individually (for simple electrical switching and processing applications) or as parts of larger circuit designs (Zino, 2011). Active discretes include transistors and diodes; individual passive components are also referred to as discretes.
- **Integrated circuits (ICs)** are electronic circuits in which many active and/or passive elements are fabricated and connected on a continuous substrate (Zino, 2011). The main types of integrated circuits include processors, memory, and logic chips. The capital investment required to set-up a state-of-the-art microprocessor facility can

[4] Active electronic components are often referred to as semiconductors however the terms are not exactly the same. Electron tubes are active electronic components, but not semiconductors, and semiconductors broadly include any "material, such as silicon, whose properties lie in between that of a conductor and an insulator" including discretes (diodes, transistors), ICs, and optoelectronics (Freedonia, 2012c).

cost $5 billion in the U.S. or $3 billion in a lower cost Asian site ("Industrial R&D: electronics/computers," 2010).

- **Printed circuits** or **printed circuit boards (PCBs)** consist of patterns of circuitry etched from copper that have been laminated together using intense heat and pressure under vacuum. Manufacturers in this segment print, perforate, plate, screen, etch or photoprint interconnecting pathways for electric current on laminates (Waterman, 2012a). The final product at this stage is a "bare" printed circuit board without mounted electronic components. PCBs are used in virtually all electronic equipment from consumer products to high-end commercial electronic equipment. Printed circuit boards used on consumer electronic products typically have lower layer counts and lower performance materials and require less manufacturing capability. High-end commercial equipment manufacturers require more complex multi-layer PCBs, often constructed with advanced materials. Manufacturing printed circuit boards for high-end products requires more investment in advanced production facilities and process technology as well as engineering and manufacturing expertise (IBISWorld, 2012b). Prior to creating the circuit board, PCB artwork must be created which is the schematic that shows how the circuits are connected. This was originally a labor-intensive process, but now computers can be used to automate these steps.

Other passive electronic and electrical components include electrical cables and other passive devices that influence flow but cannot create an electrical current. They are used on circuit boards or as part of electrical subassemblies such as electrical panels, switchgear equipment and power transmission devices.

- **Wire and cables** include insulated fiber-optic cable and nonferrous wire and cable made from drawn wire (Waterman, 2012c).
- **Insulators** are devices intended for electrical insulation and mechanical fixing of equipment or conductors subject to electric potential differences (IEC, 2012).
- **Electrical accessories and equipment** include devices for switching, protecting, or making connections to or in electrical circuits and the base materials they are mounted on to create subassemblies. The component products in this category are used as circuit board components and as parts of subassemblies for telecommunications and power transmission equipment. Products include base panels, switches, connectors, plugs, sockets, junction boxes, relays, and fuses. The term 'electrical equipment' typically encompasses power conversion equipment and components including transformers (power, distribution and specialty), relays, and industrial controls.

Subassemblies: E&E subassemblies include the main components that make up final parts. The actual subassemblies vary by final product, however circuit boards and a display are found in the majority of electronic products.

- **Electronic displays** provide a visual interface that allows the user to see information generated or transmitted by (or within) the electronic system. Electronic displays include flat panel displays such as liquid crystal displays (LCDs), plasma display panels, and other types such as organic light-emitting diode displays (OLEDs)(Freedonia, 2012b).

- **Printed circuit (board) assemblies (PCA or PCBA)** are printed circuit boards with the electronic components attached. The two primary techniques for circuit board assembly are surface mount (SMT) and through-hole (THT). Surface mount is the more advanced technique in which components are placed on pads and soldered to the surface of the PCB. In through-hole, component leads are inserted in holes in the board to keep them in place.
- **Electrical equipment and power transmission subassemblies** include switchgear, switchboard apparatus (panel boards), electric motors, generators and motor-generator sets, and primary and rechargeable batteries subassemblies (Waterman, 2012b).

The **distribution and sales** methods for E&E components and subassemblies vary by the stage in the value chain and the relative value of the part. Passive electronic and electrical component manufacturers (other than semiconductors) sell their products to distributors (accounting for more than 50% of sales) and to end-users, mainly electronic product manufacturers (Waterman, 2012a). Three of the main electronic component distributors include DigiKey, Arrow, and Avent. Semiconductor, display and printed circuit board companies tend to sell most or all of their products to original equipment manufacturers and their contract manufacturers (IBISWorld, 2012b).

There is no single or standard definition of what is encompassed by the term ‘electronics industry’ (definitions range from one market segment, consumer electronics, to nine market segments). Its continuous growth and influence on new industries makes it difficult to classify all the final products and end markets encompassed by it (Padilla-Perez & Hernandez, 2010). In this report, the **final products** of electronic components and subassemblies are divided into seven **market** segments. The first three market segments (computers, consumer electronics, and communications and networking) can be considered more ‘traditional’ electronics segments, and the final four (automotive, medical, industrial, and aerospace/military) are emerging segments in which E&E components or parts are used, but the final products (e.g., cars, airplanes, house) are rarely referred to as electronics.

Table 1. Electronics Market Segments and Final Products Values ($US Bil), 2011

	Market	Final Products	Market Size ($US Billion)
1	Computers	Personal Computers (PC): Desktop, Laptop, Notebook, Netbook	$190.0
		Industrial Computers	$1.9
		Peripherals/Hardware: keyboard, mouse, portable storage (memory cards/sticks), hard disk drives (HDD) & external storage Office Equipment: printer, fax machine, copier, scanner Commercial: server, enterprise computing systems	N/A
2	Consumer Electronics	Portable: Mobile Phone Handsets (78%), Cameras & Camcorders-Imaging, (14%), Media Players (8%)	$311.1
		In-Home: TVs/Projectors (82%), Audio/Cinema (10%), & Video Players (8%)	$212.2
		Video Games: Hardware/Game Consoles	$2.7
3	Communications & Networking	Public telecommunications, private communications networks, Internet, mobile phone infrastructure	N/A
4	Automotive	Entertainment, navigation, communication, vehicle control (braking, acceleration, traction, suspension, parking assist)	N/A
		Aftermarket Only: Media Players (43%), Navigation (38%), Speakers (10%)	$1.8
5	Medical	Consumer medical, diagnostics and testing equipment, imaging, telemedicine, meters and monitoring, implants, fitness	$156.6
6	Industrial	Security, surveillance, factory and building automation and energy, banking & ATM, transportation systems	N/A
7	Aerospace & Military	Ground combat systems, aircraft, sea-based systems, satellites, eavesdropping and surveillance, missile guidance & intercept	N/A

Sources: market segmentation (Padilla-Perez & Hernandez, 2010; Sturgeon & Kawakami, 2011)
Industrial Computers Market (Frost & Sullivan, 2012); Medical Market (Databeans, 2011)
Market size for other markets is based on Retail Selling Prices from (Euromonitor, 2011)
N/A indicates that data is not available for the particular market.

There are several significant growth opportunities for the electronic components and parts industry in the automotive, industrial, medical, and the aerospace and defense markets. In the automotive market, electronically-enabled features continue to be the catalyst for growth. An estimated 10% of the cost to manufacture a vehicle is from electronic content (ATOTECH, 2012). Opportunities for electronics stem from many factors including general trends such as the substituting electronic components for mechanical devices and rising automobile sales in emerging countries (e.g., Brazil, India, and China) as well as increases in demand for in-car entertainment systems and safety features such as anti-lock braking system (ABS), stricter fuel economy and emissions standards, and the growth of hybrid electric and battery electric vehicles (Frost & Sullivan, 2011b).

The use of electronic components is also increasing in household appliances, electricity products such as smart meters and industrial products including automation and control and other equipment that conserves energy (IBISWorld, 2012b). For semiconductors, the fastest growing segments include medical equipment (see Box 2), process controls, and military and aerospace applications (Zino, 2011). These markets are different from the traditional markets such as computers and telecommunications because the overall size of the market is smaller, the required production volumes are lower, and industry growth is slower (van Liemt, 2007). Whereas these are drawbacks for large-scale contract manufacturers and suppliers, these 'niche' markets provide opportunities for smaller, flexible, and more customized suppliers.

Box 2. Medical Electronics & Powered Medical Devices

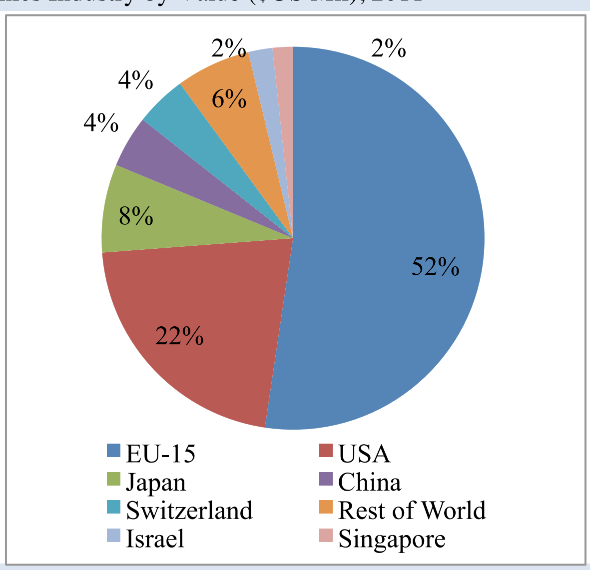
The medical electronics market is a sub-segment of the entire medical devices market. Medical electronics include the entire capital equipment product segment and part of the therapeutics category (hearing aids and pacemakers). The segment includes both large medical imaging equipment (X-ray machines, MRI, and ultrasound machines) as well as smaller equipment that can be used in healthcare facility or in the home (monitoring systems for blood pressure, activity levels, or heart rate). In 2011, total exports were $225 billion, led by the EU-15 (52.4%) and the United States (21.5%). Due to the complexity, inherent risk, stringent safety standards, and high shipping costs of large medical equipment, the industry is still highly concentrated in western Europe and the United States. Unlike consumer electronics, there has not been a large scale shift to offshore manufacturing however some mid-tier countries are beginning to tap into this market such as Israel, China, Singapore, and South Korea. Medical electronics is experiencing steady growth due to advances in semiconductor-enabled technology that are enabling the development of increasingly smaller and more powerful medical devices. In 2010, the medical segment represented around 10% of the global industrial semiconductor market.

In a broader classification, the entire medical device industry can be divided into two segments: (1) devices that require an external energy source to be operational (powered) and (2) those that do not. Powered medical devices include the capital equipment and therapeutics product category as well as a subset of the medical/surgical instruments and equipment category and to a lesser extent, disposables. Energy sources include electrical, heat, RF, laser, microwave, ultrasound, and cyro with laser and RF being the most popular. Powered surgical instruments such as defibrillators, dialysis instruments, dental drills, and laser-based instruments, are not medical electronics but they can be considered electrical medical products.

Some of the areas exhibiting significant growth in the medical device industry include imaging and scanning devices, patient monitoring systems, devices' employing Bluetooth and wireless technologies, and laser technology devices such as those used in laser surgery.

Table 2. Top Exporters in the Medical Electronics Industry by Value ($US Mil), 2011

Exporter	Medical Electronics	
	Value	Share
World	**225,459**	
EU-15	118,032	52.4
USA	48,363	21.5
Japan	16,787	7.4
China	9,862	4.4
Switzerland	9,760	4.3
Israel	4,587	2.0
Singapore	3,888	1.7
Rep. Korea	3,378	1.5
Canada	2,427	1.1
Mexico	1,599	0.7
Top Ten	**218,684**	97.0
Costa Rica	123	0.1
HS07 Codes	90214-5, 9022, 90181-2	



Source: UNComtrade, 2012

Sources: (Associates, 2010; Daher, 2012; Deepa, 2008; "Indian Medical Electronics Industry: Outlook 2020," 2011; Koon, 2012)

2.3. Geographic Distribution

Global Demand

Global demand for electronic components and parts is represented by the countries that assemble final electronic products that incorporate these parts.[5] Table 2 lists the top five exporters of the main final electronic products. These categories include (1) cameras, radar equipment, radios, and televisions, (2) telephones and communication equipment, (3) computers, office equipment, and calculating machines, (4) sound and video projection (speakers, microphones) and recording equipment, (5) analytical instruments, and (6) medical electronics. In 2011, the total export value of all of these products was $1.3 trillion. The EU-15 (29.8%), China (25.8%), and the United States (14.0%), were all one of the top five exporters in every category.

Table 3. Top Five Exporters of Final Electronic Products by Value ($US Mil), 2011

Exporter	Camera, Radar/Radio, & TV		Phones		Computers, Office Equip, Calc. Machines		Analytical Equipment		Total [(b)]	
	Value	Share	Value	Share	Value	Share	Value	Share	Value	Share
World [(a)]	**184,904**		**239,024**		**310,885**		**338,789**		**1,337,361**	
EU-15	31,912	17.3	46,621	19.5	50,636	16.3	143,985	42.5	398,718	29.8
China	48,546	26.3	95,168	39.8	154,932	49.8	17,289	5.1	344,694	25.8
USA	13,626	7.4	22,847	9.6	28,111	9.0	70,862	20.9	186,624	14.0
Japan	12,488	6.8	--	--	--	--	32,104	9.5	66,986	5.0
Mexico	20,861	11.3	11,211	4.7	16,545	5.3	9,660	2.9	61,198	4.6
Rep. Korea	--	--	16,843	7.0	--	--	--	--	33,428	2.5
Malaysia	--	--	--	--	--	--	--	--	25,963	1.9
Thailand	--	--	--	--	11,215	3.6	--	--	19,795	1.5
Top Five	**127,433**	**68.9**	**192,690**	**80.6**	**261,439**	**84.1**	**273,899**	**80.8**	--	--
Switzerland	316	0.2	399	0.2	541	0.2	8,443	2.5	19,550	1.5
Costa Rica	3	0.00	11	0.00	6	0.00	96	0.03	242	0.02
HS07 Codes	85255-6, 8; 8526, 8527; 85284-7, 90061, 3-5; 90071-2, 9008, 3		85171, 85176		8469-72; 844312		90121; 90141-8; 9016; 90241-8; 90271-8; 90281-3; 90291-2; 90301- 8; 90321-8			

Source: UNComtrade, 2012; values in US millions and shares represent percentages of the world total.
(--) indicates exporter not in the top five in 2011, but the value for the product category is included in the total column.
Note (a): the world value only includes Hong Kong's domestic exports calculated as Hong Kong Total Exports - Re-Exports. World value also does not include Taiwan.
Note (b): Sound/Video Projection & Recording (represented by 85181-5; 8519, 8521) is not shown in table due to space limitations, but is included in the total: world value: $38,299 million. Medical Electronics (90214-5, 9022, 90181-2) are also not shown (included in Box), but included in the total: world value: $225,459 million.

[5] Most electronics final products are exported rather than consumed in the same country they are manufactured in (link between global demand and exports).

The production of final electronics products has been shifting from developed countries (such as the United States, Japan and countries in Western Europe) to countries where labor costs are relatively low (mainly in Asia). China has been the major beneficiary of the transfer of production activity from the advanced world (including from Taiwan[6]). For example, in the computer product segment, China's share was only 25% in 2004, however that has doubled to 50% in 2011 (UNComtrade, 2012). Other beneficiaries include the developing countries of Malaysia, Thailand and the Philippines and some countries in Eastern Europe, and these countries tend to have relatively large computer and consumer electronics manufacturing industries (IBISWorld, 2012b).

Global Supply

The shift in final electronics assembly to low-cost countries primarily in Asia is also pulling component manufacturers in the same direction. OEMs are looking for efficient and reliable supply chains, and as a result, component and part manufacturers are moving closer to their customers to reduce time to market and to facilitate faster product development. Table 3 includes the top five global exporters of specific parts and accessories for five of the final product groups in Table 3. The total value of parts was $355.5 billion in 2011 led by China (27.3%), the EU-15 (21.6%), the USA (11.5%), Singapore (7.6%), and South Korea (7.1%). The overall size of this market is likely much larger as many parts are produced within the same country or facility, however intra-country production is not included in international trade data.

Table 4. Top Five Exporters of Parts for Specific Electronics by Value ($US Mil), 2011

Exporter	Camera, Radar/Radio, & TV		Phones		Computers, Office Equip, & Calc. Machines		Analytical Instruments		Total [b]	
	Value	Share	Value	Share	Value	Share	Value	Share	Value	Share
World [a]	**51,911**		**77,216**		**101,284**		**32,856**		**355,520**	
China	12,531	24.1	38,246	49.5	30,642	30.3	2,502	7.6	97,128	27.3
EU-15	8,602	16.6	11,822	15.3	20,801	20.5	10,564	32.2	76,672	21.6
USA	4,385	8.4	4,582	5.9	14,921	14.7	5,332	16.2	40,740	11.5
Singapore	--	--	--	--	10,549	10.4	1,997	6.1	26,923	7.6
Rep. Korea	8,472	16.3	8,959	11.6	--	--	--	--	25,231	7.1
Japan	5,270	10.2	--	--	--	--	6,432	19.6	11,192	3.1
Malaysia					6,319	6.2	--	--	10,677	3.9
Mexico	--	--	4,761	6.2	--	--	--	--	8,413	2.4
Top 5	**39,260**	**75.6**	**68,370**	**88.5**	**83,231**	**82.2**	**26,827**	**81.7**	--	--
Thailand	1,786	3.4	552	0.7	4,001	4.0	272	0.8	11,449	3.2
Indonesia	391	0.8	112	0.1	331	0.3	22	0.1	1,522	0.4
Costa Rica	64	0.12	1	0.00	21	0.02	10	0.03	141	0.04
HS07 Codes	8529 for (8525-28); 90069; 90079		851770 for (85171-8)		8473 for (8469-72)		90129, 90149, 90249, 90279, 90289, 90299, 90309, 90329, 9033			

[6] In 2006, over half of Taiwan's electronic components manufacturers were reportedly already manufacturing in China.

