Diverse paths of upgrading in high-tech manufacturing: Costa Rica in the electronics and medical devices global value chains

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Costa Rica has sought to improve its position in the global economy by prioritizing export growth in two high-tech manufacturing industries led by foreign direct investment (FDI): electronics and medical devices. We use a global value chain (GVC) perspective to identify key commonalities and contrasts in Costa Rica's performance in upgrading these two sectors. Because the electronics and medical devices GVCs have very different structures in Costa Rica (electronics is dominated by a single large firm, Intel, whereas medical devices has a highly diversified set of foreign manufacturers), multiple forms of upgrading, downgrading and knowledge spillovers are possible. Although the experience of these two industries illustrates different paths to upgrading, developing backward linkages in Costa Rica was not the preferred nor the only way of moving up the value chain. The medical devices sector exhibited more traditional knowledge spillovers and labor market features of local industrial agglomerations, whereas the electronics sector demonstrated significant wage and skill-level gains because of the incorporation of high-value service activities due to the evolving global strategy of its GVC lead firm, Intel. By combining a GVC perspective with a focus on knowledge flows and value creation at the local level, we seek to promote more explicit integration of international business and economic geography concepts and methods.

Keywords: global value chains; electronics; medical devices; upgrading; downgrading; knowledge spillovers; local linkages; servicification; industrial agglomerations.

1. Introduction

Developing nations have sought to improve their positions in the global economy through various upgrading strategies, including the use of foreign direct investment (FDI) to help them catch up with advanced country competitors in high-tech manufacturing and service industries. This emphasis on entering high-tech export-

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oriented sectors is particularly attractive for relatively small economies, which often do not have the natural resource base or large domestic markets needed for inward-oriented development strategies.

Evidence is mixed on the potential for FDI-led development to support high-tech upgrading in developing economies. Early studies of Costa Rica's high-tech development strategy agreed that FDI has been very successful in boosting the country's export competitiveness, but achievements were far less in terms of the transfer of technology, local linkages and knowledge spillovers needed for a more sustainable pattern of industrial upgrading (Giuliani, 2008; Paus and Gallagher, 2008). For example, Ciravegna and Giuliani (2007) concluded that Costa Rica has successfully created FDI-dominated clusters in both the electronics sector and the medical devices sector, although backward linkages to local suppliers are weak and of low technological content.

For medical devices in Galway, Ireland, Giblin and Ryan (2012) demonstrated that inward FDI was initially attracted to the region through "top-down" public policy rather than through a pre-existing cluster or a large domestic market. However, the success of two world-class multinational enterprises (MNEs), Boston Scientific and Medtronic, resulted in positive reputational effects for the Galway region, which made it easier for local firms to establish their own linkages abroad and participate in global networks. This finding challenges earlier studies that suggested external economies or knowledge spillovers of MNEs could be captured only if FDI entered existing clusters driven by indigenous firms (Phelps, 2008; De Propris and Driffield, 2006).

This debate sets up our main research questions in this paper: Under what conditions can FDI-led, export-oriented industries in Costa Rica, such as electronics and medical devices, generate significant and sustainable patterns of upgrading in the local economy, and what types of policies can help create such conditions? We address these questions by using the global value chains (GVC) framework to integrate global, national and local levels of analysis (Gereffi and Fernandez-Stark, 2016). At the global level, we examine the governance structure of the electronics and medical devices GVCs and the strategies of the lead firms that located in Costa Rica. At the national level, we highlight Costa Rica's development strategy of export-oriented industrialization with a particular focus on high-tech manufactured exports. Also relevant are key institutional features that shape the role played by FDI in the country, such as Costa Rica's free trade zones (FTZs) and its foreign investment promotion agency (CINDE), which markets the country's location-specific assets to potential foreign investors. At the local level, we focus on specific activities that MNEs carried out in each sector and how these activities changed over time. In addition, we analyze the local labor market impact of MNEs in terms of jobs, skills and wages in these two industries, along with backward and forward linkages involving suppliers of goods and services across the value chains.

Our GVC focus highlights the interplay between global and local factors, and does not assign causal priority ex ante to host-country absorption capacity, domestic institutions or local linkages as determinants of upgrading (or downgrading) outcomes. Our empirical research uses value chain mapping to document which activities are carried out locally in each industry, and how and why these activities evolve over time. The contrasting structures and FDI dynamics of the electronics and medical devices sectors in Costa Rica generate different patterns of upgrading, linkages and knowledge spillovers, and both domestic and external factors will affect their future trajectories.