Source: UNComtrade, 2012; values in US Millions and shares represent percentages of the world total.
(--) indicates exporter not in the top five in 2011, but the value for the product category is included in the total column.

Note (a): the world value only includes Hong Kong's domestic exports calculated as Hong Kong Total Exports - Re-Exports. World value also does not include Taiwan.

Note (b): Sound/Video Projection & Recording (represented by 851890 for 85181-5 and 8522 for 8519-21) is not shown in table due to space limitations, but is included in the total: world value: $8,691 million. Semiconductor Media/Microassemblies (represented by 854390, 854890, & 852352) is also not shown, but included in total: world value: $83,562 million.

Going back another stage in the value chain to electronic components producers, a similar set of top exporters emerge. Exports in these categories are not industry-specific and are therefore used across the product categories included in Table 3 and Table 4 as well as other final products. In 2011, the total export value of electronic components (including active discrete components, ICs, printed circuits and passive components) was $457,206 million (Table 5). China is also the leader in this category with 18.8% of the market. Even though Singapore is only in the top five exporters for ICs, they are still the second largest exporter overall (18.7%) which reflects the higher value of semiconductors.

Table 5. Top Five Exporters of Electronic Components by Value ($US Mil), 2011

Exporter	Printed Circuits		Active Discrete		Integrated Circuits		Total [b]	
	Value	Share (%)	Value	Share (%)	Value	Share (%)	Value	Share (%)
World [a]	**29,562**		**105,175**		**295,158**		**457,206**	
China	12,587	42.6	35,428	33.7	32,900	11.1	85,958	18.8
Singapore	--	--	--	--	75,633	25.6	85,343	18.7
EU-15	2,881	9.7	21,370	20.3	32,617	11.1	61,808	13.5
Japan	3,424	11.6	12,257	11.7	--	--	54,222	11.9
Rep. Korea	3,375	11.4	--	--	39,665	13.4	49,773	10.9
USA	1,664	5.6	7,985	7.6	35,705	12.1	47,683	10.4
Malaysia	--	--	7,481	7.1	--	--	36,528	8.0
Top Five	**23,931**	**81.0**	**84,522**	**80.4**	**216,520**	**73.4**	--	--
Mexico	59	0.2	1,367	1.3	1,101	0.4	3,192	0.7
Costa Rica	19	0.1	11	0.0	1,889	0.6	1,962	0.4
HS07 Codes	8534		8541		8542			

Source: UNComtrade, 2012

(--) indicates the country was not in the top five in 2011
Note (a): the world value only includes Hong Kong's domestic exports calculated as Hong Kong Total Exports - Re-Exports. UNComtrade does not report values for Taiwan. In 2011, exports of integrated circuits and electronic components (HS 8540-42) from Taipei were $66 billion, and the world value was $494 billion (WTO, 2012b). The WTO definition includes HS8540, but does not include 8532 and 8533.
Note (b): Passive components (HS 8532 & 8533) not shown, but included in total. World value: $27,311 million.

This shift to low-cost countries has been more pronounced in segments with higher labor intensity including passive components, circuit boards and semiconductor test, assembly, and packaging (TAP) operations relative to semiconductor and display panel fabrication (IBISWorld, 2012b). For example, plants for back-end or TAP operations tend to be located in low-cost regions in Southeast Asian and Pacific Rim countries such as South Korea, the

Philippines, and Malaysia. TAP operations are sophisticated, but less so than wafer fabrication operations, and labor is a more significant factor in overall costs (Zino, 2011).

Semiconductor fabrication and display panel fabrication activities are more capital and technology intensive and resultantly have not seen as dramatic a shift to countries with lower labor costs. Semiconductors and display panels devices are still produced in advanced countries and shipped to low-wage cost countries where final electronic products are assembled (IBISWorld, 2012b). The largest cluster of semiconductor foundries is located in the Asia-Pacific region and Japan. Since 2004, nine of the top 10 pure-play foundries have been in Asia (Zino, 2011). This is an ideal location for these facilities given the large number of nearby contract electronics manufacturers. Japan, Taiwan, and more recently China are now setting up special areas known as "science cities" designed to attract high-tech plants and encourage even more of the high-value adding activities to the region such as R&D, product development, and design (Zino, 2011).

Overall, companies in the electrical and electronic value chain can roughly be divided into the following four categories:

- Asia-based global contract manufacturers and component suppliers:
  - Volume production: China, Philippines, Indonesia, and Vietnam (most recent)
  - Niche/Volume: Thailand (Hard Disk Drives (HDD))
  - Moving into higher-end: Malaysia (Semiconductors)
- Regional assembly:
  - For the United States: Mexico (OEM Assembly; EMS)
  - For Western Europe: Hungary, Poland, and the Czech Republic
- Advanced assembly and EMS/ODM services: Singapore, Taiwan, and South Korea
- Lead firms: United States, EU-15, and Japan.

2.4. Lead Firms and Governance

The electronics GVC is characterized as a producer driven chain, in which the power in the chain is exerted by lead firms that control product and technology development that are crucial for competing in the final-product market. This is in contrast to buyer driven chains in which the most powerful (and profitable) firms control marketing, branding, and retailing activities. The distinction between these two types has diminished in recent years as aesthetic design and branding have increasingly played a larger role in the consumer electronics and computer market segments, however the introduction of new applications and better engineered components is what continues to drive the growth in electronics end market.

In the electronics hardware GVC there are three principal actors: lead firms, contract manufacturers, and platform leaders. Many other entities play important roles in the broader industry, including software vendors, production equipment manufacturers, distributors, and producers of more generic components and subsystems, but understanding how these three firm-level actors interact provides the most important insights into economic development opportunities. The share of the total value captured by the most powerful firms in GVCs, lead firms with global brands and component suppliers with strong "platform leadership", can be extremely high (Sturgeon & Kawakami, 2010).

Lead Firms

Lead firms in the electronics industry are often referred to as OEMs. These firms are responsible for the highest value-adding steps in the value chain including marketing, branding, and new (final) product development. OEMs sell final electronic products through one or more distribution channels (e.g., consumer, institutional, industrial) depending on the end market segment.

Some lead firms still assemble products in-house in their owned and operated facilities, but the use of contract manufacturers has been a strong trend since the late 1980s (Sturgeon & Kawakami, 2011). Lead firms form relationships with global contract manufacturers that assemble electronics that bear the brand names of the OEM. This permits OEMs to focus on the highest 'intangible' value-adding activities including research, NPD, design, and marketing and eliminates the more arduous tasks related to maintaining production efficiencies. On the other hand, contract manufacturers do not have to worry about non-production related factors, and can focus on improving efficiency, plant utilization and reducing costs.

Table 6. Lead Firms and Top Companies in Electronic Markets by Units, 2011

	Market	Top Companies (2011): Units	Other Top Firms
1	Computers	Hewlett-Packard (HP) Microsoft Apple Inc. Acer Inc.	IBM, Fujitsu, Siemens, Dell, Lenovo
	Peripherals and Office Equipment	Logitech International SA	HP, Xerox, Epson, Kodak, Cannon, Lexmark, Acer, Fujitsu, Sharp
	Servers & Data Storage		Toshiba, Western Digital, EMC, NetApp, HP, Hitachi, Seagate, Maxtor, LeCie, Quantum
2	Consumer Electronics	**Firm — Market Share 2011** Samsung 14.3% Sony 12.1% LG Electronics 8.9% Panasonic* 8.5% **Top Four 43.8%**	Philips, Apple, Toshiba, TCL Multimedia
	Audio & Visual: Portable	Samsung Corp Nokia Corp Apple Inc. Nokia Group LG Corp	HTC (Taiwan; phones) NEC (Japan)
	Audio & Visual: In-Home	Samsung Corp Sony Corp LG Corp Panasonic Corp Philips Electronics NV	Leading TV & Video Sony Samsung Panasonic (Matsushita-former name) Philips Electronics NV Others: Vizio, Hitachi, & Sharp
	Video Game Hardware	Nintendo (Wii, Super Nintendo) Sony (PlayStation, PS2, PS3) Microsoft (Xbox, Kinect)	
3	Communication & Networking		Alcatel*, Cisco*, Motorola, Juniper, Huawei, Ericsson, Nokia, Tellabs
4	Automotive Electronics		Clarion, Toyota, General Motors, Renault, Bosch, Siemens
	Aftermarket	Garmin Ltd (Taiwan) Pioneer Corp TomTom (Netherlands) JVC Kenwood Corp Sony Corp	
5	Medical Electronics		General Electric, Philips, Medtronic, Varian
6	Industrial Electronics		Diebold, Siemens, Rockwell, Philips, Omron, Dover
7	Military & Aerospace Electronics		L-3*, Lockheed Martin, Boeing, BAE Systems, Northrop Grumman, General Dynamics, EADS, Finmeccanica, United Technologies

Sources: (Euromonitor, 2011); represented by units sold in 2011 by Global Brand Owner (GBO) (Datamonitor, 2011; IBISWorld, 2011)

*Indicates firm has a manufacturing location in Costa Rica

Contract Manufacturers

Contract manufacturers establish their own global production networks to produce products and/or provide design services on behalf of lead firms for a specified period of time. The popularity of contract manufacturing in the electronics industry is a direct result of value chain modularity, which enables a clear technical division of labor between design and manufacturing at multiple points in the value chain, most notably between the design and assembly of final products and the design and fabrication of integrated circuits, or ICs (Sturgeon & Kawakami, 2011).

Production services in the electronics industry include activities such as component purchasing, circuit board assembly, final product assembly, and testing. In the industry, this is also referred to as electronics manufacturing services (EMS). Many of the large EMS companies originated in the US, but new companies are now emerging from Asia as well. In addition to manufacturing, some contract manufacturers also provide design services; contractors that provide manufacturing plus product design services are known collectively as original design manufacturers (ODM). Most large ODM contract manufacturers are based in Taiwan, with manufacturing concentrated in China. IDC estimates global EMS and ODM revenues reached $297 billion in 2010 (Cathers, 2012).

The majority of the EMS business is at the circuit board assembly level, and manufacturing process technology at this level is fairly generic. For this reason, EMS providers can serve lead firms in a variety of end market sectors which provides a large pool of potential customers. However this limits the market power of EMS providers because their services are highly substitutable. On the other hand, design expertise is much more sector-specific, which limits the potential for end market upgrading. So far the majority of EMS providers work for lead firms in the personal computer (PC) industry, and the majority of these firms are headquartered in Taiwan with manufacturing in China (Sturgeon & Kawakami, 2010). Furthermore, the EMS industry is highly concentrated. In 1999, the ten largest EMS firms held 42 percent of the market, and by 2003 this share had risen to 70 percent (van Liemt, 2007). Table 7 lists the top global EMS and ODM providers in 2009 by region based on industry revenue. The following link provides an interactive map of the global locations of these firms.

Table 7. Top Five Electronics Contract Manufacturers by Region/Revenue, 2009

Top-Five Contract Manufacturers	Headquarters	Primary Service	2009 Revenue ($US Million)
Taiwan / China			
Foxconn/Hon Hai*	Taiwan / China	EMS	44,065
Quanta Computer*	Taiwan / China	ODM	23,265
Compal Electronics	Taiwan / China	ODM	19,424
Wistron*	Taiwan / China	ODM	16,226
Inventec*	Taiwan / China	ODM	12,349
North America			
Flextronics*	USA	EMS	30,949
Jabil Circuit	USA	EMS	11,685
Celestica	Canada	EMS	6,092
Sanmina-SCI	USA	EMS	5,177
Benchmark	USA	EMS	2,089
Other			
Venture	Singapore	EMS	2.428
Elcoteq	Luxembourg	EMS	2,090
SIIX	Japan	EMS	1,360
Beyonics	Singapore	EMS	1,120
Zollner Elektronik	Germany	EMS	970

Source: (Sturgeon & Kawakami, 2011)

Note (*): indicates top company for global computer hardware: market shares: Quanta 6.3%; Wistron 3.6%; Inventec 2%; Hon Hai 1%; Flextronics <1% (IBISWorld, 2012a)

Contract manufacturers purchase the bulk of the world's electronic components on behalf of their global buyers. Purchase contracts for the more expensive components such as microprocessors and other key integrated circuits are negotiated directly by the lead firms and the semiconductor companies or platform leaders (see below). The global prices for the other generic electronic and electrical components are typically low and are often purchased through global distributors. As a result, despite the significant volume of components purchased by contract manufacturers, their buyer power is low because it is ultimately the lead firms that negotiate prices and coordinate development with key platform leaders (Sturgeon & Kawakami, 2010).

Platform Leaders & Component Suppliers

Platform leaders are component or supplier companies that have been successful in implanting their products in the products of other companies and often deal directly with lead firms. Contrary to the case in most global value chains, some platform leaders exert more influence on innovation and are more profitable than lead firms in the chain. Personal computers and mobile phones are two industries in which platform leaders dominate (Sturgeon & Kawakami, 2011). The most notable example of a platform leader is Intel (see Box 3), a dominant force in the microprocessor business (IBISWorld, 2012b).

Other top semiconductor companies are listed in Table 8 and their global locations are including and profiled in these maps and charts. Semiconductors, including discretes, integrated circuits, and optoelectronics, are among the most technologically advanced and expensive component products in electronic products.

Table 8. Top Ten Semiconductor Firms by Revenue, 2010

Rank	Company	Country	Revenues		Global Market Share (2012)
			2009	2010	
1	Intel	USA	32.19	40.02	8.6%
2	Samsung Electronics	South Korea	17.5	28.14	5.0%
3	Toshiba	Japan	10.32	13.08	
4	Texas Instruments	USA	9.67	12.97	2.0%
5	Renesas Technology	Japan	5.15	11.84	1.6%
6	Hynix Semiconductor	South Korea	6.25	10.58	1.3%
7	STMicroelectronics	Switzerland	8.51	10.29	1.4%
8	Micron Technology	USA	4.29	8.85	
9	Qualcomm	USA	6.41	7.2	
10	Elpida Memory	Japan	3.95	6.88	

Source: (Zino, 2011) from company reports; iSuppli. Global market share information is based on global semiconductor and electronic parts from (IBISWorld, 2012b)

Box 3. Intel

Intel was established in 1968 and is headquartered in Santa Clara, California. Intel is the world's largest semiconductor chip maker, developing advanced integrated digital technology platforms for the computing and communications industries. Intel's products include microprocessors, chipsets, motherboards, wired and wireless connectivity products, NAND flash memory, communications infrastructure products, network and server storage products, and software products. Intel's customers include OEMs and ODMs who make computer systems and communications and networking equipment, manufacturers of industrial equipment, and distributors. Intel's processors are installed in 80% of the world's PCs.

Market Segmentation

At the end of 2009, Intel reorganized its business to better align its major product groups around the core competencies of Intel architecture and the company's manufacturing operations. Operating groups include:

- PC Client Group (microprocessors and related chipsets and motherboards designed for the desktop, notebook, and netbook markets), and wireless connectivity products;
- Data Center Group (microprocessors and related chipsets and motherboards designed for the server, workstation, and storage computing market segments), and wired network connectivity products; and
- Other Intel Architecture Group
- Software & Services Group.

Wafer Manufacturing and Electronic Component Production (Assembly & Testing)

In 2010, 60% of Intel's wafer manufacturing was conducted in the United States (overseas facilities accounted for the remainder), compared with 70% in 2008. After wafer production, the majority of Intel's components are assembled and tested at one of seven facilities. Intel primarily uses subcontractors to manufacture board-level products and systems, but manufactures some microprocessor- and network board-level products primarily in Malaysia.

- Wafer Fab Locations: United States (OR, AZ, NM, and MA), Ireland, Israel, and China.
- Assembly & Test Locations: Costa Rica (1), Malaysia (3), China (2) and Vietnam (1). Until 2009, Intel also had a facility in the Philippines and two other facilities in Malaysia.

Intel in Costa Rica

- **1998:** after the initial announcement in 1996, the first assembly and test plant opened in Costa Rica ($300 million investment).
- **2000:** Intel expands into services in Costa Rica with its Latin America Engineering Services (LAES) Group. This provided jobs for 100 engineers for global engineering support in circuit design and validation and 40 engineers to design enabling code for microprocessors.
- **2003/2004:** the volume of A&T products from the two plants in Costa Rica represented around 23% of total corporation sales. In 2004, Intel implemented a new A&T line in Costa Rica for chipsets with an additional $110 million investment and 600 more jobs. This represented product upgrading for the firm in Cost Rica, as chipsets are considered a more advanced product. Intel also expanded in services to include financial services.
- **2006:** Intel added procurement and technical assistance to its service operations. The five service-related units in Costa Rica are referred to as the "Shared Services Group." Intel also invested in two software development companies in Costa Rica.[7] In 2006, accumulated investment in Costa Rica reached $770 million with 2,900 employees.
- **2011:** Intel opened a new engineering development center (EDC), which hosted a team of 300 Costa Rican engineers and technicians, specialized in the design, development and testing of advanced hardware and software for the company. The team also works to integrate technology into the fields of science, entertainment and medicine. Intel will reach almost $900 million investment in Costa Rica by the end of 2012.

Sources: (Brown, 2009; IBISWorld, 2012b; "Industrial R&D: electronics/computers," 2010; MIGA, 2006)

The world's largest electronic component companies tend to be headquartered in developed countries (principally the US, Japan, South Korea, Taiwan and countries in Western Europe) with manufacturing facilities in low-cost countries (such as China). In some cases these facilities are owned by the parent company and sometimes they are set up as joint ventures. In addition to manufacturing in-house, many companies outsource some of their production to contract manufacturers also located in low-cost countries (IBISWorld, 2012b).