Costa Rica is a very interesting case for exploring these questions. Although it is a small country of fewer than 5 million people, Costa Rica has been the most successful Latin American economy, after Mexico, in attracting FDI into high-tech manufacturing (Paus and Gallagher, 2008: 54-55). Costa Rica's traditional exports were bananas, coffee and clothing, but in the 1990s the country shifted to a high-tech industrialization strategy emphasizing FDI and manufactured exports.[1] Intel's decision in 1996 to invest US$300 million in an assembly-and-testing (A&T) semiconductor factory proved that Costa Rica was able to attract high-tech FDI, and the country subsequently expanded its efforts to target other high-tech sectors such as medical devices and information technology (IT)-enabled services (Monge-González, 2017). Although electronics and medical devices both involve high-tech products and processes, the two sectors vary considerably in their global production structures and in the relevance of local linkages for industry growth and sustainability.

Our paper is structured as follows: Section 2 provides an overview of the literature on GVCs and upgrading, and several propositions that link the GVC perspective to the local and institutional contexts of upgrading in Costa Rica. Section 3 discusses the data and methodology used in our study. Section 4 analyzes our empirical findings for the electronics and medical devices GVCs in Costa Rica, showing how the contrasting structures and lead-firm strategies of these sectors produce varied results in terms of local upgrading trajectories. Section 5 discusses the key lessons from our findings for the sustainability of high-tech upgrading efforts in Costa Rica, and Section 6 examines the policy implications of our analysis for other countries.

[1] By 1994, apparel products represented 36 per cent of the total exports of Costa Rica's FTZs; the low value-added of this assembly industry led to a rapid decline in the 1990s (Giuliani, 2008: 388).

2. Global value chains and the upgrading challenge

The GVC perspective looks at global industries from two contrasting vantage points: top down and bottom up (Gereffi and Fernandez-Stark, 2016). The key concept for the top-down view is the "governance" of GVCs, which examines the organization of global industries by linking GVC lead firms and their varied networks of suppliers, while the central concept for the bottom-up view is "upgrading", which highlights the strategies used by countries, regions and firms to maintain or improve their positions in the global economy (Gereffi, 2014). Global lead firms are a defining feature of the governance structure of GVCs, including the initial distinction between producer-driven and buyer-driven chains (Gereffi, 1994) as well as the more comprehensive typology involving captive, relational and modular GVC governance structures along a continuum whose end points are markets and hierarchies (Gereffi et al., 2005).

Economic upgrading can be defined as "the process by which economic actors – nations, firms and workers – move from low-value to relatively high-value activities in global production networks" (Gereffi, 2005: 171). Various typologies have been used to analyze how this upgrading process takes place. One of the best-known formulations of firm-level strategies to improve their competitive position in GVCs (Humphrey and Schmitz, 2002) involves four types of upgrading:

- *Product upgrading*: moving into more sophisticated product lines with higher unit values.
- *Process upgrading*: transforming inputs into outputs more efficiently by reorganizing production systems or by using superior technology.
- *Functional upgrading*: acquiring new, superior functions in the chain (or abandoning low value-added functions) to raise the skill content of activities.
- *Intersectoral or chain upgrading*: using the competence acquired in a particular chain to move into new sectors.

Early GVC studies suggested that local upgrading trajectories were associated with moving away from assembly production into original equipment manufacturing (OEM) or full-package production, and eventually into original design manufacturing (ODM) and original brand manufacturing (OBM), all of which utilize more extensively the higher-value activities associated with pre- and post-production services (Gereffi, 1999; Bair and Gereffi, 2001; Schmitz and Knorringa, 2000). However, newer GVC studies have shown that this "linear" upgrading scheme is just one among a much larger range of possible upgrading trajectories, many of which involve more extensive linkages between manufacturing and services activities within local clusters as well as along GVCs (Sturgeon et al., 2008; Gereffi, 2015; Low and Pasadilla, 2016).

A new World Bank study highlights that the development impact of manufacturing comes not only from production per se, but also increasingly from the services involved in a product's broader value chain (Hallward-Driemeier and Nayyar, 2018). The boundaries between the manufacturing and services sectors are blurring. The so-called "servicification" of manufacturing refers both to services *embodied* in goods (as part of the manufacturing process) and to services *embedded* in goods during the post-production process (including after-sales support and other add-on services such as manufacturing-related engineering services). The key theme is that upgrading in high-tech industries is about making and adding value at every stage of the production process – from raw materials to design and production, and all the way to sales and follow-on services.

This review of both the GVC and upgrading literatures provides us with the necessary foundation to employ these frameworks in our analysis of the electronics and medical devices GVCs in Costa Rica. The GVC perspective is used to better understand the governance structures of these two industries at the global level, as well as the role played by lead-firm strategies in both sectors as they have been established within Costa Rica. The upgrading concept is applied not to analyze the atomistic position of single firms, but rather as a relational concept to assess the role of market players, inter-firm networks and public policy across the entire value chain. Our emphasis is dynamic because we need to evaluate the evolution of value chain structures, strategies and upgrading outcomes over time.

2.1 Propositions

To clarify our perspective, we briefly outline three theoretical propositions that guided our research on the Costa Rica case.

Proposition 1: *The strategies of GVC lead firms in the electronics and medical devices sectors determine how Costa Rica is inserted in export-oriented production networks and the potential gains from trade in these sectors.*

GVC lead firms are the key drivers of upgrading, and public policy plays a facilitating role. Neither the electronics nor the medical devices industries in Costa Rica had previous clusters of export-oriented firms, so MNE lead firms entered Costa Rica to respond to top-down public policy initiatives by the national government rather than to exploit pre-existing sectoral capabilities or a large local market. Upgrading dynamics are largely determined by local industrial agglomerations established by inward FDI.

Proposition 2: *The contrasting roles played by MNE lead firms in the electronics and the medical devices GVCs in Costa Rica create different kinds of industrial agglomeration in the host economy: Intel has a quasi-monopoly in electronics production and exports, whereas medical devices has a much greater diversity of foreign investors that instigate cluster-like patterns and competitive dynamics.*

These differences have implications for FDI-related knowledge spillovers in Costa Rica. With only one firm participating in the production segment of the electronics value chain, there are limited possibilities for intra-sector spillovers. By contrast, medical devices MNEs have instigated cluster-like properties in the local industrial agglomeration they generated in Costa Rica, resulting in much higher levels of technological upgrading through exports, a more diversified group of local suppliers, and some forward linkages into manufacturing-related services.

Proposition 3: *Different GVC characteristics and lead firm strategies in electronics and in medical devices led to diverse upgrading and downgrading patterns in Costa Rica.*

We expect the patterns in Costa Rica to be mixed. On the upgrading side, we anticipate the strongest performance in terms of exports over time because this was an explicit objective of Costa Rica's policy of FDI-led export-oriented growth. We also look closely at local labor market effects through employment, skill training and wage performance. The role of local linkages is likely to be weakest in backward linkages to suppliers as there is a very limited industrial base on which to build. However, GVCs have incentives to create needed linkages of goods and services if export growth is rapid and diversified. On the downgrading side, we assess the impact of the closure of Intel's plant in 2014, and the associated drops in exports and employment. This is a byproduct of Costa Rica's dependence on a single GVC lead firm in the electronics sector. However, the story of Intel's expansion of relatively high-value services in Costa Rica is also very intriguing, as that expansion may offset some of the employment and manufacturing export losses.

Several factors condition sustainable upgrading in these two GVCs in Costa Rica:

- *GVC lead-firm strategies* – Will Intel continue to promote Costa Rica as a hub in its regional and global service activities? Will Costa Rica be able to diversify the number of GVC lead firms that operate in high-tech sectors so as to create more sustained demand for high-value manufacturing-related and professional services?

- *Endogenous variables* – Public policy is a core issue, especially Costa Rica's policies related to its local innovation system. Although the innovation system literature tends not to emphasize the role of GVC linkages in knowledge flows (Pietrobelli and Rabellotti, 2011), there are clear roles for specialized training programs and industry-university linkages in expanding pools of skilled labor and promoting local start-ups.

- *Exogenous variables* – Given Costa Rica's export-oriented strategy, the policies of its major trade partners are a key factor, especially protectionist policies that could limit Costa Rica's access to its primary export market, the United States. Costa Rica's extensive set of free trade agreements with a variety of countries in Europe and elsewhere provides a hedge against protectionism from the public policy side. GVC lead-firm strategies can also play a role here by connecting Costa Rica to a more diversified set of global production networks and end-markets.

In our broader assessment of knowledge flows related to high-tech upgrading in Costa Rica's electronics and medical devices GVCs, we discuss the role of five potential determinants of FDI-generated spillovers: (1) the characteristics of the manufacturing GVCs being analyzed; (2) the transnational strategies of MNE lead firms within these GVCs; (3) Costa Rica's industrial policies, including those related to the establishment of the FTZ regime; (4) the position of Costa Rica within these GVCs; and (5) the absorptive capacity of Costa Rican institutions to manage FDI flows and convert them into value-adding activities at the local level.

3. Data and methodology

The research was undertaken in two stages. The objective of the first stage was to understand the evolution of the two industries in Costa Rica and establish comparable metrics for both sectors. A longitudinal data set of electronics and medical devices firms operating in Costa Rica was created. This data set covered annual trade data, investment year, employment, key product categories and activities. It was created using information from the Costa Rican Central Bank together with annual surveys for the Costa Rican FTZs. The data set covered firm-level exports, employment and wages for 2000–2015, and imports for 2009–2014. Import-export data included the Harmonized System (HS) product code, value, weight and destination or origin. These data were supplemented with information from CINDE about the year of investment. Company annual reports, industry reports and news articles were used to identify the health care subsectors in which medical devices firms were engaged.