2.5. Standards & Institutions

The proliferation of product standards and the wide-spread adoption of process standards have enabled a very complex supply chain to become codified which has facilitated the electronics industry's reputation for rapid development. Standardization has both enabled the growth in the number of products and end markets that incorporate electronic components and the transferability of at least some components among multiple products and brands.

Standard-Setting Organizations

There are a number of bodies involved in setting electronics standards and platforms. At the global level, the International Electrotechnical Commission (IEC) is the standards organization that prepares and publishes international standards for all electrical, electronic and related technologies – collectively known as "electrotechnology". The IEC works closely with the ISO and the International Telecommunications Union (ITU), and in some cases

[7] Intel Capital for Latin America, a one-person venture located at Intel Costa Rica, is charged with finding and supporting technology companies that complement Intel.

develops joint standards. IEC membership is composed of National Committees, and there can only be one per country[8]. Members help in the development of the standards themselves and conformity assessments. The main standard setting organization in Europe is the European Committee for Electrotechnical Standardization (CENELEC) (Portugal-Perez et al., 2009). [9] Electronic-specific organizations involved in standard setting in the United States include Electronic Industries Alliance (now the Electronic Components Industry Association: ECIA) and the Association Connecting Electronics Industries (IPC) at the global level.

Process Standards

Quality standards are very important in the electronics industry. Given the rapid pace of development, OEMs require low defect rates and quick turnaround times. Resultantly, maintaining certifications for international standards, particularly, ISO 9000 is of the utmost importance. Certification is important for firms throughout the supply chain from component suppliers to final product manufacturers.

The ISO 9000 family of standards covers quality management systems and how products are produced rather than the product itself. ISO standards are published by the International Organization for Standardization (ISO) and are available through national standard bodies (in Costa Rica this is the Instituto de Normas Técnicas de Costa Rica (INTECO)). Companies are actually certified through accredited[10] certification organizations (e.g., INTECO and CIC in Costa Rica) and must renew the certification at regular intervals (usually around 3 years). ISO 9001 was first released in 1987, and has been through four versions with ISO 2008 being the most recent. [11] All requirements are generic and are intended to be applicable to all organizations, regardless of size, industry or products provided. Most E&E companies obtain an ISO certification (IBISWorld, 2012b).

Given the non-specific nature of the ISO 9001 standard, several industries have developed more specific standards that cater more to their specific market. Several of these are applicable for companies producing goods in the electronics sectors.

- ISO/TS 16949: 2009: this standard combines the ISO 9001 requirement along with automotive-specific requirements agreed upon by the major US and European automotive manufacturers.
- AS 9000: specific for the aerospace industry and developed by major manufacturers.

[8] Costa Rica is not a full or associate member with a National Committee. However, the country does participate in the IEC's affiliate country program for newly industrializing countries through INTECO.
[9] Several country-level standard development organizations also exist in Europe including the British Standard Institute (BSI), the Association Française de Normalisation (AFNOR) and the Deutsches Institut für Normung (DIN).
[10] The national accrediting body in Costa Rica is the ECA.
[11] Many firms will simply state they are ISO 9000; however in reality, ISO 9000: 2005 provides the fundamentals and eight principles of the system and ISO 9001is the standard that provides the actual requirements an organization must meet to be certified.

- TL 9000: this is specific to the telecommunications industry, and was developed by the telecom industry group QuEST Forum. This standard also includes standardized product measurements for benchmarking.
- ISO 13485: this standard is specific to the medical device industry and unlike the automotive standard, is not just an addendum to ISO 9001.

Similar to the ISO 9000 standards, the ISO 14000 family focuses on environmental management and helps companies minimize their environmental impact. These are increasing in importance for all global industries, including electronics. For example, in a 2007 sample of 103 firms (drawn from 160 firms) in the electronics industry in Malaysia, all firms in the sample reported having ISO 9000 series certification. The incidence was less with the ISO 14000 series with 55.3% reporting certification. Participation in various quality management practices was also quite high (Rasiah, 2010).

ISO standards are applicable for firms from all stages of the value chain, and lead firms often require their suppliers to maintain certifications. In some cases, acquiring these standards can be a constraint to new firms or those in developing countries due to the costs required to meet the qualifications of the standard and to become certified.

Product Standards

There are numerous product standards for the electronics industry, most of which can be found on the IEC's database of standards. Adoption of IEC standards is voluntary, although they are often referenced in national laws or regulations around the world.

Institutions: Laws and Tariffs

The semiconductor and electronic components industry is not highly regulated. Laws and regulations affecting this industry are primarily associated with anti-trust, intellectual property rights and patents, and environmental impacts. Hazardous waste regulations are in place in many countries. While varying by country, import tariffs for semiconductors and electronic components tend to be low (IBISWorld, 2012b). Over 70 countries have signed the WTO Information Technology Agreement (ITA).[12] The ITA provides for participants to completely eliminate duties on IT products covered by the Agreement (WTO, 2012a).

2.6. Human Capital and Workforce Development

The majority of workers in E&E firms are production workers including operators and technicians. Workers at these levels typically have at least primary education as well as secondary education and some additional technical/vocational school at the technician level. Non-production workers include research scientists, product developers, process developers,

[12] See www.wto.org/english/tratop_e/inftec_e/itscheds_e.htm for a list of signatory countries.

managers, supervisors, and other administrative staff. These employees typically have a four-year university degree in engineering or a business administration field. Firms employ a range of engineers that focus on various aspects of process and product development, including process and systems engineers, component and machine design, field applications, and quality control.

The highest level workers are scientists who engage in research related to theory and conceptually development new ideas for technologies that will enable new processes and products. Scientists typically have a Doctor of Philosophy (PhD) in basic sciences, engineering, or a degree that combines aspects of the two. After an idea is generated, product developers with a strong background in engineering principles work to create a product or prototype. Product developers typically have a Master of Science (M.S.) degree in an engineering related field, or they have a Bachelor of Science (B.S.) degree and have many years of experience in the field. Process developers look at the results of experiments and determine how the process can be modified to improve productivity, reduce costs, or facilitate NPD. These activities are more repetitive and less innovative than product development, and positions are typically held by someone with a B.S. in engineering. Related to process development, mechanical engineers are also involved in areas related to manufacturing equipment. Industrial engineers are often involved in activities related to inventory and supply chain management. Employees with a background in business are engaged in scheduling, procurement, marketing and other administrative roles.

The most common engineering degrees vary by company, but popular fields include electrical or electronic, mechanical, and industrial. Increasingly firms are looking for employees that have cross-disciplinary skills across two or more fields within engineering (e.g., electromechanical, industrial design) or more often in engineering and business. These positions are particularly important in areas where employees need to be able to communicate the benefits of their technology in a way that someone outside of the engineering field can understand such as customers, government officials, and potential investors. Similarly, employees with these qualifications are also well-suited for management positions or starting their own companies. Technology management degree programs are gaining in popularity where coursework is divided between business classes and a specific scientific or industrial area.

In a recent study on technological capabilities in the electronics industry, authors outlined two types of firm-level technical capabilities; those related to process organization and others that are product centered. Process capabilities relate to the knowledge and skills need to efficiently operate the production process, whereas product capabilities are required to improve or introduce new products (Iammarino et al., 2008). Each type of capability is broken into three levels—basic, intermediate, and advanced. These firm-level capabilities can be translated into the workers' skills required for firms to improve their firm activities and upgrade their position in the value chain.

Beyond process and product related upgrading, a different workforce profile is required for firms to functionally-upgrade at the firm level to input sourcing and product logistics and distribution. Employees in these categories include production-level workers in distribution centers, receiving, and shipping, and university-level employees in fields related to business management to work in procurement, supply chain management, and sourcing.

Table 9. Firm-Level Technological Capabilities in Electronics

Types & Levels of Capabilities	Process Organization	Product Centered
Basic	Subassembly and assembly of components and final goods	Replication of fixed specifications and designs
	Minor changes to process technology to adapt to local conditions	Minor adaptations to product technology driven by market needs
	Maintenance of machinery and equipment	Routine quality control to maintain standards and specifications
	Production planning and control	
	Efficiency improvement from experience in existing tasks	
Intermediate	Manufacture of components	Product design department (design for manufacturing)
	Improvement to layout	Development of prototypes
	International certifications (ISO 9000)	Improvement of product quality
	Introduction of modern production organizational techniques (e.g. JIT, TQC)	
	Automation of processes	
	Flexible and multi-skilled production	
	Selection of technology (capital goods)	
Advanced	Own-design manufacturing	Development of new products/components
	Major improvements to machinery	R&D into new product generations
	Development of equipment, new production processes and embedded software	Research into new materials and new specifications
	Radical innovation in organization	
	Process oriented R&D	

Source: (Iammarino et al., 2008), p. 1984

2.7. Upgrading Trajectories

Process upgrading (machinery): given the rapid development of new products and process technologies, investment in new machinery and equipment is imminent to remain competitive. Indicators of process upgrading include purchases of new capital equipment and software. This is especially true for companies in the semiconductor and integrated circuit segments of the chain. For example, at Intel, 18-month product cycles require them to continually reconfigure lines and refresh equipment (MIGA, 2006). The high focus on quick deliveries and low defects explains why the incidence of participation in cutting-edge technologies is high in electronics firms (Rasiah, 2010).

Process upgrading (manufacturing activities): each stage of the value chain includes a series of manufacturing-related activities a firm engages in to produce the product. For example, steps required to make electrical components may include molding, stamping, finishing, and assembly. These activities can be performed in-house, or by subcontractors that perform a portion of manufacturing-related activities on behalf of another firm. In the case of both raw material and manufacturing activities, the firms that carry out these operations can be foreign-owned firms that establish an operation in a host country, or domestic firms can emerge to provide these linkages.

For multinational electronics companies (characteristic of those in Costa Rica) that have branch plants in several countries, a sign of process upgrading is seen in the increasing number of activities in the component manufacturing process performed in the same facility. For example, in Costa Rica, several firms have slowly moved operations that were performed at other global locations owned by the parent company to their manufacturing facilities in Costa Rica. To a lesser extent, subcontractors (both foreign and locally-owned) have emerged that are capable of performing these additional tasks.

Product (& process) upgrading: in recent years, electronics export-oriented firms in Central America and Mexico have moved toward ''high mix, low volume'' production processes, which refers to manufacturing several types of products in low and medium quantities rather than mass producing one type of product. To effectively compete under this strategy, firms frequently have to modify their production lines (process upgrading) which requires process and production organization technological capabilities (Padilla-Perez & Hernandez, 2010). A high mix, low volume scheme is often seen in firms that manufacture several types of electronic goods and components for various clients or end markets. Firms using this strategy focus on product customization, which often requires more interaction with the clients and their other suppliers to address specific needs. Interacting with other firms along the value chain facilitates learning related to production and business development if the workers at the manufacturing facility communicate with the downstream partners rather than engineers at the company headquarters.

In the case of Guadalajara, Mexico several steps were taken by existing firms to move into this type of business model. First, new systems were developed to configure and customize products for small orders. This required an increase in the number of engineers employed at the companies. Second, inflexible tooling dedicated to a single product was replaced with “soft tooling.” This transformation meant less automation and greater labor intensity and worker skills, especially in final assembly. Lastly, due to the increased diversity and complexity of products, new systems were needed to maintain product quality. These changes impacted procedures for product testing, inventory management, and work processes (Sturgeon & Kawakami, 2010).

Product upgrading: for U.S. and European regional country suppliers, firms have been shifting to final products in which they have a comparative advantage over Asian suppliers due to product characteristics, geographic proximity, and trade agreement advantages. One example is large and/or heavy products that have high transportation costs and are therefore unprofitable to ship from Asia such as big, flat-screen TVs or video game consoles (Padilla-Perez & Hernandez, 2010; Sturgeon & Kawakami, 2010). Related to free trade agreements, NAFTA has provided Mexico with an advantage in exporting mobile phones to the U.S. market by eliminating the 18 percent tariff imposed on other non-FTA countries. Even though this is a high volume, labor-intensive product that could be produced for a lower manufacturing cost in Asia, the high tariff rate increases the landed cost and enables Mexican exports to be on the same playing field.

These geographic advantages for final products in regional markets also presents 'trickle down' opportunities for **geographic end market upgrading** for regional component suppliers. In order to maintain the quick supply chain cycles for electronic products, these final product manufacturers can benefit from having local or regional component suppliers. For example, when Foxconn recently set up a new plant in San Jerónimo Mexico, it created a "powerful magnet" for suppliers to set up in surrounding areas including TE Connectivity, a global supplier of electrical accessories (Robinson-Avila, 2011).

End market upgrading: as an increasing number of products incorporate electronic components, new market segments (e.g., medical, aerospace, defense) are continually emerging that require lower volume, more specialized goods and components that still offer large profit margins. In this type of upgrading, firms still carry out the same type of activities in the value chain, but sell them to new customers that incorporate the product into different final products. Asian competition is less intense in these markets as many of the lead firms still produce their goods in-house and do not have long standing relationships with contract manufacturers as is the case in consumer electronics and computers. However, many of these products have strict, industry-specific standards, so entrance into these end markets will require firms to meet and maintain certifications for each end market they sell to.

Linkages: industry-specific backward linkages in the electronics components industry include: (1) direct raw material inputs (e.g., metals, chemicals, plastic) and (2) non-essential inputs such as packaging and labels. A third, general category can also be included that covers broad services applicable to any industry such as logistics, maintenance of cleanrooms, equipment and facilities, IT services, gardening, security, health services, and catering. Forward linkages include electronic component distributors, subassemblies, final product manufacturers, and retail/final product distribution.

Functional upgrading: functional upgrading is the movement into new value-adding activities in the chain, and typically represents a shift from production-related activities to 'intangible activities' such as distribution, sourcing, design, product development, R&D,

marketing and sales. It can be viewed from the perspective of performing these functions on behalf of the entire value chain and thus represents the stages to becoming a lead firm, or it can represent increasing the range of value-adding activities performed by a single firm in one stage of the value chain or within a country. The first shift is typically when a firm moves from assembling imported inputs, to taking on the responsibility of sourcing the components and distributing products to the next stage in the supply chain rather than shipping products back to the parent company. Beyond manufacturing and logistics activities, the next steps entail engaging in product and process design and engineering, and finally working on research and new product development, marketing and sales.

In the electronics value chain, the introduction of EMS and ODM firms in the PC sector are perhaps the most noticeable examples of functional upgrading. Contract manufacturers have moved from merely assembling final products on behalf of lead firms, to distributing the final products to the ultimate buyers, handling sourcing and financing of components, and providing after sale services in the case of EMS providers to even providing design and new product development in the case of ODM firms in the PC market. Firms engaged in these activities have increasing levels of control over the entire value chain, but their power is still limited by lead firms who still control the most valuable activities in the chain related to marketing, branding, and sales. Functional upgrading requires acquiring new technology and knowledge-intensive capabilities and thus represents a more sustainable competitive edge than advantages related to low labor costs, geographical proximity, or favorable trade agreements.

Table 10. Types of Upgrading in the Electronics Value Chain

Upgrading Type	Description
Functional	Final product manufacturers acquire responsibility for more value-adding activities; a switch from manufacturer to service provider often occurs over time: Categories: Assembly→EMS→ODM→Lead Firm Activities: Assembly→Sourcing/Distribution→Development/Design→Marketing
Linkages (Manufacturing-Related Upgrading)	Establish backward (or forward) manufacturing linkages within the supply chain; related to vertical integration: Inputs →Components→ Subassemblies→ Final Products
End Market	Market diversification: serving new buyers or markets often in emerging domestic or regional markets (new geographic destinations or distribution/market channels) Geographic: exporting only to the US and now to Mexico as well Market Sector: consumer electronics to medical
Product	Shift to customized products, use of higher quality inputs, or other additions that increase the value of the product or otherwise provide a competitive edge
Process	Reduce cost, increase productivity and improve flexibility by investing in new or better machinery or logistics technology. Specific steps within a stage (for example, components): Assembly→Metal Fabrication→Stamping→Finishing→Testing

Source: Authors

3. Profiles and Lessons from Other Countries

Given the small size of the electronics GVC in Costa Rica, no other countries were identified that had similar sizes in terms of firms and workers (Table 11). Rather, countries were selected that have similar development timelines and products, and have engaged in economic and workforce development initiatives that are relevant for Costa Rica. Several key themes emerge from the country cases including: funding for research and development for both foreign and domestic companies through a variety of models including venture capital, private partnerships, and government grants; educational and workforce development initiatives focused on the existing and future needs of industry in areas related to technical and engineering development combined with entrepreneurial and business skills; and a strong, multi-tiered supporting environment composed of a at least one industry association (Table 11) if not several and strong public-private research collaborations.