In total, 14 firms were identified as participating in the electronics sector and 35 firms in the medical devices sector. All firms engaging in GVC exports in either sector were located in the country's FTZs. In both sectors the firms listed in the data set accounted for 96 per cent of the country's exports, as reported by UN Comtrade over the 15-year period analyzed. Firm exports were categorized as either intermediate or final products. The final products were grouped together by technological sophistication in the case of medical devices (i.e. disposables, instruments, therapeutic devices or capital equipment; see table A-1) and by end-market in the electronics sector (e.g. consumer electronics, medical; see table A-2). Firm activities were also coded into four groups: R&D Services; Component Manufacturing; Final Products Assembly; and Distribution. This information was used to map Costa Rica's participation in the two GVCs by examining a series of empirical indicators: the activities performed by different firms in the sectors;

backward linkages with both local and foreign suppliers; employment and salary information; primary end-markets; and type of products exported.

In the second stage, we analyzed how these firms had altered their participation or increased their value addition in their respective chains, including through expansion or change of activities undertaken, products made, and subsectors and markets served. This research combined year-on-year analysis of the data set with information derived from 23 semi-structured interviews with senior executives of firms from both industries (12 medical devices firms, 10 electronics firms and one firm operating in both sectors). The interviews covered topics such as company background, detailed history of firm investments in Costa Rica, evolution of processes undertaken at plants, changes in employment number and profiles, industry linkages (with both foreign and domestic firms), and engagement with local educational institutions and public agencies. The information from these interviews was supplemented with interviews from several public and private stakeholders including the Ministry of Foreign Trade, CINDE, the Ministry of Education, the National Training Institute and other academic institutions. Based on this information, comparative analysis was undertaken to evaluate the upgrading trajectories.

Table 1. Methodological approach

Research Stage	Research Method	Data Sources
GVC Mapping	Compilation of firm-level data set (including firm name, origin, exports and imports, local sourcing, employment, activities and products exported) Segmentation of exports and activities by value chain stage 7 personal multi-stakeholder interviews	• Costa Rica Central Bank, Annual Survey for Costa Rican Free Trade Zones • Costa Rican Investment Promotion Agency (CINDE) • Ministry of Foreign Trade (*Ministerio de Comercio Exterior, COMEX*) • Costa Rican Export Promotion Agency (PROCOMER) • United Nations Statistics Division
Upgrading Analysis	Analysis of evolution of product exports, evolution of activities, backward linkages Personal interviews with 23 firms	• Analysis of GVC mapping data set • Foreign-owned medical devices firms • Foreign-owned electronics firms

Source: Authors.

4. A GVC analysis of high-tech upgrading in Costa Rica

In the mid-1990s, Costa Rica sought to diversify its economy by focusing on an FDI strategy to promote high-technology manufacturing exports. The opening in 1998 of Intel's factory in Costa Rica was the first major step in realizing this strategy, but Intel's decision to close this plant in 2014 and lay off 1,500 workers highlighted the vulnerabilities of depending on just one high-profile MNE. The medical devices sector represented a very different approach to Costa Rica's economic diversification efforts. Instead of targeting a single dominant MNE such as Intel, in the medical devices sector Costa Rica recruited a more diverse set of MNEs. This enabled the country to follow a trajectory of upgrading based on successive waves of FDI, embodying different categories of medical devices with higher levels of technological content. As a result, medical devices emerged as the most successful cluster developed in Costa Rica under its FDI-driven, high-tech export strategy. Investment, trade and upgrading patterns of the two sectors are discussed in the following sections.

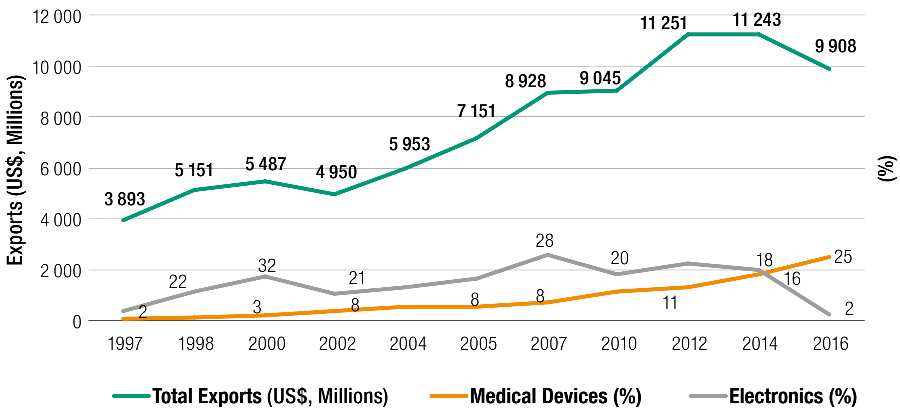
4.1 Costa Rica in the electronics GVC

Costa Rica's initial foray into a high-tech manufacturing export sector was in electronics. The first foreign firms in the electronics GVC started investing in Costa Rica in the 1960s and 1970s, when import-substitution policies were being implemented. These "market-seeking" subsidiaries were mainly European, and they made simple electrical components (batteries, switches and connectors) and consumer appliances (washing machines and hair dryers) for the domestic and regional markets. During the 1980s and 1990s, Costa Rica shifted its strategy to the attraction of high-tech FDI geared to export-oriented industrialization. Instead of local markets, the new "efficiency-seeking" MNE subsidiaries thus attracted were typically American-owned firms that exported their entire output to the United States.

When Intel opened its A&T factory in Costa Rica in 1998, it became the star performer in terms of the country's manufactured exports, but with a focus on intermediate inputs rather than final consumer goods. Thus, Costa Rica was positioned in the upstream (components) side of the electronics GVC, rather than in the final products side. By 2000, electronics represented 32 per cent of Costa Rica's total exports. Between 2000 and 2014, electronics was Costa Rica's leading manufactured export item, and Intel represented over 80 per cent of Costa Rica's electronics exports (figure 1).[2]

[2] For an in-depth analysis of the GVC in Costa Rica, see Frederick & Gereffi (2013).

Figure 1. Costa Rica's exports: total, medical devices and electronics, 1997–2016 (Millions of dollars and per cent)



Source: UN Comtrade (2017).

a. Governance and global firm strategy in the electronics sector

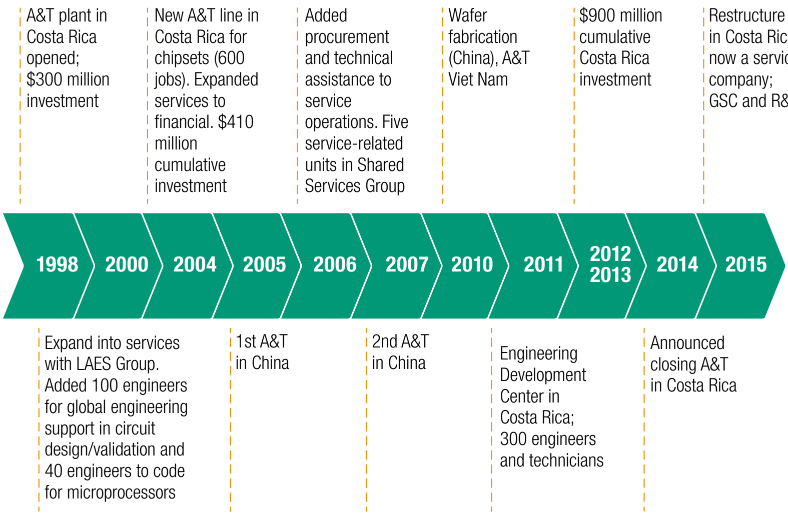
Global: The ecosystem of the electronics GVC has three principal actors: lead firms with global brands (such as Apple, Samsung and Lenovo); large contract manufacturers that make products and sometimes provide design services for lead firms (such as Foxconn and Flex); and platform leaders, which are companies (such as Intel and Microsoft) that have successfully implanted their propriety technology (hardware, software or a combination) in the products of other companies in industries such as personal computers, mobile phones, and a few industries unrelated to electronics such as bicycles (Sturgeon and Kawakami, 2011: 124-129). Platform leaders often capture a large share of industry profits and influence the innovative trajectory of global lead firms by unilaterally determining the "pinch points" in modular GVCs such as the personal computer industry.

Consumer electronics are price sensitive, and the center of gravity for manufacturing in this industry has been in Asia since the rise of offshore manufacturing. Asia's share of 3C (computers, consumer electronics and communication device) final products, subassemblies and electronic components exports increased from 51 per cent to 73 per cent between 2000 and 2015. In all three segments, the increase was driven by East Asian countries, particularly China. This has been at the expense of exports from Europe across all three segments, and from North America in intermediates (subassemblies and components) (Frederick & Lee, 2017).

Costa Rica: Given that one firm dominates investment in Costa Rica's electronics sector, the country's development is highly dependent on that firm's strategy. Intel invested in Costa Rica in 1998 to assemble and test integrated circuits. In 2000, the company began to add services to the activities it conducted in Costa Rica. It started with manufacturing-related engineering services for Latin American clients[3] and expanded into back-office services such as finance and purchasing. In 2006, Intel added procurement and technical assistance service operations, followed by more R&D service jobs (300 engineers) for global operations in 2011. In 2015, Intel restructured its service activities in Costa Rica to establish two "centers of excellence": a Global Services Center and an R&D Center.

In manufacturing, Intel continued to expand its base in Costa Rica throughout the 2000s, adding a second A&T line in 2004. However, the company began investing in manufacturing facilities in Asia in 2005. Between 2005 and 2010, Intel opened three plants in China and one in Viet Nam, while manufacturing employment in Costa Rica declined. In 2014, Intel announced it was closing electronics manufacturing in Costa Rica (ICS News, 2014) and moving to Viet Nam (figure 2). The 1,500 workers employed in Intel's assembly plant were laid off, and new workers were hired as engineers and technicians.