Table 11. Exporters in the Electronics and Electrical Industry Comparisons

Country	Emp. Est.	Locations	Main Products	Industry Associations
Philippines	400,000 (2005)	926 (2010)	Radio, TV & Communication Equipment HDD	SEIPI
Thailand	300,000	800+	HDD ICs Electrical Appliances	EEI EEAIC
Malaysia	336,408 (2009)	1,695 (2009)	Semiconductors Air conditioners	FMM
Mexico	550,000	1,600	Electrical Appliances Consumer Electronics EMS Contract Manufacturers	AMITI CANIETI
Singapore	76,209 (2009)		ICs	AEIS EEAI IG
Israel	68,000		Defense Communications Medical Equipment Controls/Instrumentation Components	IAESI
Costa Rica	8,800	39	Components	--

Sources: (BOI, 2008; Frost & Sullivan, 2011a; IAESI, 2010; MGCC, 2012; Negocios, 2011; Santiago, 2007; Wiriyapong, 2012; Young Jr., 2010)

A brief profile of the electronics industry in Mexico (Box 4) is also included as the country is the most significant exporter in the region. A key point to highlight from the Mexican case is the country's position in the global value chain. Unlike Costa Rica, the country is primarily engaged in producing parts and final electronics products rather than components. During the course of interviews with manufacturers in Costa Rica, firms did not consider Mexico to be a main competitor or a threat for relocation or new FDI due to safety and security issues and product differences (Field Research, 2012).

Box 4. Overview of the Mexican Electronics Industry

The Mexican electronics industry emerged in the 1960's, however the growth of the industry really took off in the 1990's with the establishment of NAFTA. Many of the activities carried out in Mexico were previously performed in the US. NAFTA set the tone for the emergence of contract manufacturing; a relatively new concept for the electronics industry at the time. It provided an entry point for Mexico into the export assembly business as a low-cost provider for regional exports to the United States market. Today, Mexico is the second largest supplier of electronics to the US market and over 80% of Mexico's exports are to the US.

The main centers of activity for the electronics industry are in the northern region, in the states of Baja California, Chihuahua, Tamaulipas, and Jalisco. In 2011, there were over 730 manufacturing plants related to the electronics industry, 709 companies dedicated to the electric industry, and 109 electric-appliance companies in the country. Overall, the country has some 1,600 electronics facilities that generate nearly 550,000 jobs and attract annual investments averaging nearly $1.3 billion dollars. These industries are one of the fastest growing industrial sectors in the country for employment generation and exports.

Products

The nature of the products produced in Mexico has changed over the last decade--assembly of high volume, price sensitive products has shifted to other locations, mainly China. In the 1990s, contract manufacturers were heavily concentrated on manufacturing and assembling products such as circuit boards, printers, telephones and answering machines. Starting around 2006, their range of products included digital cameras, audio and video equipment (35%), telecommunications equipment (26%), servers, routers and their peripherals (22%), electronic components (9%), and industrial and medical equipment (8%). Flat screen TVs represent around 25% of Mexico's electronics exports, and in 2009, Mexico was the largest exporter.

Mexico is also Latin America's leading producer of electrical manufacturing equipment and the main supplier of energy distribution products, transformers, engines and generators to the US market. Major companies with operations in Mexico include ABB, Eaton, Furakawa, ACME, Belden, Cooper, GE, Hammond, Schneider, Siemens, Thomas and Betts, Mitsubishi and WEG.

Major Companies with Operations in Mexico

Eight out of the 10 largest electronic companies operate in Mexico. Examples include Foxconn, Flextronics, Jabil Circuit, Celestica, Sanmina SCI, Areva, Delphi, HP, IBM, Sony, Motorola, Toshiba, LG, Samsung, and Intel. Major transnational household appliances companies established in Mexico are Whirlpool (US), LG (South Korea), Mabe (Mexico), Samsung (South Korea) and General Electric (US). LG's three plants in Mexico supply 90% of LG products sold in Mexico and 80% of those sold in the US. LG also manufactures for Latin America, which represents 10% of the company's total sales worldwide.

The Mexican electronics industry was originally built on US foreign investment, but they are now targeting investors from other countries including South Korea, the Netherlands, Switzerland, Japan, and Canada. In 2011, Mexican authorities promoted the industry at a trade event in South Korea to target Asian investments and Celestica, a Canadian electronics designer and manufacturer, created 2,000 new jobs in the country. In 2009, Korean companies invested $73 million in FDI in Mexico, led by Posco, Samsung and LG. Moreover, Mexico has 11 FTAs encompassing 43 countries.
In addition to attracting foreign investment, several local firms have also set up successful operations in the country, including:

- Lanix: 1990: consumer and commercial electronics, contract manufacturer, & parts (www.lanix.com)
- Falco Electronics: 1991: electronic components (www.falco.com)
- Kyoto Electronics: consumer electronics (www.kyoto.mx)
- Meebox: 2011: consumer and commercial electronics (www.meebox.com.mx)
- Zonda Telecom: electronics, mobile telephones (www.zondatelecom.com)

Workforce & Education

Mexico has received criticism for labor practices and conditions. On average, an electronics worker earns 116 pesos a day ($US 8.70), 60-80% less than in the United States (second source stated hourly rates starting at $2.10/hour). The use of temporary workers in the electronics sector is also common and is estimated at 90% of the labor force in some cases. Contracts are also very short term, in some cases only seven days. However workers often stay with the same company for several years working on these week to week contracts.

Mexico has established specialized linkage programs between schools and growing industries to provide students with industry-specific, highly technical training. In Baja California there are 115 technical training schools and 32 universities and Ciudad Juarez has 13 technical schools and 10 universities with 9,215 students (34%) in engineering. Each year, 114,000 students of engineering and technology-related fields graduate from Mexican universities with 10,000 new students enrolling each year.

Sources: (CEREAL, 2011; Morales, 2012; NAPS, 2012a, 2012b; Negocios, 2011; Padilla-Perez & Hernandez, 2010; Sturgeon & Kawakami, 2010; Young-jin, 2011)

3.1. Malaysia: Government Incentives & Workforce Development

Development of the Electronics Industry

The development of the electronics industry in Malaysia has followed a similar timeline as Costa Rica. The electrical industry in Malaysia started in 1965 when Matsushita Electric invested in the country to supply the domestic market with final consumer goods. The electronics industry emerged in the 1970s, primarily focused on offshore chip assembly. The first two operations opened in 1972, which coincided with the new Free Trade Zone in Penang. In the early 1980s, the main focus was consumer electronics, followed by computer-related equipment in the late 1980s, and the most recent stage involves the production of communication and networking equipment. The initial wave of export-oriented firms from developed countries started relocating manufacturing in Malaysia in search of not only low wages but also safe and secure tax havens. The Malaysian Government attracted these firms to tax-free export-processing zones in the country to create employment opportunities (Rasiah, 2010).

In the late 1990s, foreign ownership started to decline. Local firms focused on contract manufacturing and consumer electronics using largely foreign labor from Indonesia and Bangladesh started to emerge, providing a substitution for foreign investment. Foreign ownership has continued to fall in the electronics industry because of serious labor shortages in Malaysia and the emergence of more attractive manufacturing sites for labor-intensive operations in China, Vietnam and Philippines. A combination of slow upgrading and the lack of human capital have been documented as the prime reasons for this contraction (Rasiah, 2010;Mahadevan & Ibrahim, 2007).

The main focus for current and future developments in Malaysia is on green and smart technologies such as LEDs and the solar industry. In addition, new products such as advanced integrated circuits, high brightness light emitting diodes (HBLEDs); radio frequency (RF) and Microelectromechanical Systems (MEMS) devices are also given emphasis due to their growth potential. These industries are being promoted by leveraging on the ecosystem and supporting cluster development (MIDA, 2012).

Activities that Enabled Rapid Growth in the Semiconductor Industry

- Economic Transformation Program (ETP) by the Malaysian government is one such initiative. Included in ETP budget by the government, total cumulative funding requirement for developing E&E sectors from 2010 to 2020 is RM78.03 billion, with 12 percent coming from the public sector, and the remaining 88 percent from the private sector (Frost & Sullivan, 2011a). The Malaysian government offers generous financial incentives, investment guarantees and even subsidization where investments in high-tech activities are made. The government has also set up various institutions to stimulate upgrading though the lack of performance standards, compelling conditions and leadership attributes has reduced their contribution to firms' activities.
- Industrial Linkage Program: initiated in 1997, a total of 170 small and medium-size local companies have forged linkages with larger companies and MNCs, notably in the areas of electronics, machinery, fabricated metal products and engineering support industries (MGCC, 2012).
- Introduction of techno-entrepreneurship courses to all science, technology and engineering undergraduates (Mahadevan & Ibrahim, 2007).
- The significant increase in capabilities in electronics firms is explained by both the higher technological change faced in the value chain and the greater support given to them by the Malaysian Government through the provision of R&D incentives and grants. Classified as strategic, electronics firms have enjoyed grants from the Malaysian Government from 2006 (Rasiah, 2010).

Initiatives Specifically Focused on Workforce Development

- To facilitate technology transfer and supplement the local pool of managerial and technical skills, the Government continued to grant approvals for expatriate posts, particularly managerial and technical posts to Malaysian as well as foreign-owned companies. In 2011, a total of 1,915 expatriate posts were approved, of which 301 were key posts which could be permanently filled by foreigners. The remaining 1,614 were term posts, generally granted for three to five years where Malaysians are trained to eventually take over the posts (MIDA, 2012).
- All local undergraduates are now required to do a minimum of four months internship and industrial attachment (Ninth Malaysian Plan 2006-2010). In addition, the Graduate Training Scheme launched in August 2005 aims to equip local graduates who have been unemployed since 2003 with specialized skills. The Graduate Reskilling Scheme is targeted at engineering and selected technical graduates with no previous employment history. The Graduate Apprenticeship Program, initiated in 2005, is a program where graduates are attached to companies for work experience

and training, and at the end of their stint, the companies can choose to employ them (Mahadevan & Ibrahim, 2007).

- Electronics firms are now interested in personnel equipped with managerial and entrepreneurial expertise in addition to technical skills, due to extension in their activities towards distribution, sales and marketing. Thus industrial training institutes have to provide a good combination of technical and managerial courses to address the emerging requirement to increase the breadth of workers' skills. To achieve this, Malaysia has made two steps. One is the introduction of techno-entrepreneurship courses to all science, technology and engineering undergraduates. The other is the three-fold increase in the government's development allocation for management training from the period of 2001- 2005 to about RM 510 million for the next five years (Mahadevan & Ibrahim, 2007)
- The Ministry of Human Resources is on the long-term target for Malaysia to have 33% of its workforce fall under the highly skilled workers category by 2015 and 45% by 2020 for all skills across different industries. Currently only 28% of the workforce can be classified as highly skilled. In comparison, Singapore has a 45% skilled workforce, Hong Kong and Taiwan above 40%, and most European countries over 70%. To identify the skills required and current gaps in the workforce, the Ministry of Human Resources (MoHR) is coordinating a project to reflect the up-to-date needs of existing industries. The National Occupational Skills Standards (NOSS) is a set of benchmark standards developed by industries. The group has created a profile for 1/3 of the 6,000 identified occupations. The process of creating a NOSS is lengthy and detailed. One article describes the process. "For example, in documenting the aviation industry we have to work with Malaysian Airports Holdings Berhad, Malaysia Airlines, Air Asia and others. They work out the skills needed in every stage of the operations process and then document them to create the NOSS for the aviation industry".

  Once the skills are identified, the country is using a three-level approach:
  - Institutional Training Courses: the MoHR accredits training programs through government and private institutions. To supplement the capacity of their public vocational training institutions they have partnered with private institutions as training providers.
  - National Dual System Training: this is similar to an apprenticeship or co-op program in which students spend 30 percent of their time in institutes and 70 percent in the field with employers. Employers receive incentives to train the students, and they also have the first pick of the best candidates before they graduate. As of 2011, 20,000 skilled workers have been produced from this program and the automotive and aviation industries have been some of the main beneficiaries of this approach.
  - Recognition of Prior Achievement: workers that have been in their respective industries for decades can obtain a certificate granted by a board of experts in

a variety of fields. This certificate improves workers' credentials and improves their prospects for getting into formal education programs and acquiring bank loans (Graduan.com, 2011).

3.2. Israel: R&D and Entrepreneurship

The driving force of the Israeli economy for the past decade has been the information and communication technology sector; 25% of exports of goods and services came from this sector in 2006 (Prestowitz & Carliner, 2008). One of Israel's great strengths is the entrepreneurial nature of its society, marked by its long track record of starting up new technology companies. In 2011, the country had the second highest concentration of high-tech companies in the world with 4,000 businesses (Israel, 2012). The country is also good at attracting R&D centers and currently hosts at least 260 R&D centers of international companies (Druckman, 2012). Israel lacks a natural resources and raw materials industry, so rather the country has created its main assets through its labor force, scientific institutes, and R&D centers. Israel shares many characteristics with Costa Rica in terms of labor force, lack of raw materials industry, and emphasis on electronics and information technology. However unlike Costa Rica, the country has an exceptionally strong R&D and entrepreneurial community. To achieve this, the country has invested in and created several programs that may be useful to facilitate economic development in Costa Rica.

Activities that Enabled Functional Upgrading & Entrepreneurship

- **Venture Capital Funds for Israeli Start-up Companies:** there are at least 100 VC funds in Israel. In 2006, venture capital investments in the ICT sector totaled $1.62 billion (Prestowitz & Carliner, 2008). Israel has the fifth largest venture capital market in the world (Israel, 2012).
- **Science and Technology Incubators:** Technological incubators are partially funded and administrated by the Office of the Chief Scientist (OCS) of the Ministry of Industry, Trade and Labor. The program was established in 1991 to support development of innovative technological ideas into viable startup companies after a two year period at an "incubator". There are at least 23 incubators in Israel.
- **The Binational Industrial Research & Development Foundation (BIRD):** BIRD was established between the US and Israeli governments in 1977 to generate mutually beneficial cooperation between the private high-tech sectors in the two countries. The Foundation provides matchmaking services as well as funding to cover up to 50 percent of the development and commercialization costs.
- **High Level of Scientists and Engineers:** Israel has the highest number of scientists and engineers per capita. Israel spends 45% of its education funding at the tertiary level, 34% at the secondary level, and 21% at the primary level. The level of investment in tertiary education is higher than most other developed countries

including Ireland (27%), the United Kingdom (29%), Finland and Sweden (34%), and the United States and Japan (both 38%).

- **MATIMOP:** is the executive agency within the Ministry of Industry, Trade, and Labor that generates and implements international cooperative industrial R&D programs between Israeli and foreign enterprises. One of their main initiatives is maintaining an updated database of projects in a range of advanced technologies and profiles of Israeli industrial companies seeking international cooperation (MATIMOP, 2012).
- **Leverage Existing Lead Firms:** Intel in Israel is working with the Education Ministry in a new initiative to double the number of students with a scientific and technological matriculation certificate. Intel will invest $5 million in the program, which will be launched in 25 schools in southern Israel and will be offered to students throughout their studies. Intel officials will visit the schools as mentors and talk to the students about the advantages of working in the high-tech industry and studying exact sciences (Cohen, 2012).

3.3. Singapore: Functional Upgrading

The main thrust of Singapore's strategy has been to industrialize and move up the scale of skill and value added **by persuading MNCs to transfer production, development, and eventually R&D** to the country (Prestowitz & Carliner, 2008). Similar to Costa Rica, Singapore began by concentrating on foreign investment and building an economy that was attractive for MNCs to set up export-oriented manufacturing operations. Their education system focused on creating quality technicians and managers, but it did not encourage the independent thinking and creativity that is essential to entrepreneurial activity. To encourage functional upgrading and the development of domestic firms, the country has approached the situation from several angles.

Activities to Stimulate Functional Upgrading and Entrepreneurial Growth

- Began to become selective about the kinds of MNCs and investment it sought to attract. The theme became technological catch-up, and the focus was on attracting investment from skill and technology intensive sectors such as electronics, pharmaceuticals, computers, precision engineering, and other industries that generated higher value-added per worker.
- Revised school curricula to foster more creative thinking; send students to Silicon Valley to intern with Venture Capital firms and start-up companies.
- Established state subsidized training centers operated jointly with the MNCs to build engineering and other skills.
- Created business incubators: SPRING (Singapore Productivity Innovation Growth) program that provides loans, export insurance, and other benefits to SMEs.
- Created venture capital funds: there are now 160 venture capital groups active in Singapore with $10 billion available for investment.

- Coordination between the programs of the universities, the government research institutes, private corporations, venture capital groups, and the EDB is extensive and intimate.
- Developed high-tech parks and Special Economic Zones (SEZs)
- Government R&D grants to encourage MNCs to upgrade: Singapore spends 2.3% of GDP on civilian R&D and .5% on military R&D.
- Focused on developing inter-cluster linkages: for example, the country recognized that the electronics cluster is closely linked to the plastics cluster and started to view economic development from an inter-industry perspective to capitalize on synergies..
- Created Temasek Holdings, an independent but government linked investment management firm to manage government investments in companies.
- Invested in roads and telecommunications infrastructure: To limit use of roadways and generate funding for continued development, the country imposes user fees and requires vehicles to acquire a permit to travel in areas prone to congestion. The Government also focused on developing a fast, reliable telecommunications network. Internet bandwidth in Singapore is 26 terabits/second (Prestowitz & Carliner, 2008).

4. Costa Rica and the Electronics Global Value Chain

In 2012, approximately 39 firms operate exclusively in the electronics and electrical industries in Costa Rica. Over three-quarters (82%) of these firms have parent companies in the US, three firms (8%) are under Costa Rican ownership, three are from the European Union, and one is from Japan. Firms are concentrated in the production segments of the value chain primarily manufacturing components. In this section, we examine how the industry has evolved and upgraded over time and where in the value chain the country is currently positioned. Next, potential constraints to upgrading are identified and analyzed.

4.1. The Development of the Electronics Industry in Costa Rica

The electronics industry has a relatively long history in Costa Rica. In the 1960s, decades before Intel established an operation in Costa Rica, the electrical components and subassemblies industries started to emerge. Between 1960 and 1980 at least 12-14 foreign firms were established in the country. However the major growth spurt in the electronics sector came in the 1990s when 16 new firms opened in the country. In 2006, there were 35-55 firms operating in the industry employing around 12,000 workers (Padilla-Perez & Hernandez, 2010). Table 12 details the characteristics of firms in each of these stages.