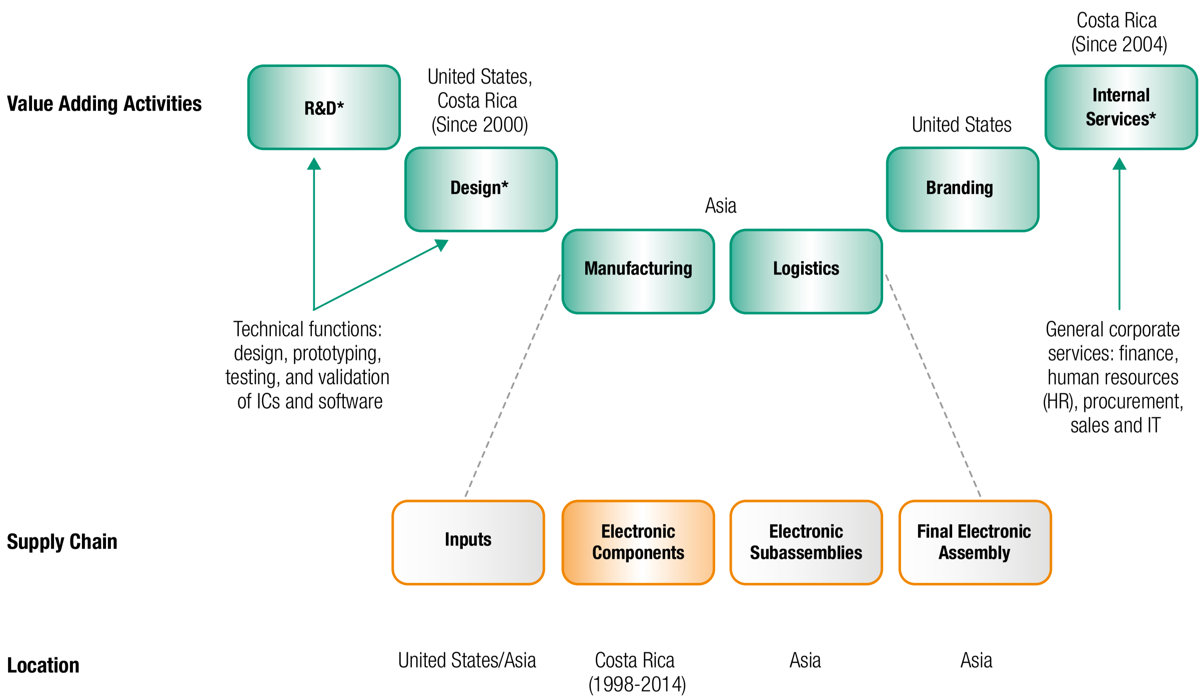
Figure 2. Intel timeline (Primarily in Costa Rica but also key events in Asia)



Source: Authors.

[3] Intel's Latin America Engineering Services (LAES) Group provided jobs for 100 engineers for global engineering support in circuit design and validation, and for 40 engineers to design enabling code for microprocessors.

Figure 3. Activities in the electronics global value chain and Costa Rica's shift from manufacturing to services (1998–2015)



Source: Authors.
* Higher wages and education levels than manufacturing.

b. Local agglomeration effects

Over the course of its investment in Costa Rica, Intel made few direct local linkages. Because of their large scale and demanding technological requirements, platform leaders such as Intel typically work with well-established global contract manufacturers on a “follow-sourcing” basis, rather than seeking inputs from local suppliers. Furthermore, Intel’s upstream location in the electronics GVC severely constrains the potential for backward linkages, since the natural resources and silicon wafers used in semiconductors are available from only a few locations in the world. Thus, Intel’s primary contribution to Costa Rica’s economy from the outset was going to be its high volume of exports, which indeed had an immediate and sustained impact on Costa Rica’s total exports, as shown in figure 1. However, Costa Rica was unable to maintain its cost competitiveness relative to Asia in the cost- and scale-driven electronics components sector, and electronic exports in Costa Rica collapsed after Intel closed its A&T plant.

c. Upgrading, knowledge transfer and local institutions

Overall employment by Intel in Costa Rica declined after the plant closure in 2014, but wages increased significantly owing to a shift in the composition of the company’s workforce. Manufacturing workers (entry-level technicians) were replaced by an increase in IT-related positions (programmers, developers and engineers). After the closure of the A&T facility, the IT-related share of the company’s workforce rose from 13 to 28 per cent, while production operations fell from 37 to 5 per cent.[4] Intel’s new workers typically have a three- to four-year college degree. Approximately 80 per cent are recent graduates, with the remaining 20 per cent hired from other companies with experience. In 2014, the average salary of electronics[5] FTZ workers in Costa Rica was US$27,800 per year; this was significantly higher than the average wage of all FTZ workers (US$19,000) and the average for the overall economy (US$9,200). Although there has been no formal study of where the laid-off workers went, it is believed most were easily absorbed by other companies in Costa Rica’s FTZs, specifically life sciences.