The main reasons cited by firms that have established an operation in Costa Rica include political stability and safety, competitive labor and overall operating costs, availability of qualified, skilled labor, and proximity to the United States and the Latin American market. Overall, firms have been pleased with the work ethic and skill level of employees.

Table 12. Overview of Electronic & Electrical Firms in Costa Rica, by Entry Year

Entry Year	Firm Characteristics	Main Product Export Category	Firm & Year Established
1960-1980s	Electrical Equipment; Telecommunications	1. Electrical Appliances (Large)	1. Atlas (1961)/Mabe (2007)
		2. Electrical Assemblies	2. Eaton (1963)
		3. Electrical Products	3. Havells/Sylvania (1966)
		4. Batteries	4. Panasonic (1966)
		5. N/A	5. Motorola (1970s-2000s)
		6. Wire & Cable	6. Conducen (1971)
		7. Analytical Instruments	7. Xeltron (1974)^
		8. Switches	8. Bticino (1975)
		9. Electrical Subassemblies	9. Schneider (1976)
		10. Switches	10. Materiales Aguila (1978)
		11. Passive Components	11. Trimpot (1979)^
		12. Parts of Electronics	12. Vitec (1986)^
		13. Switches	13. C&K (1988)
		14. Electrical Appliances (Small)	14. Babyliss (1988-2011)
		15. Passive Components	15. Pharos (1989) ^/Sensortronics
		16. Switches	16. Suttle (1989)
1990s	Electrical Components to Electronic Components/ Circuit Boards	1. Connectors	1. Camtronics (1992)
		2. Wire & Cable	2. Panduit (1994)
		3. Final Electronic Product	3. Saco International (1995)^
		4. Wire & Cable/Switches	4. Tico Electronics (1995)
		5. LED Lighting	5. CML (1995)^
		6. Semiconductor-Related	6. Remec (1995-2007) ^
		7. Printed Circuit Boards	7. DSC (1995-2000) ^
		8. Analytical/Medical Instruments	8. DeRoyal (1996)^
		9. Parts of Electronics	9. Triquint (1996)^
		10. Inductors	10. Current Controls (1997)
		11. Active Discrete	11. EMC (Smith Labs)(1997)^
		12. Integrated Circuits	12. Intel (1997)^
		13. Inductors	13. Magneticos*/ETI (1998)
		14. Circuit Board Assembly	14. AeteC (1998-2008)*^
		15. Printed Circuits	15. Photocircuits (1998-2007)*^
		16. Printed Circuits	16. Multimix/Merrimac(1999)^
		17. Switches	17. Micro Technologies (1999)
		18. Medical Electronics	18. Hologic (1999)^
2000s	Electronic Components; Parts of Electronics & Repair & Engineering Services	1. Integrated Circuits	1. Teradyne (2000)^
		2. Integrated Circuits	2. Irazú Electronics (2001)^
		3. Parts-Analytical & Telecom	3. L3 (2001)^
		4. Circuit Board Repair	4. KES System (2002)+^
		5. Integrated Circuits	5. Merlin VMS (2004)^
		6. Lasers	6. Marysol Technologies^
		7. Analytical/Medical Instruments	7. Veridiam (2005)^
		8. Switches	8. Samtec (2006)
		9. Analytical Instruments	9. Sensor Group (2006)^
		10. Integrated Circuits/Connectors	10. MedConx (2007)^
		11. Circuit Board Repair	11. Altanova (2008) +^
		12. Wire & Cable	12. Astrolab (2008)
		13. Engineering	13. National Instruments ('10)+^
		14. Printed Circuit Boards	14. General Microcircuits ('10)^

Sources: Author analysis

Note: *indicates came as an Intel supplier; ^ indicates firm in electronics; +indicates service firm

Key Trends and Highlights

Shift in product focus: During the 1990's the profile of new companies shifted from a focus on electrical assemblies to electronics. The first major electronics investment was in 1995 when DSC Communications Corporation set up the first printed circuit board assembly plant in the country (Rodríguez, 2001).

Concentration in the components manufacturing segment: Throughout the development of the E&E industry in Costa Rica firms have been concentrated in the components segment of the chain. At present, over three-quarters of the companies are engaged in manufacturing components. This puts Costa Rica in a unique position compared to other export-oriented countries in the E&E value chain in which representation is more balanced across all segments including subassemblies, specific parts, and final products. Furthermore, firms are primarily engaged in the manufacturing/assembly functions with limited participation in the higher value, intangible activities related to research, process and product development, sourcing, distribution, marketing, and service.

High mix, low volume production model: Operations in Costa Rica operate using a high mix, low volume manufacturing strategy that is characteristic of firms that produce for multiple end markets and/or specific customers. In a 2007 study of electronic component manufacturers in Costa Rica, the competitiveness of all but one of ten firms was based on this strategy (Padilla-Perez & Hernandez, 2010).

End markets: component manufacturers sell their products to a wide variety of end markets. Over one-third of companies compete in the aerospace, medical and industrial end markets (see Table A. 9). Around 20% of firms are engaged in the automotive and communications/networking markets and the smallest end markets are computers (15%) and consumer electronics (5%). This goes hand-in-hand with the findings that firms primarily use a high mix, low volume production model. Having a diverse mix of end markets with a stronger focus on emerging, niche markets is an ideal position for manufacturers in Costa Rica because these products tend to be less cost sensitive, more customized, and the value chains are less centered in Asia.

Intel is the largest company to set up operations in Costa Rica in 1998, however after Intel, no other global leader has opened in the Costa Rican electronics cluster. Hewlett-Packard and IBM both considered Costa Rica for manufacturing locations in the late 1990s, but they did not come to fruition (MIGA, 2006). However both of these companies now have offshore service locations in Costa Rica, so even though no other electronics' firms manufacturing locations were established in the country, their consideration of the country for manufacturing likely had an impact on their decision to set up service locations in the country.

Limited local linkages: In 1993, CINDE focused on the electrical, electronic, and telecommunications sectors for foreign investment and in 1997 the arrival of Intel coincided with an economic development strategy focused on cluster development. A local supplier base was seen as a means to increase economic impact through the multiplier effect, while also helping to attract other foreign investors. Given this focus on cluster development, several studies have attempted to measure the presence and degree of backward linkages in the Costa Rica, particularly with a focus on activities after Intel's investment in 1997 (Ciravegna & Giuliani, 2008; Monge-Ariño, 2011; Patton & Moore, 2012). Results of these studies (Table 13) indicate that there has been limited development of domestic or foreign firms in the country. Intel attracted a large base of suppliers of services but this is less true for inputs. Many of Intel's suppliers did not invest in Costa Rica because they would be setting up operations to serve only one firm. A few of Intel's suppliers (~10) did set up in the country, but these were small operations with few employees.[13] (Larraín et al., 2000; Rodríguez, 2001). As of 2012, it appears that many of these companies are no longer operating in the country.

Table 13. Linkages to the Electronics GVC in Costa Rica: 2000-2012

Year	Local Firms		Activities
	Direct Inputs	In-Direct Inputs	
2000	10	63	Purchases of manufactured goods provided by local suppliers were limited to packaging and non-direct inputs such as office equipment and supplies, spare parts, and security equipment. Total local suppliers: 200; services (over 100).
2006	13	n/a	Metalwork, plastic injection molding, engineering services. For Intel, locally acquired direct materials were 2% of the total value of exports; in-direct non-essential were 2% and services were 6-8%. Services were acquired from a broader network of about 460 firms.
2012	25	35	Over half of these companies (~30) are engaged in packaging and around 10 are engaged in automation and others are engaged in metal services such as tooling.

Sources: (Field Research, 2012; Larraín et al., 2000; MIGA, 2006)

In a recent report, the Domestic Component of Exports (DCE) for 2009 was calculated for four GVCs based on five areas: profit and taxes, capital, labor, local supplies, and local services (Monge-Ariño, 2011). For electronics, the two lowest contributors to the DCE were purchases of local supplies (9%) and local services (10%). The share for local supplies was similar to the overall average of the four industries, however the share for local services was lower than average (Monge-Ariño, 2011). Services required by electronic firms in Costa Rica for the electronics industry are primarily related to electricity, gas and telephone expenses (66%), followed by 'other services' (27%), professional services (4%), transportation (2%), and financial services (1%)(Monge-Ariño, 2011).

[13] Photocircuits was the largest of these suppliers, with an estimated 700 employees. They produced the board Intel's semiconductors were mounted on, however after a number of years, Intel changed their product line and stopped purchasing the boards.

In 2011, there were six firms in the EPZ zone that used subcontractors and approximately six firms that purchased raw materials domestically. The total value of subcontracted processes was approximately $2 million ($USD), and the total value of raw materials purchased domestically was $8 million ($USD). The majority of purchases fall into the broad category of parts and components (99%), followed by chemicals, and packaging materials (Procomer EPZ data). Interviewees also recognize that there has been no 'cluster' development. Backward linkages are only for packaging; raw materials too diverse and too capital intensive and there are also no forward linkages to distributors or final product manufacturers (Field Research, 2012).

Process upgrading: the two highest contributors to the DCE were profit and taxes (33%) and capital (25%) where electronics had the highest contribution of all GVCs. The high shares for these two categories can be viewed as a proxy for process upgrading because a considerable share of profit is reinvested by the companies to increase productive capacity. The high share for capital (measured by the depreciation costs reported by the firms) indicates a high degree of investment in machinery and equipment (Monge-Ariño, 2011). Furthermore (for the 17 firms in which data is available), all but two have ISO 9001 certifications and at least eight are ISO 14001 certified.

4.2. Costa Rica's Current Participation in the Electronics GVC

Today there are 24 firms primarily engaged in the electronics manufacturing industry. Fifteen are producing electronic components and subassemblies/parts and six are producing final electronic products. Two of these firms are also medical device firms that are producing instruments. One firm is both a subcontractor for firms in the EPZ as well as an exporter and the other produces plastic medical tubing and electronic components such as probes that are used with medical tubes or wire as parts of medical instruments. There is also one company primarily exporting medical electronics.[14] Overall, the medical electronics final product category represented 1.3% of Costa Rica's electronics exports in 2011. This is entirely made up of exports of products from HS 901819, which represents small electro-diagnostic equipment. There are also three firms providing services for the electronics industry.

There are also at least 15 companies primarily engaged in the electrical components and subassemblies portion of the industry. Thirteen of these are manufacturers of passive electrical components and parts.[15] Two of these firms were formerly manufacturers, but are now distributors to the local and regional market.

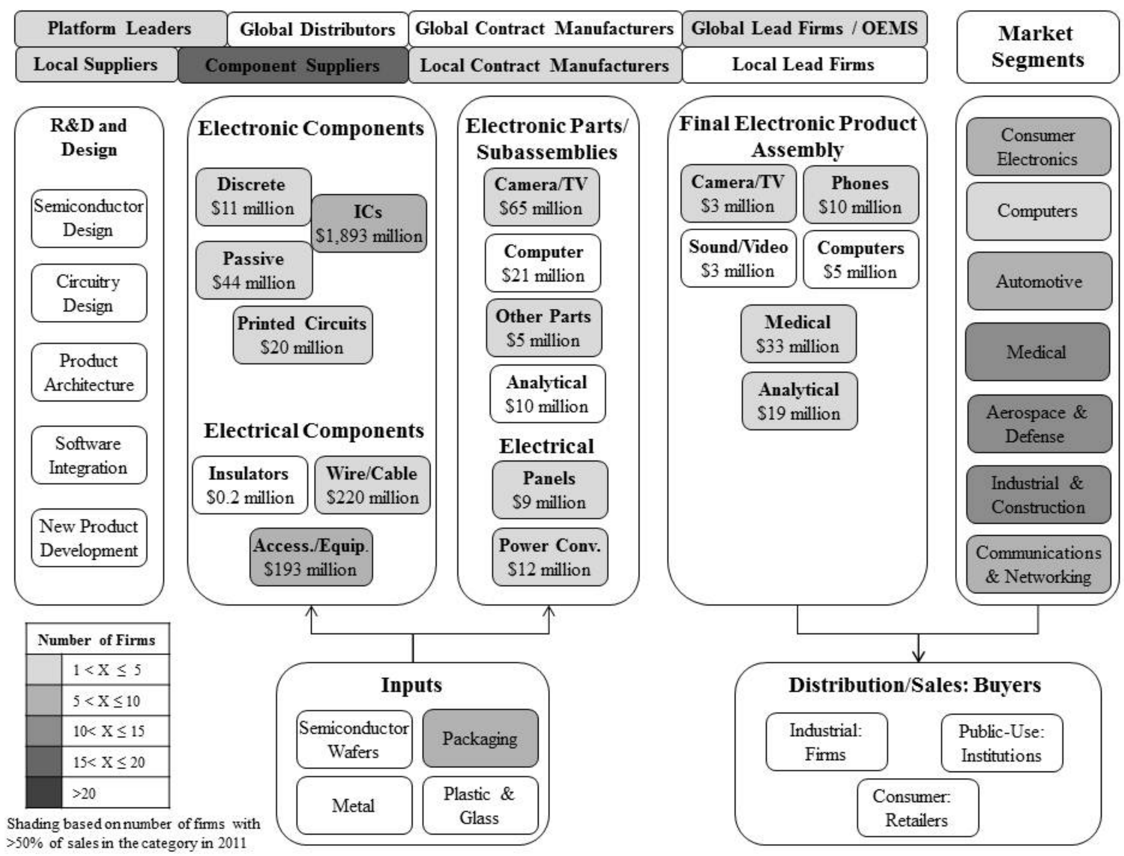
[14] There are three others included in the medical device report that have partial exports in this category, but are not included here because medical electronics made up less than 50% of their exports in 2011.

[15] Additionally, there are at least two known companies primarily engaged in final electrical products (Mabe and Havells), but this sector is beyond the scope of this analysis.

Figure 2 highlights Costa Rica's position in the electronics and electrical components value chain. No shading indicates there are no known firms participating in these segments of the chain, and progressively darker shading indicates areas where there is increased participation. The values represent Costa Rica's total exports in 2011 for each product category. The shading in the market segments reflects the share of firms selling components, subassemblies, or final products into these markets.

The largest concentration of firms is in the electrical accessories and equipment category followed by wire and cable-related products. However the largest export values are in integrated circuits.

Figure 2. Costa Rica's Participation in the Electronics GVC



Source: Authors.

E&E exports have averaged around 25-30% of Costa Rica's total exports for the last decade (2000-2011) [16] The total value of Costa Rica's electronics exports (components, parts/subassemblies, and final products) in 2011 was $2.14 billion representing 20.4% of the

[16] This depends on how the industry is defined. The simple definition of the industry is HS chapters 84-85 whose total export value in 2011 was $2.66 billion.

country's total exports.[17] Electrical components and subassemblies exports totaled $433 million in 2011, representing 4.1% of total exports for a combined total of $2,573 million.

Table 14. Costa Rica's Electronics/Electrical Exports by Value Chain Segment, 2011

Category	Value ($US Mil)	Share of Electronics & Electrical Total	Share of Total Costa Rica Exports
Electronic Components	1,967	76.4%	18.7%
Electronic Parts & Subassemblies	100	3.9%	1.0%
Final Electronic Products	74	2.9%	0.7%
Electronics Total	**2,141**	**83.2%**	**20.4%**
Electrical Components	412	16.0%	3.9%
Electrical Subassemblies	21	0.8%	0.2%
Electrical Total	**433**	**16.8%**	**4.1%**
Electronics & Electrical Export Total	**2,573**		**24.5%**
Total 84-85 Exports	2,660		25.3%
Costa Rica's Total Exports (All Products)	10,502		

Sources: PROCOMER, 2012

Costa Rica's electronics exports are highly concentrated in one product, electronic integrated circuits, processors and controllers (HS 854231), which represented 86.9% of all electronics exports and 72.3% of the combined total with electrical products.

The top five overall export destinations for electronic components in 2011 were the United States, representing 31.9% followed by Hong Kong (23.5%), the Netherlands (19.2%), Malaysia (9.1%), and China (9.1%). In 2010, the top destination was China however one firm shifted to a new product line, resulting in an overall impact on the export profile of the sector.

Table 15. Costa Rica's Top Five Electronic Component Export Destinations, 2011

Export Destination	Active Discrete		Printed Circuits		Passive IC Components		Integrated Circuits & Parts		Totals	
	Value	Share	Value	Share	Value	Share	Value	Share	Value	Share
World	**10,887**		**19,619**		**43,701**		**1,892,549**		**1,966,756**	
United States	9,399	86.3	4,469	22.8	31,688	72.5	581,484	30.7	627,039	31.9
Hong Kong	1,342	12.3	--	--	--	--	461,744	24.4	463,108	23.5
Netherlands	--	--	--	--	226	0.5	378,270	20.0	378,496	19.2
Malaysia	6	0.1	5,861	29.9	104	0.2	172,582	9.1	178,552	9.1
China	--	--	8	0.0	--	--	143,825	7.6	143,916	7.3
Taiwan	82	0.8	9,091	46.3	--	--	--	--	61,807	3.1
Japan	--	--	187	1.0	--	--	--	--	50,799	2.6
South Korea	--	--	--	--	--	--	--	--	13,244	0.7
Germany	--	--	--	--	11,188	25.6	--	--	11,235	0.6
Guatemala	--	--	--	--	174	0.4	--	--	368	0.0
Top Five	**10,828**	**99.5**	**19,616**	**100.0**	**43,380**	**99.3**	**1,737,905**	**91.8**	**1,928,564**	**98.1**
HS Codes	8541		8534		8532, 8533		85423, 9		All Values	

Source: PROCOMER, 2012; Values in $US '000

[17] Based on definition in the appendix

The value of Costa Rica's electrical component and subassembly exports totaled $433 million in 2011 with 45.7% destined for the United States. Beyond the US, the majority of exports are shipped to other DR-CAFTA countries: Panama (8.7%), Guatemala (7.1%), Honduras (6.9%), Dominican Republic (5.4%), El Salvador (4.4%), and Nicaragua (3.7%). There are, however, differences between these main categories. Wire and cable and electrical panels are almost entirely exported within the US and DR-CAFTA countries whereas switches and other electrical accessories are shipped to the US as well as Asia and Europe.

Table 16. Costa Rica's Top Five Electrical Export Destinations, 2011

Export Destination	Wire & Cable		Switches (Low-Voltage)		Other Elec. Accessories		Electrical Panels		Totals [a]	
	Value	Share	Value	Share	Value	Share	Value	Share	Value	Share
World	**219,539**		**167,788**		**11,883**		**8,600**		**432,892**	
United States	79,881	36.4	97,416	58.1	5,401	45.5	655	7.6	197,907	45.7
Panama	28,218	12.9	--	--	835	7.0	3,938	45.8	37,864	8.7
Guatemala	20,838	9.5	7,628	4.5	--	--	374	4.3	30,773	7.1
Honduras	25,384	11.6	--	--	--	--	658	7.7	29,678	6.9
DR	18,833	8.6	--	--	--	--	--	--	23,214	5.4
China	--	--	14,744	8.8	--	--	--	--	16,572	3.8
Nicaragua	--	--	--	--	675	5.7	1,913	22.2	15,861	3.7
Ecuador	--	--	8,483	5.1	--	--	--	--	9,031	2.1
UK	--	--	7,915	4.7	--	--	--	--	8,004	1.8
Hong Kong	--	--	--	--	696	5.9	--	--	2,268	0.5
Germany	--	--	--	--	1,060	8.9	--	--	1,637	0.4
Top Five	**173,153**	**78.9**	**136,186**	**81.2**	**8,666**	**72.9**	**7,538**	**87.7**		
HS Codes	8544		8536		8504, 8538, 8535		8537		8501-4;6-7, 8535-38, 8544, 8546-47	

Source: PROCOMER, 2012; Values in $US '000
Note (a): Several codes are not shown due to space limitations (8501-03; 8506-07; 8546-47) but included in totals; El Salvador and Puerto Rico are also top destinations but are not in the top five in any category.

4.3. Workforce & Training

Total employment in the electronics and electrical industries was at least 8,800 in 2011 with the top 10 largest firms representing 81% of this employment.[18] The largest category of workers is direct laborers, which can be broken into two categories: technicians and operators. Operators or production line workers represented 30% of all employment. Workers in this category have been through primary education with the majority of skill development through on-the-job training. Technicians have some technical and industry-specific skills beyond performing basic tasks and represented half (50%) of total employment. The general education requirements for this level are mandatory secondary education, with the majority receiving additional training at technical high schools or vocational institutions. Engineers

[18] No employment information is available for seven companies; around 16% of employees overlap with the medical device industry and 27% with the aerospace industry.

represented 14% of total employment amongst interviewed firms. Engineers have a university degree in engineering, and are in charge of tasks such as process engineering, systems optimization, and quality control. The majority of engineers in Costa Rica were related to processes and quality assurance. The remaining share was composed of administrative and supervisor positions in which the majority of employees have received a university degree. Outside of industry-specific skills, English proficiency is not necessarily required, but is highly encouraged at all employee levels.

Table 17. Employee Profile for Select Segments of the Electronics Value Chain

Position	Share	Education	Job Characteristics
Operators	30%	Mostly primary education	Production line workers; majority of training is on the job
Technicians	50%	Secondary education, technical high school, vocational training	Some specific technical or industry-specific skills required
Engineers	14%	Tertiary; university degree in engineering	Process engineering; systems optimization, quality control
Administrative	6%	Tertiary; university degree in business	Sales, finance, customer service, supervisors, management

Source: (Field Research, 2012) and secondary information

Costa Rica offers several programs targeted to workers at the technician level. Many firms stated that employees receive training at INA and that many operators and technicians go to school part time to advance their educational profile. The majority of engineers tend to come from the Instituto Tecnológico de Costa Rica (ITCR) and the Universidad de Costa Rica (UCR).

Several programs have been created as a result of the improvements Intel has requested in technical education to guarantee the country could produce enough professionals with the right profiles in Costa Rica. General links have been established between Intel and UCR's School of Physics as well as with vocational schools for electronics, but the main programs have been established at ITCR (Larraín et al., 2000; MIGA, 2006; Rodríguez, 2001). These programs include:

- A one-year certificate program for high school and technical high school graduates focused on technical skills and physics/chemistry competency.
- A one-year associate degree program on semiconductor manufacturing and microelectronics for qualified applicants and graduates of the one-year certificate program (later a material science program was created as well).
- A language training program to provide foreigners coming to Costa Rica with Spanish training and Intel employees hired in Costa Rica English training.
- An Electronics Master program has also been established with the guidance of Intel and HP. This program emphasizes VLSI design, micro-electromechanical systems, embedded systems, signal digital processing, and electronics manufacturing.

Most firms originally set up an operation in Costa Rica due to lower labor costs in a 'near shore' environment, but many of them have found that workers are capable of additional tasks beyond basic assembly of simple products. Based on firm interviews and secondary accounts of firms operating in the country, firms view workers as having good work ethic and skilled at learning new operations quickly. In nearly all cases, this has lead multinationals to slowly transfer additional steps of the manufacturing process to Costa Rica (process upgrading), increasing the range of skills available in the workforce. This is also reflected in the low level, and in many cases non-existence, of expatriate workers from the parent companies employed in the factories in management, engineering, and administrative positions.

4.4. Challenges for Future Expansion and Upgrading

The main factors affecting the location of a semiconductor and electrical component manufacturer include: the cost of production, which is impacted by labor rates and exchange rates; the levels of capital intensity and technology involved in manufacturing; proximity to suppliers and customers; government support for electronic component manufacturers (such as tax holidays, depreciation concessions and grants); and historical factors (such as where major players have established their head office, and links with countries that are major sources of demand) (IBISWorld, 2012b). Costa Rica is at a competitive and comparative disadvantage compared to global competitors in several of these key areas outlined in this section.

Electronics manufacturing is centered in Asia: along with the shift in final product assembly[19] to low-cost Asian countries, there has been a subsequent shift of electronic component production. The Asian region is attractive because it is cost competitive, has a strong, well-developed supply base and has the world's fastest growing consumer end market. It also has an ample supply of highly educated engineers at competitive costs (van Liemt, 2007). Interviewees view China as the major country threat to the future of the industry in Costa Rica. Furthermore, given Costa Rica's relatively small labor force, the opportunity to build a critical mass in the electronics sector is limited. For example, the E&E industry alone employs 68,000 in Israel (the smallest workforce identified by a country engaged in this industry) compared to roughly 9,000 in Costa Rica.

Existing companies are branch plants of MNCs: nearly all of the E&E companies in Costa Rica are owned by multinational companies, primarily from the US. Therefore all of the decision-making regarding which value-adding activities take place in each of their global locations (including Costa Rica) is determined at their corporate headquarters. Given the dominance of FDI versus domestic firms, the ability for the Costa Rican government to directly facilitate upgrading is limited. Given this situation, the main tools to influence the

[19] See maps and charts for visual examples

future of the industry are through strategically targeting new foreign investments and through the programs they create to develop and assist domestic businesses.

Limited number of leading firms in the country: thus far, Costa Rica has only one platform leader in the electronics sector. This is comparatively low compared to other countries competing in this industry. Potential new investors are more likely to set up in a new location in a country that has a developed support industry of international and local vendors as well as other major firms in their value chain and competitors.

Limited scope for backward linkages: The potential to develop backward linkages into input materials for the electronics component industry is difficult and unlikely to occur in Costa Rica for several reasons. First, given the perspective from the components stage of the value chain, the only direct inputs are raw materials. This limits the opportunities from the onset unless the country is endowed with natural resource deposits or a significant chemical production industry. Second, many of the firms use a global sourcing policy that is coordinated from the headquarters in the United States. Inputs are either shipped from other facilities owned by the firm, or headquarters orders for all locations. Third, there is not a critical mass of companies producing large volumes of the same product in Costa Rica, so the necessary inputs are varied. As seen in the case of Intel, follow sourcing is unlikely to occur if a company has to set up a location for one buyer due to risks and economies of scale. Fourth, for semiconductors, the potential to integrate into wafer manufacturing is limited due to the capital and scale requirements and the demand needed to set up a new facility. The potential for non-essential inputs, such as packaging and labels is much more likely, however this type of input makes up an insignificant portion of overall purchases and is a low value contribution.

Growth in the electronics industry in Costa Rica is stagnant: the majority of existing investments in the electrical segments of the industry were established in the 1970s and 1980s, and the 1990s for the electronics segment. Investments made in the last decade have primarily been in tangential, service-related areas that have little connection to the existing manufacturing sectors. Interviewees felt that the electronics industry has been shrinking in recent years, and the peak of the industry was 10-20 years ago. They recognize that the E&E industry is very cost sensitive and many felt that services are the way forward for Costa Rica (Field Research, 2012).

Lack of supporting organizations for electronics: the electronics sector in Costa Rica lacks an organizational structure, such as an industry association or consortium, for companies (as well as other government and academic stakeholders) to meet to talk about similar issues and concerns or to discuss collaborative projects. The closest operation that has existed specific to the electronics industry was a foreign office set up by CINDE in Silicon Valley between 2000-2004, however when funds decreased the agency had to close the offshore locations (MIGA, 2006). Connectivity and coordination are critical for knowledge flows. Intermediary organizations such as industry–government coordination, councils and chambers of commerce play an important role to increase connectivity and coordination in dynamic clusters.

Lack of educational programs that cater to functional upgrading: Existing programs in the country are adequate to meet the needs of the existing manufacturing-focused operations, but key programs in areas such as technology management, or Masters and PhD level engineering programs are limited. Although the country produces quality graduates, there is significant misalignment between the supply of graduates by area of specialization (i.e., concentration in social sciences0 and the skills required by industry, especially at the post-graduate level.

5. Potential Upgrading Trajectories for Costa Rica in the Electronics GVC

The analysis in Section 4 highlights Costa Rica's stages of development in the electrical and electronics value chain. In this section, we highlight two potential upgrading trajectories.

1) **End market upgrading:** rather than view "electronics" as a strategic sector, emphasis should be placed on promoting the end market sectors that are enabled by developments in electronics and target firms that produce or use electronic and electrical products in their final products. Smaller end markets such as medical, aerospace, automotive, and industrial products rely on smaller volumes of more customized products compared to traditional electronic product markets such as consumer electronics and PCs. Furthermore, the supply chains for these products are not as highly concentrated in Asia. Within these markets, medical electronics firms are an ideal initial target for new investments as it builds on the country's existing foundation of medical device and electronics companies. Examples of leading firms in this sector include Philips, GE, Medtronic, Siemens Healthcare and Varian. Having a group of firms in a similar market sector will also help to facilitate backward and forward linkages. From the perspective of the medical device value chain, this will facilitate product upgrading into a higher value segment.

2) **Functional upgrading**: encourage and facilitate shifts to higher value-added activities in the chain such as distribution/sales, sourcing, product and process development/engineering, and research. This is a potential upgrading strategy for existing firms and an important factor to consider for future recruitment.
    - Distribution/Sales: in addition to manufacturing, Costa Rica can be a location for distribution, sales, and marketing for the Latin America market. Several existing electronics firms, including Panasonic, Bticino, Materiales Aguila Eléctrica Centroamericana, and Schneider, all fall into this category. Costa Rica can take advantage of free trade agreements with nearby countries to

form an export-oriented regional network and taking advantage of synergies with complementary industries within Costa Rica (e.g., medical, aerospace, automotive, and offshore services).

- Process and Product Development: some firms in Costa Rica are engaged in process development, but very little product development is carried out by facilities in the country. In order to move into these activities, there needs to be a readily available pool of workers in relevant engineering fields that preferably also have technical and management skills as well.
- Research: moving into this stage will require workers with advanced theoretical development skills and accredited PhD programs. This will require increased public and private research funding and facilities such centers, labs, and incubators that engage in research.

6. Appendix

6.1. Definition of Product Categories

Table A. 1. Electronic Components Categories

Product Category	Product Examples	HS Code	HS02 Codes and Descriptions
Active Discrete[20]	Transistors Diodes PV cells	8541	8541: Diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, incl. photovoltaic cells whether or not assembled in modules or made-up into panels; light emitting diodes; mounted piezo-electric crystals (same)
Active Integrated Circuits & Parts	Integrated Circuits (ICs) IC Parts	85422 (HS02) 85426 (HS02) 85423 (HS07) 85429	85422: Monolithic integrated circuits (HS02) • 8542.31, 8542.32, 8542.33, 8542.39 (Equiv. in HS07) 854260: Hybrid integrated circuits (HS02) • 8542.31, 8542.32, 8542.33, 8542.39 (Equiv. in HS07) 85423: Electronic integrated circuits (HS07) 854231[21]: Processors and controllers, whether or not combined with memories, converters, logic circuits, amplifiers, clock and timing circuits, or other circuits (HS07) 854231.11: Metal oxide semiconductors (MOS) 854231.12: Bipolar technology circuits 854231.19: Other 8542.31.20: Non-digital 8542.31.30: Hybrid integrated circuits 8542.31.80: Waste and scrap 854232: Memories (HS07) 854233: Amplifiers (HS07) 854239: Other (HS07) 854290: Parts of electronic integrated circuits & microassemblies of 85.42 (code same; microassemblies removed from description)
Printed Circuits	Circuit Boards (PCs)	8534	8534: Printed Circuits (same)
Passive Components	Resistors Varistors Capacitors	8533 8532	8533: Electrical resistors (including rheostats and potentiometers), other than heating resistors 8532: Electrical capacitors, fixed, variable or adjustable (pre-set)

Source: the definition of the industry in this paper is based on the authors interpretation of the electronics industry and the definition of the electronics industry in (Sturgeon & Memedovic, 2011) based on SITC codes, converted to HS02 and correlated to HS2007. HS codes were placed in respective value chain stages and product categories by the author. In the above table, the only added code is 8532.

[20] HS02 code 8540 (Thermionic, cold cathode or photo-cathode valves and tubes) is considered an active component, but it is not in chip form and tubes have been replaced by liquid crystal display (LCD) and plasma technologies. It is included here for the purpose of recognition, but is not included in statistics.
[21] Using the Costa Rica H8 code, the different types of circuits can be identified. They all follow the same wording and pattern as the first one listed.

Table A. 2. Other Electrical and Electronic Components and Subassemblies

Product Examples	HS Code	HS02 Codes and Descriptions
Wire & Cable		
Winding wire Co-axial cable Conductors	8544	8544: Insulated (incl. enameled/anodized) wire, cable and other insulated electric conductors; optical fiber cables, made of individually sheathed fibers 854411: Winding wire of copper; 854419: Winding wire; other 854420: Co-axial cable and other co-axial electric conductors 854430: Ignition and other wiring sets of a kind used in vehicles, aircraft or ships 85444: Other electric conductors, for a voltage not exceeding 80V 854441: Fitted with connectors; 854449: Other 85445: Other electric conductors, voltage > 80V but not < 1,000V 854451: Fitted with connectors; 854459: Other 854460: Other electric conductors, for voltage exceeding 1,000V 854470: Optical fiber cables
Insulators		
	8546 8547	8546: Electrical insulators of any material (same) 854610: of glass; 854620: of ceramics; 854690: other 8547: Insulating fittings for electrical machines, appliances or equipment, being fittings wholly of insulating material apart from any minor components of metal (e.g., threaded sockets) incorporated during molding solely for purposes of assembly, other than insulators of heading 85.46; electrical conduit tubing and joints therefor, of base metal lined with insulating material (same) 854710: Insulating fittings of ceramics; 854720: of plastics; 854790: Other
Electrical Accessories & Equipment		
Electrical Accessories: Wiring Devices Switches Plugs Sockets Circuit Breakers Junction Boxes Connectors Electrical Equipment: Fuses Relays Equipment bases Generator Parts Transformers	8535 8536 8538 8503 8504	8535: Electrical apparatus for switching or protecting electrical circuits, or for making connections to or in electrical circuits, for a voltage > 1,000 volts (same) 853510: Fuses 85352: Automatic circuit breakers 853530: Isolating switches and make-and-break switches 853540: Lightning arresters, voltage limiters and surge suppressors 853590: Other 8536: Electrical apparatus…, for a voltage not exceeding 1,000 volts 853610: Fuses 853620: Automatic circuit breakers 853630: Other apparatus for protecting electrical circuits 85364: Relays 853650: Other switches 85366: Lamp-holders, plugs and sockets 853670: Connectors for optical fibers, fiber bundles or cables (HS07) equiv. in HS02 (392690, 690919, and 74199) 853690: Other apparatus 8538: Parts suitable for use solely/principally with apparatus of heading 8535-37 853810: Boards, panels, consoles, desks, cabinets and other bases for the goods of heading 85.37, not equipped with their apparatus; 853890: Other 8503: Parts suitable for use solely/principally with machines of heading 8501-02 8504: Electrical transformers, static converters (e.g., rectifiers) and inductors (same)

Source: Author; these are not included in the (Sturgeon & Memedovic, 2011) definition

Table A. 3. Electrical Subassemblies

Product Examples	HS Code	HS02 Codes and Descriptions
Switchgear Panel boards	8537	8537: Boards, panels, consoles, desks, cabinets and other bases, equipped with two or more apparatus of 8535 or 8536, for electric control or distribution of electricity, incl. those incorporating instruments or apparatus of Chap. 90, and numerical control apparatus, other than switching apparatus of heading 85.17. 853710: For a voltage not exceeding 1,000 V; 853720: For a voltage > 1,000 V
Electrical	8501	8501: Electric motors and generators (excluding generating sets).