Intel’s operations in Costa Rica generated better sources of employment over time, evidenced by the increase in domestic value-added as the company shifted from manufacturing to services. In 2013, when Intel was still engaged in manufacturing, for each dollar Intel produced and sold outside the country, only 18 cents stayed in the country in the form of payments for the factors of production and inputs produced by Costa Rican companies. By 2016, when the company was solely focused on services, this increased to 44 cents (Monge-González, 2017).

[4] Estimated from firm-level interviews.
[5] This is a proxy for Intel’s wages. Monge-González (2017: 18) provides similar findings.

Costa Rica's entry into R&D services was through Intel's original investment in electronics manufacturing (figure 3). As such, this single MNE has had a significant impact on Costa Rica's development. Intel trained some workers for higher-wage service-level positions, while others employed in the A&T assembly plant acquired skills that were easily transferable to other formal work environments. Intel's transition from manufacturing to services in Costa Rica has made the company a leader in bringing higher-skill and better-wage service jobs into the country. As Costa Rica's wage levels are too high to be competitive in the manufacturing segment of price-sensitive consumer goods markets such as those for electronics or apparel, the Intel case is instructive. It shows that a developing economy such as Costa Rica can transition from high-tech manufacturing into high-value services *in the same industry* if GVC lead firms involved in manufacturing can supplement their production activities with relatively high-value service jobs that increase both skills and wages in the local workforce. Indeed, because of the dramatic change in the composition of Intel's operations in Costa Rica in 2014, the company is no longer considered an electronics manufacturer, but an R&D services firm.[6]

While exports of electronics declined, R&D service exports increased. In 2015, Costa Rica's R&D service exports amounted to US$124.8 million, of which Intel accounted for 60 per cent (Monge-González, 2017: 22). Intel's new operations demonstrate to other MNEs that the country is a good location for R&D operations in the same way it showed efficiency-seeking MNEs that the country was a suitable location for manufacturing. Intel's decision to invest in services put Costa Rica on the map as a potential destination for firms across multiple industries; thus, it had an important demonstration effect that led to increased FDI. IBM and HP established service divisions in Costa Rica in 2004, and Amazon did the same in 2008; each has more than 1,000 employees in Costa Rica, with HP employing over 6,000 (CINDE, 2012).

4.2 Costa Rica in the medical devices GVC

The medical devices industry has become Costa Rica's largest and most dynamic high-tech export cluster. It has succeeded in improving the quality and increasing the quantity of its exports over time, with different strengths and limitations in upgrading than those in the electronics industry. The sector has demonstrated more

[6] The case of Intel and electronics in Costa Rica illustrates the deficiencies of national industrial statistics in distinguishing industry-specific services from "service industries" and thus measuring industry-specific upgrading without tracing firm-level data over time. When a firm engages in functional upgrading by moving from manufacturing to services, its activities are reclassified from electronics to a generic service industry that is not affiliated with the manufacturing industry (Frederick, 2014).

traditional upgrading patterns, with participation diversified across a large number of MNEs focused on multiple end-markets. This diverse base has facilitated the establishment of forward linkages in supplier operations with economies of scope.

a. Governance and global firm strategy in the medical devices sector

The medical devices GVC until recently has been characterized by vertical integration with relatively low degrees of outsourcing and offshoring. The majority of lead firms in the GVC operate as OBM firms (Bamber & Gereffi, 2013), due to the substantial investment required in developing new products and thus the need to protect intellectual property, together with the very strict regulatory environment in the sector. Given heightened awareness of product safety and quality concerns globally, these factors have led to increased concentration in the industry, with few firms able to sustain the significant investment costs while simultaneously maintaining strong global production and marketing. As a result, lead firms in the GVC are large, diverse and from developed-country markets, such as Koninklijke Philips (Netherlands), Becton Dickinson (United States), Baxter (United States), Boston Scientific (United States) and Medtronic (Ireland). These dynamics make it very difficult for new firms to emerge in the sector and increase the scale requirements for the industry's global suppliers.

The medical devices sector has been slower than the electronics sector to offshore operations in order to take advantage of lower-cost locations. Where it has done so, offshoring has been concentrated in a limited number of countries where firms can ensure quality, regulatory compliance and intellectual property protection. These include Costa Rica, the Dominican Republic, Ireland, Mexico, and Singapore. In many of these locations, special export-processing zones provide an additional layer of security for firms.

Medical devices products vary in their technological complexity and their capital and labor intensity in manufacturing. They differ in the degree of oversight and protection required by brands, and their offshoring has been uneven. Medical devices can be placed in four key product categories:

- *Disposables*: single use-products, such as catheters, tubing and syringes, which are cost-driven and subject to less stringent regulatory requirements. Their production was the first to be offshored.
- *Medical instruments*: multi-use products, such as forceps and surgical scissors, that are sterilized between uses with different patients.
- *Therapeutic devices*: highly diverse products that may be inserted in the human body (e.g., orthopedic implants, pacemakers and hearing aids), which are subject to very high levels of international health and safety regulation and quality standards.