Equipment Power Conversion Batteries	8502 8506 8507	8502: Electric generating sets and rotary converters. 8506: Primary cells and primary batteries. 8507: Electric accumulators, incl. separators, whether or not rectangular (includes rechargeable batteries)

Source: Author; these are not included in the (Sturgeon & Memedovic, 2011) definition

Table A. 4. Electronic Subassemblies

Product Category	Product Examples	HS Code	HS02 Codes
Computer, Office Equipment, & Calculating Machines		8473	8473: Parts and accessories (other than covers, carrying cases and the like) suitable for use solely or principally with machines of headings 84.69 to 84.72. 847310: Parts & accessories of the machines of heading 84.69 84732: Parts & accessories of the machines of heading 84.70: 847321: Of the electronic calculating machines of subheading 8470.10, 8470.21 or 8470.29 847329: Other 847330: Parts & accessories of the machines of heading 84.71 847340: Parts & accessories of the machines of heading 84.72 847350: Parts & accessories equally suitable for use with machines of two or more of the headings 84.69 to 84.72
Cameras, Radar, Radio, & TV		8529 90069 90079[22]	8529: Parts suitable for use solely or principally with the apparatus of headings 85.25 to 85.28. 90069: Parts/accessories of cameras and apparatus of 90.06 90079: Parts/accessories of cinematographic cameras and projectors of 90.07
Sound & Video		8522	8522: Parts and accessories suitable for use solely or principally with the apparatus of headings 85.19 to 85.21. 852210: Pick-up cartridges; 852290: Other
Sound Projection		85189	851890: Parts of the app. & equip. of 85.18 (same)
Telephones		85179 (HS02) 85177 (HS07)	851790: Parts of the app. & equip. of 85.17 (HS02) 851770: Parts of telephone sets (HS07)
Semiconductor Media & Microassemblies	Smart cards Microassemblies	85421 (HS02) 85427 (HS02) 85439 (HS07) 85489 (HS07) 852352 (HS07)	854210: Cards incorporating an electronic integrated circuit ("smart" cards)(HS02)(switches to 852352*) 854270: Electronic microassemblies (HS02)(switches to 854390* & 854890*) 852352: "Smart cards" (HS07; 854210 in HS02) 854390: Parts of the mach. & app. of 85.43 (both, but changes) 854890: Electrical parts of mach/app nes in Ch.85 (both, but changes)
Analytical Instruments		90129 90149 90249 90279 90289 90299 90309 90329 9033[23]	901290: Parts & accessories of the app. of 90.12 901490: Parts & accessories of nav. instr. & appls. 90.14 902490: Parts & accessories of the machines & appls. of 90.24 902790: Microtomes; parts & accessories of instr. & app. 90.27 902890: Parts & accessories of the meters of 90.28 902990: Parts & accessories of the instr. of 90.29 903090: Parts & accessories of the instr. & app. of 90.30 903290: Parts & accessories of the instr. & app. of 90.32 9033: Parts and accessories (not specified or included elsewhere in this Chapter) for machines, appliances, instruments or apparatus of Chapter 90.

[22] Not included in Sturgeon & Memedovic (2011) definition
[23] 9033 also includes other medical equipment and other instruments in Chap. 90

Table A. 5. Final Electronics Product Categories

Product Examples	HS Code	HS02 Codes
Computers & Storage Devices		
Laptops Desktops Storage Devices	8471	8471: Automatic data processing machines and units thereof; magnetic or optical readers, machines for transcribing data onto data media in coded form and machines for processing such data, not elsewhere specified or included. 847110: Analogue or hybrid automatic data processing machines (HS02) 847130: Portable digital automatic data processing machines, weighing not more than 10 kg, consisting of a least a central processing unit, a keyboard and a display (HS07, no digital) 84714: Other digital automatic data processing machines: (HS07, no digital) 847141: Comprising in the same housing at least a central processing unit and an input and output unit, whether or not combined 847149: Other, presented in the form of systems 847150: Digital processing units other than those of subheading 8471.41 or 8471.49, whether or not containing in the same housing one or two of the following types of unit: storage units, input units, output units (HS07, no digital) 847160: Input or output units, whether or not containing storage units in the same housing 847170: Storage units 847180: Other units of automatic data processing machines 847190: Other
Office Equipment		
Typewriters Copiers Mail-Related Printers Scanners Calculating Machines Cash Registers	8469 8470 8472 844312 9009 (HS02)	8469: Typewriters other than printers of heading 84.71; word-processing machines (HS02) 846911: Word-processing machines (HS02) 846912: Automatic typewriters (HS02) 846920: Other typewriters, electric (HS02) 846930: Other typewriters, non-electric (HS02) New: 8469: Typewriters other than printers of heading 84.43; word-processing machines. New: 846900: Typewriters other than printers of heading 84.43; word-processing machines. 8472: Other office machines (e.g., hectograph or stencil duplicating machines, addressing machines, automatic banknote dispensers; coin-sorting, coin-counting, wrapping, pencil-sharpening, perforating, or stapling machines). 847210: Duplicating machines 847230: Machines for sorting or folding mail or inserting mail in envelopes or bands; for opening, closing or sealing mail and for affixing or cancelling postage stamps 847290: Other 844312: Offset printing mach., sheet-fed, office type (sheet size not >22x36cm) 9009: Photocopying apparatus incorporating an optical system or of the contact type and thermo-copying apparatus (HS02) 8470: Calculating machines and pocket-size data recording, reproducing and displaying machines with calculating functions; accounting machines, postage-franking machines, ticket-issuing machines and similar machines, incorporating a calculating device; cash registers.
Phones, Fax Machines, & Routers		
Telephones Fax Machines Routers	85171 85172 (HS02) 85173 (HS02) 85175 (HS02) 85176 (HS07) 85178 (HS02)	85171: Telephone sets; videophones: 851711: Line telephone sets with cordless handsets (both); 851719: Other (HS02) 85172: Facsimile machines and teleprinters (HS02) 851730: Telephonic or telegraphic switching apparatus (HS02) 851750: Other apparatus, for carrier-current line systems or for digital line systems (HS02, switches to 8517.61-62*) 851780: Other apparatus (HS02) 85171: Telephone sets, incl. phones for cellular or other wireless networks: 851712: Phones for cellular or other wireless networks (HS07) 851718: Other (HS07)

		85176: Other apparatus for transmission or reception of voice, images or other data, incl. apparatus for communication in a wired or wireless network (such as a local or wide area network): (HS07) 851761: Base stations (HS07) 851762: Machines for reception, conversion and transmission or regeneration of voice, images or other data, incl. switching & routing apparatus (HS07) 851769: Other (HS07)
Radio & TV Transmission		
	85251 (HS02) 85252 (HS02) 85255 (HS07) 85256 (HS07)	852510: Transmission apparatus (HS02) switches to 852550 (HS07) 852520: Transmission apparatus incorporating reception apparatus (HS02); switches to 852560 (HS07)
Cameras & Projectors		
Digital Cameras Camcorders TV Cameras Video Projectors Cinematographic Cameras & Projectors	85253 (HS02) 85254 (HS02) 85258 (HS07) 85283 (HS02) 85286 (HS07) 90061 90063 90064 90065 90071 90072 90081 90083	852530: Television cameras & 852540: Still image video cameras and other video camera recorders; digital cameras (HS02); switches to 852580 (HS07) 852830: Video projectors (HS02); switches to 85286: Projectors (HS07) 900610: Cameras for preparing printing plates or cylinders 900630: Cameras specially designed for underwater or aerial survey use or medical or surgical examination of internal organs; comparison cameras for forensic or criminological purposes 900640: Instant print cameras 90065: Other cameras 90071: Cinematographic cameras (same)[24] 900720: Cinematographic projectors (same) 900810: Slide projectors (same) 900830: Other image projectors (same)
Radar & Radio Navigation Equipment		
	8526	8526: Radar, radio navigational aid and radio remote control apparatus. 852610: Radar apparatus 85269: Other 852691: Radio navigational aid apparatus 852692: Radio remote control apparatus
Radios & Alarm Clocks		
Cassette Players Car Radios CBs	8527	8527: Reception apparatus for radio-telephony, radio-telegraphy or radio-broadcasting, whether or not combined, in the same housing, with sound recording or reproducing apparatus or a clock. 85271: Radio-broadcast receivers capable of operating without an external source of power, including apparatus capable of receiving also radio-telephony or radio-telegraphy: 85272: Radio-broadcast receivers not capable of operating without an external source of power, of a kind used in motor vehicles, including apparatus capable of receiving also radio-telephony or radio-telegraphy: 85273: Other radio-broadcast receivers, including apparatus capable of receiving also radio-telephony or radio-telegraphy
Televisions & Monitors		
Televisions Computer Monitors (HS07 only)	85281 (HS02) 85282 (HS02) 85284 (HS07) 85285 (HS07) 85287 (HS07)	85281: Reception apparatus for TV, whether or not incorporating radio-broadcast receivers, sound or video recording or reproducing apparatus (HS02) 852812: Color; 852813: Black and White (HS02) 85282: Video Monitors: 852821: Color; 852822: B&W or monochrome (HS02) 85284: Cathode-ray tube monitors (HS07) 85285: Other monitors: 852851: Of a kind solely or principally used in an automatic data processing system of heading 84.71; 852859: Other (HS07) 85287: Reception apparatus for television, whether or not incorporating radio-broadcast receivers or sound or video recording or reproducing apparatus: 852871: Not designed to incorporate a video display or screen 852872: Other, color; 852873: Other, B&W or other monochrome (HS07)
Sound Projection		

[24] 9007: not included in Sturgeon & Memedovic (2011) definition, but included here

Microphones, Loudspeakers, Headphones, Amplifiers	85181-5	8518: Microphones and stands therefor; loudspeakers, whether or not mounted in their enclosures; headphones and earphones, whether or not combined with a microphone, and sets consisting of a microphone and one or more loudspeakers; audio-frequency electric amplifiers; electric sound amplifier sets (same)
Sound & Video Recording Devices		
Record Players Cassette Players Answering Machines VHS DVD Players	8519 8520 (HS02) 8521	8519: Sound recording or reproducing apparatus (HS07) (all six-digit codes change, but stay within 8519 heading) 851910: Coin- or disc-operated record-players (HS02) 851921: Other record players (HS02)(merges with above) 851920: Apparatus operated by coins, banknotes, bank cards, tokens or by other means of payment (HS07) 85193: Turntables/record-decks (goes from two 6-digit to one) 851940: Transcribing machines (HS02) 851950: Telephone answering machines (HS07) 85198: Other apparatus (HS07) 85199: Other sound reproducing apparatus (HS02) 8520: Magnetic tape recorders and other sound recording apparatus, whether or not incorporating a sound reproducing device (HS02; switches to 8519 codes) 8521: Video recording or reproducing apparatus, whether or not incorporating a video tuner (same)
Medical		
Capital Equipment Therapeutics (partial)	90214[25] 90215 9022 90181 90182	90214: Hearing aids (excl. parts & accessories) 90215: Pacemakers for stimulating heart muscles (excl. parts & accessories) 9022: Apparatus based on the use of X-rays or of alpha, beta or gamma radiations, whether or not for medical, surgical, dental or veterinary uses, including radiography or radiotherapy apparatus, X-ray tubes and other X-ray generators, high tension generators, control panels and desks, screens, examination or treatment tables, chairs and the like. 90181: Electro-diagnostic apparatus (including apparatus for functional exploratory examination or for checking physiological parameters) 90182: Ultra-violet or infra-red ray apparatus
Analytical Instruments		
Microscopes Navigation Instruments Balances Mechanical Testing Calibration Counters Electricity Measuring	90121 90141-2, 8 9016 90241, 8 90271-5, 8 90281-3 90291-2 90301-4, 8 90321-2, 8	901210: Microscopes other than optical microscopes; diffraction apparatus 9014: Direction finding compasses; navigational instruments and appliances. 9016: Balances of a sensitivity of 5 cg or better, with or without weights. 9024: Machines & appliances for testing the hardness, strength, compressibility, elasticity or other mechanical properties of materials 9027: Instr. and app. for physical or chemical analysis; for measuring or checking viscosity, porosity, expansion, surface tension or the like; for measuring or checking quantities of heat, sound or light (incl. exposure meters) 9028: Gas, liquid or electricity supply or production meters, including calibrating meters therefor. 902910: Revolution and production counters, taximeters, mileometers, pedometers and the like 902920: Speed indicators and tachometers; stroboscopes 903010: Instr. and apparatus for measuring or detecting ionizing radiations 903020: Cathode-ray oscilloscopes and cathode-ray oscillographs (changes) 903031: Multimeters (HS02); Multimeters without a recording device (HS07) 903032: Multimeters with a recording device (HS07) 903033: Other, w/o recording device (HS07) 903039: Other (HS02); Other, with recording device (HS07) 903040: Other, specially designed for telecommunications (e.g., cross-talk meters, gain measuring instruments, distortion factor meters, psophometers) 903082: For measuring or checking semiconductor wafers or devices 903083 (84): Other, with a recording device (HS02; HS07) 903089: Other instruments & apparatus specially designed for telecommunications, exclud. 9030.82/84 9032: Automatic regulating or controlling instruments and apparatus.

[25] Sturgeon & Memedovic (2011) includes all of 9021, but this report does not include 90211 (orthopedic fracture devices), 90212 (artificial teeth), 90213 (artificial joints) or 90219 (other).

Not included		
Clocks and Watches	9101 9102 9103 9105	9101: Wrist-watches, pocket-watches and other watches, including stop-watches, with case of precious metal or of metal clad with precious metal. 9102: Wrist-watches, pocket-watches and other watches, incl. stop-watches, other than those of heading 91.01. 9103: Clocks with watch movements, excl. heading 91.04. 9105: Other clocks
Not included		
Musical Instruments	9201 9203 (H02) 9204 (H02) 9206 9207 9208	9201: Pianos, including automatic pianos; harpsichords and other keyboard stringed instruments. 9203: Keyboard pipe organs; harmoniums and similar keyboard instruments with free metal reeds (HS02) 9204: Accordions, similar instruments; mouth organs (HS02) 9206: Percussion musical instruments (e.g., drums, xylophones, cymbals, castanets, maracas) 9207: Musical instruments in which sound is produced or must be amplified electrically (e.g., organs, guitars, accordions) 9208: Musical boxes, fairground organs, mechanical street organs, mechanical singing birds, musical saws and other musical instruments not falling within any other heading of this Chapter; decoy calls of all kinds; whistles, call horns and other mouth-blown sound signaling instruments.

Note: (Sturgeon & Memedovic, 2011) includes all from the above table

6.2. Additional Export Data Tables

Table A. 6. Costa Rica's Final Electronic Product Exports by Value ('000), 2011

Export Destination	Phones		Computers		TVs; Cameras; Radar & Radio		Sound & Video		Total	
	Value	Share	Value	Share	Value	Share	Value	Share	Value	Share
World	**9,800**		**5,363**		**3,143**		**3,357**		**21,663**	
USA	3,401	34.7	2,276	42.4	1,372	43.6	3,108	92.6	10,157	46.9
Mexico	1,270	13.0	637	11.9	445	14.2	133	4.0	2,485	11.5
Hong Kong	1,694	17.3	--	--	--	--	--	--	1,729	8.0
Nicaragua	--	--	1,149	21.4	237	7.5	32	1.0	1,491	6.9
Israel	930	9.5	--	--	--	--	--	--	1,055	4.9
Panama	--	--	202	3.8	--	--	--	--	759	3.5
Ecuador	472	4.8	--	--	--	--	16	0.5	541	2.5
Guatemala	--	--	--	--	--	--	19	0.6	534	2.5
El Salvador	--	--	267	5.0	--	--	--	--	515	2.4
Honduras	--	--	--	--	342	10.9	--	--	447	2.1
UK	--	--	--	--	137	4.3	--	--	192	0.9
Top Five	**7,766**	**79.2**	**4,532**	**84.5**	**2,531**	**80.5**	**3,308**	**98.5**	**19,906**	**91.9**
HS Codes	85171 & 6		8469-72 & 844312		85284-7; 85255-6, 8; 8526-27; 90061, 3-5; 90071-2; 90081, 3		8519, 8521, 85181-5		Total, even if country is not in top five	

Source: Author analysis based on data from PROCOMER, 2012; (--) indicates country not in the top five

Table A. 7. Costa Rica's Top Five Electronic Parts Export Destinations, 2011

Export Destination	Cameras, TV, Radar		Computers, Office Equip.		Other Specific Parts		Analytical Instruments		Totals	
	Value	Share	Value	Share	Value	Share	Value	Share	Value	Share
World	**64,680**		**20,835**		**4,921**		**9,510**		**99,946**	
USA	20,841	32.2	3,340	16.0	4,002	81.3	8,693	91.4	36,876	36.9
Germany	17,869	27.6	--	--	--	--	--	--	17,896	17.9
Hong Kong	14,499	22.4	--	--	72	1.5	--	--	14,837	14.8
Japan	--	--	9,638	46.3	--	--	--	--	10,193	10.2
Taiwan	--	--	5,233	25.1	--	--	--	--	6,202	6.2
South Korea	5,002	7.7	--	--	--	--	--	--	5,002	5.0
China	3,100	4.8	--	--	--	--	231	2.4	3,415	3.4
Malaysia	--	--	1,342	6.4	--	--	376	4.0	1,774	1.8
Mexico	--	--	--	--	149	3.0	67	0.7	518	0.5
Nicaragua	--	--	429	2.1	--	--	--	--	452	0.5
Singapore	--	--	--	--	--	--	61	0.6	445	0.4
DR	--	--	--	--	105	2.1	--	--	119	0.1
Vietnam	--	--	--	--	117	2.4	--	--	117	0.1
Top Five	**61,312**	**94.8**	**19,982**	**95.9**	**4,445**	**90.3**	**9,428**	**99.1**	**97,846**	**97.9**
HS Codes	8529, 90069, 90079		8473		8522, 9033, 85189, 85177, 85439, 85489, 85235		90279, 90299, 90309, 90329		Total, even if country is not in top five	

Source: Author analysis based on data from (PROCOMER, 2012); (--) indicates country not in the top five

6.3. Costa Rica Electronics Firms and Exports

Table A. 8. Firms in the Electronics & Electrical Value Chain in Costa Rica

	Company Names	Origin	Origin City/State	Year Est.	Sector
1	Altanova	USA	San Jose, CA	2008	Service
2	Astrolab	USA	Warren, NJ	2008	Electrical
3	Bticino Costa Rica S.A.	France		1975	Electrical
4	C&K CoActive S.A.	USA	Newton, MA	1988	Electrical
5	Camtronics	USA	Miami, FL	1992	Electronics
6	Componentes Intel de Costa Rica, S.A.	USA	Santa Clara, CA	1997	Electronics
7	Conducen, S.A. (Phelps & Dodge)	USA	Coral Gables, FL	1971	Electrical
8	Controles de Corriente, S.A.	USA	Wellsville, NY	1997	Electrical
9	Chicago Miniature Lighting (CML)	USA	Novi, MI	1995	Electronics
10	DeRoyal	USA	Powell, TN	1998	Electronics
11	Eaton Electrical S.A.	USA	Cleveland, OH	1963	Electrical
12	Electro Technik (ETI) (Hytronics)	USA	Clearwater, FL	1998	Electrical
13	EMC/Smith Labs; Smith Interconnect	England	Immediate: Stuart, FL	1997	Electronics
14	General Microcircuits	USA	Mooresville, NC	2010	Electronics
15	Hologic Cytyc	USA	Bedford, MA	2004	Electronics
16	Irazú Electronics	USA		2001	Electronics
17	KES System	USA		2002	Service
18	L3 Communications	USA		2001	E&E
19	Materiales Aguila Eléctrica Centroamericana	Costa Rica	Originally USA (Eagle)	1978	Electrical
20	MedConx	USA	Santa Clara, CA	2007	Electronics
21	Merlin VMS	USA		2004	Electronics
22	Micro Technologies	USA	Pompano Beach, FL	1999	Electrical
23	Multimix Microtechnology (Merrimac)	USA	West Caldwell, NJ	1999	Electronics
24	National Instruments	USA		2010	Service
25	Panasonic Centroamericana S.A.	Japan	Osaka	1966	Electrical
26	PANDUIT de Centroamérica	USA	Tinley Park, IL	1994	Electrical
27	Pharos de Costa Rica (Vishay)	USA	Wendell, NC/ City of Industry, CA	1989	Electronics
28	Saco International (Keystone)	USA		1995	Electronics
29	Samtec	USA	New Albany, IN	2006	Electrical
30	Schneider Centroamerica S.A.	USA	Palatine, IL	1976	Electrical
31	Sensors Group Costa Rica (SGCR)	USA		2006	Electronics
32	Suttle Costa Rica S.A.	USA	Hector, MN	1989	Electrical
33	Teradyne de Costa Rica S.A.	USA	North Reading, MA	2000	Electronics
34	Tico Electronics	Costa Rica	Originally USA	1995	Electrical
35	Trimpot Electronicas, Ltda	USA	Riverside, CA	1979	E&E
36	Triquint	USA	Hillsboro, OR	1996	Electronics
37	Veridiam (Point Technologies)	USA	El Cajon, CA	2005	Electronics
38	Vitec Videocom Ltda (Camera Dynamics)	England	German/UK/US	1986	Electronics
39	Xeltron	Costa Rica		1974	Electronics

Table A. 9. Firms in the E&E Value Chain in Costa Rica: End Markets

	Company Names	Aero	Auto	Computers	Consumer Electronics	Industrial	Medical	Tele.
1	Altanova							
2	Astrolab	X			X		X	
3	Bticino Costa Rica S.A.							
4	C&K CoActive S.A.	X	X				X	
5	Camtronics	X						
6	Componentes Intel de Costa Rica, S.A.			X		X		
7	Conducen, S.A.					X		
8	Controles de Corriente				X			
9	Chicago Miniature Lighting (CML)		X					
10	DeRoyal					X	X	
11	Eaton Electrical S.A.					X		
12	Electro Technik (ETI)							
13	EMC (Smith Interconnect)	X	X				X	X
14	General Microcircuits					X	X	X
15	Hologic Cytyc						X	
16	Irazú Electronics	X					X	
17	KES System							
18	L3 Communications	X						X
19	Materiales Aguila Eléctrica Centroamericana							
20	MedConx						X	
21	Merlin VMS					X		
22	Micro Technologies	X	X			X	X	
23	Multimix	X						X
24	National Instruments							
25	Panasonic Centroamericana S.A.				X			
26	PANDUIT de Centroamérica		X					X
27	Pharos de Costa Rica	X				X	X	
28	Saco International					X		
29	Samtec		X	X			X	X
30	Schneider Centroamerica					X		
31	Sensors Group CR	X			X	X	X	
32	Suttle Costa Rica S.A.							X
33	Teradyne de Costa Rica	X						
34	Tico Electronics	X						
35	Trimpot Electronicas	X	X		X	X		
36	Triquint				X			X
37	Veridiam						X	
38	Vitec Videocom Ltda					X		
39	Xeltron					X		
	Totals	**13**	**7**	**2**	**6**	**14**	**13**	**8**

7. Bibliography

Associates, Smith &. (2010). "Medical Electronics Is Not so Niche Anymore: A primer on the surging sector." *MarketWatch Quarterly, 4*(2).

ATOTECH. (2012). Automotive Electronics. Retrieved December 1, 2012 from www.atotech.com/markets/automotive/automotive-electronics.html.

BOI, Thailand. (2008). Thailand: The World's Electrical and Electronics Industry Investment Destination (E-brochure). Bangkok, Thailand: Thailand Board of Investment (BOI). http://www.thinkasiainvestthailand.com/boicontent/bisopp/pdf_5.pdf.

Brown, Steven. (2009). "Intel's Presentation for Session #2 on Company Engagement with Nanotechnology Safety". Paper presented at the California Nanotechnology Initiative Symposium V: An Industry Perspective. Sacramento, California. from www.dtsc.ca.gov/technologydevelopment/nanotechnology/upload/brown_nanov.pdf. November 16, 2009.

Cathers, Dylan. (2012). Computers: Hardware. New York, NY, pp. 41 pages. April 19, 2012.

CEREAL. (2011). The crisis that never went away: Centro de Reflexión y Acción Laboral (CEREAL). pp. 37 pages. http://goodelectronics.org/news-en/the-crisis-that-never-went-away-report-on-labour-conditions-in-the-mexican-electronics-industry.

Ciravegna, Luciano and Elisa Giuliani. (2008). MNC-Dominated Clusters and the Upgrading of Domestic Suppliers: The Case of Costa Rican Electronics and Medical Device Industries. In R. Leoncini & S. Montresor (Eds.), *Dynamic Capabilities between Firm Organization and Local Systems of Production* (pp. 236-263): Routledge Studies in Global Competition. London and New York: Taylor and Francis, Routledge.

Cohen, Sagi (2012). Intel to invest $5M in Israeli education. from http://www.ynetnews.com/articles/0,7340,L-4301304,00.html

Daher, Nadim Michel. (2012, July 13, 2012). Getting Down to the Business of Greening Medical Imaging. *Vital Signs*.

Databeans. (2011). Medical Semiconductors. http://www.marketwire.com/press-release/medical-electronics-market-to-reach-156-billion-in-2011-1535077.htm.

Datamonitor. (2011). Global TV & Video. New York, NY, pp. 36 pages.

Deepa, Mathew. (2008). Greater Opportunities in the Medical Electronics EMS Space. from Frost & Sullivanfrom

Euromonitor. (2011). Consumer Electronics Statistics. Retrieved May 2012, from Euromonitor Internationalfrom

Field Research. (2012). Costa Rica: Summer 2012 Series. Personal communication with P. Bamber, G. Gereffi & S. Frederick. July 2-6.

Freedonia. (2012a). Electronic Components: United States, pp. 24 pages.

---. (2012b). Electronic Displays: United States, pp. 23 pages.

Frost & Sullivan. (2011a). Assessment of Electronics Industry in Southeast Asia.

---. (2011b). Global Market for Automotive Semiconductors. Mountain View, California.

---. (2012). Strategic Analysis of Global Industrial Computer Market.

Graduan.com. (2011). Cranking Up the Malaysian Workforce. from http://www.graduan.com.my/Page/LearningCenter/Featured/Cranking-Up-the-Malaysian-Workforce.

IAESI. (2010). Israel Association of Electronics and Software Industries. www.iaesi.org.il/Eng/?CategoryID=351&ArticleID=1168.

Iammarino, Simona, Ramon Padilla-Perez and Nick Von Tunzelmann. (2008). "Technological Capabilities and Global–Local Interactions: The Electronics Industry in Two Mexican Regions." *World Development, 36*(10): 1980-2003.

IBISWorld. (2011). Global Consumer Electronics Manufacturing, pp. 37 pages.

---. (2012a). Global Computer Hardware Manufacturing, pp. 43 pages.

---. (2012b). Global Semiconductor & Electronic Parts, pp. 50 pages.

IEC. (2012). Electropedia. Retrieved October 6, 2012, from International Electrotechnical Commission (IEC)from www.electropedia.org.

Indian Medical Electronics Industry: Outlook 2020. (2011). Deloitte Touche Tohmatsu India Private Limited.

Industrial R&D: electronics/computers. (2010, 2010/12//). *R & D, 52* (7), 46+.

Israel, InVest in. (2012). Exceptional Workforce. Retrieved December 1, 2012, 2012, from http://www.investinisrael.gov.il/NR/exeres/40A8E087-4E21-4D81-BA1E-6CD7D58FBC6F.htm.

Koon, John (2012). Overview of the Medical Semiconductor Market and Applications. (April), from http://medsmagazine.com/2012/04/overview-of-the-medical-semiconductor-market-and-applications/

Kraemer, Kenneth L., Jason Dedrick and Debora Dunkle. (2010). Offshoring of NPD in the Electronics Industry: Patterns and Recession Effects. Irvine, California: University of California, Irvine. pp. 18 pages. http://pcic.merage.uci.edu/papers/2010/OffshoringOfNPD.pdf.

Larraín, Felipe B., Luis F. López-Calva and Andrés. Rodríguez-Clare. (2000). Intel: A Case Study of Foreign Direct Investment in Central America. Harvard University, pp. 40 pages. www.hks.harvard.edu/var/ezp_site/storage/fckeditor/file/pdfs/centers-programs/centers/cid/publications/faculty/wp/058.pdf.

Mahadevan, Renuka and Mansor Ibrahim. (2007). Competitiveness and Workforce Status in the Malaysian Micro-Electronics Sector, pp. 29 pages.

MATIMOP. (2012). About MATIMOP. Retrieved December 1, 2012, 2012, from http://www.matimop.org.il.

MGCC. (2012). Market Watch 2012: Electrical & Electronic Industry in Malaysia: Malaysia-German Chamber of Commerce and Industry (MGCC). pp. 15 pages. http://www.malaysia.ahk.de/fileadmin/ahk_malaysia/Market_reports/Electrical___Electronic_Industry_in_Malaysia.pdf.

MIDA. (2012). Malaysia Investment Performance 2011: Malaysian Investment Development Authority (MIDA).

MIGA. (2006). The Impact of Intel in Costa Rica: Nine Years After the Decision to Invest. Washington, DC: Multilateral Investment Guarantee Agency (MIGA) of the World Bank Group. pp. 52 pages.

Monge-Ariño, Francisco. (2011). Costa Rica: Trade Opening, FDI Attraction and Global Production Sharing. Geneva, Switzerland: Economic Research and Statistics

Division, World Trade Organization. pp. 21 pages. www.wto.org/english/res_e/reser_e/ersd201109_e.pdf.

Morales, Mariana. (2012). Mexico's Electric Industry: Meeting the World's Needs. *Negocios* (August), 20-25.

NAPS. (2012a). Electronics Manufacturing in Mexico. Retrieved October 13, 2012, 2012, from http://www.napsintl.com/electronics.php.

---. (2012b). Employment and Labor in Mexico. Retrieved October 13, 2012, 2012, from http://www.napsintl.com/labor_mex.php.

Negocios. (2011). Electronic Industry: Plug & Succeed. *Negocios* (September), 20-27.

OECD (2012). Attracting Knowledge-Intensive FDI to Costa Rica: Challenges and Policy Options,

Padilla-Perez, Ramon and Rene Hernandez. (2010). "Upgrading and Competitiveness Within the Export Manufacturing Industry in Central America, Mexico, and the Dominican Republic." *Latin American Business Review, 11*: 19-44.

Patton, David Bullón and Ryan A. Moore. (2012). *Linking Manufacturing SMEs to Global Value Chains: The Case of Metalworking and Plastics in Costa Rica.* Harvard University.

Portugal-Perez, Alberto, José-Daniel Reyes and John S. Wilson. (2009). Beyond the Information Technology Agreement: Harmonization of Standards and Trade in Electronics. Washington, DC: The World Bank Development Research Group Trade Team. pp. 36 pages.

Prestowitz, Clyde and Ben Carliner. (2008). Israel 2020: a Strategic Vision for Economic Development. Washington, DC: Economic Strategy Institute. www.econstrat.org/index.php?option=com_content&task=view&id=354.

PROCOMER. (2012). Portal de Comercio Exterior. from http://servicios.procomer.go.cr/estadisticas/inicio.aspx.

Robinson-Avila, Kevin. (2011). Foxconn spinoff effect has Santa Teresa flourishing. *New Mexico Business Weekly*. from www.bizjournals.com/albuquerque/print-edition/2011/12/09/foxconn-spinoff-effect-has-santa.html?page=all.

Rodríguez, Clare A. (2001). "Costa Rica's Development Strategy based on Human Capital and Technology: how it got there, the impact of Intel, and lessons for other countries." *Journal of Human Development, 2*(2): 311 – 324.

Santiago, Ernie. (2007). Development of ASEAN Framework for Trade Negotiations: Electronics Industry: Semiconductor and Electronics Industries in the Philippines (SEIPI). pp. 44.

Sturgeon, Timothy J. and Momoko Kawakami. (2010). Global Value Chains in the Electronics Industry: Was the Crisis a Window of Opportunity for Developing Countries? : The World Bank. pp. 53 pages.

---. (2011). "Global value chains in the electronics industry: characteristics, crisis, and upgrading opportunities for firms from developing countries." *International Journal of Technological Learning, Innovation and Development, 4*(1/2/3): 120–147.

Sturgeon, Timothy J. and Olga Memedovic. (2011). Mapping Global Value Chains: Intermediate Goods Trade and Structural Change in the World Economy. Vienna, Austria, pp. 58 pages.

http://www.unido.org/fileadmin/media/documents/pdf/Publications/110923/WP052010_Ebook.pdf.

U.S. Commercial Service (2012). Doing Business in Costa Rica: 2012 Country Commercial Guide for U.S. Companies, Available from http://www.buyusainfo.net/docs/x_1853591.pdf.

UNComtrade. (2012). United Nations Commodity Trade Statistics Database. Retrieved October 2012, from United Nations Statistics Divisionfrom

van Liemt, Gijsbert. (2007). Subcontracting in electronics: From contract manufacturers to providers of Electronic Manufacturing Services (EMS). Geneva, Switzerland: ILO. pp. 36.

Waterman, Justin. (2012a). Circuit Board & Electronic Component Manufacturing in the US (33441b), pp. 34 pages.

---. (2012b). Electrical Equipment Manufacturing in the US (33531), pp. 37 pages.

---. (2012c). Wire & Cable Manufacturing in the US (33592), pp. 39 pages.

Wiriyapong, Nareerat (2012). Thailand faces electronic exodus. from http://www.bangkokpost.com/learning/learning-from-news/297732/electronics-workforce-skill-upgrade-plus-english-needed

WTO. (2012a). Information Technology Agreement. Retrieved December 1, 2012, 2012, from http://www.wto.org/english/tratop_e/inftec_e/inftec_e.htm.

--- (2012b). International Trade Statistics 2012, Available from http://www.wto.org/english/res_e/statis_e/its2012_e/its12_merch_trade_product_e.htm.

Young-jin, King (2011). Mexico promotes thriving electronics sector. Retrieved October 13, 2012, from http://www.koreatimes.co.kr/www/news/special/2012/09/176_83042.html

Young Jr., Arthur. (2010). The Philippine Electronics Industry: Cultivating an Innovation and Entrepreneurship Culture. De La Salle University, Manila.

Zino, Angelo. (2011). Industry Surveys: Semiconductors. New York, NY, pp. 48 pages.