- *Capital equipment*: large, long-term investments for complex, single-purchase machines that can be used repeatedly over the years, such as magnetic resonance imaging (MRI) equipment. Comparatively little offshoring of final production has occurred in these industries.

Offshoring of products to specific locations tends to be a long-term investment. Because of regulatory compliance requirements and technological complexity, and the importance of supply continuity in the life-sustaining industry, product transfers and production site shifts can be lengthy (up to 18 months). Training for some complex products can take up to six months before line operators reach full productivity. As a result of these factors, relocations have consisted primarily of movements in initial outsourcing to new offshore locations; once investments are made, they are stable over time. These characteristics indicate greater sustainability for including sector-based investment as part of an economic development strategy. Costa Rica, which offers a stable economy close to the headquarters of many of these lead firms, has benefited from these characteristics.

b. Local industrial agglomeration effects

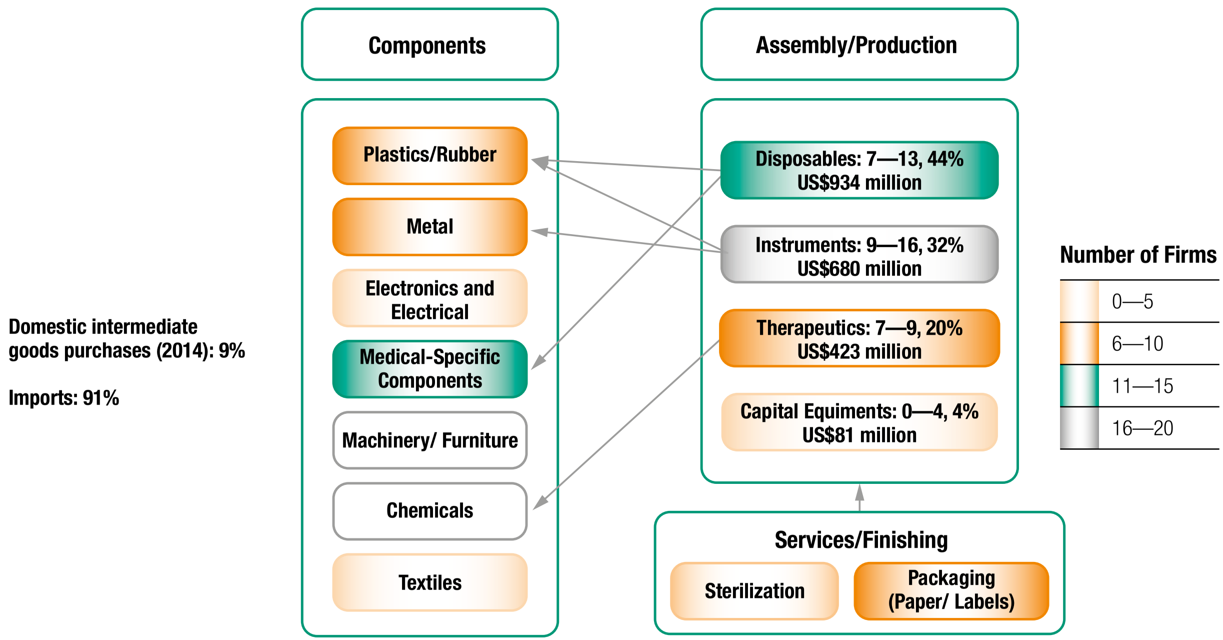
The Costa Rican medical devices sector consists of a consolidating base of foreign manufacturers that offer increasingly sophisticated products. The local industry dates to 1985, when the first device companies – Baxter Healthcare and Abbott – established operations in the country. By 2015, medical devices exports had reached US$2.1 billion (22 per cent of total exports), the largest export sector in Costa Rica (UN Comtrade, 2017).[7] In 2012, about 50 firms participated directly in the value chain, with an additional 16 companies providing packaging and support services. Over half (60 per cent) of these firms were from the United States and less than 30 per cent were Costa Rican[8] (Bamber and Gereffi, 2013: 33).

By coding the activities of these firms and categorizing their output as intermediate and final products, we found that these companies are concentrated in the production segments of the value chain, with 70 per cent of them manufacturing components or assembling final goods. Product exports are concentrated in two categories: disposables (44 per cent) and instruments (32 per cent) (as of 2015). Figure 4 uses these details to illustrate Costa Rica's participation in the medical devices GVC with the degree of shading illustrating the number of firms in the sector at each stage of the chain in 2015.

The earliest investors arrived in the late 1980s, but rapid growth did not occur in the sector until the 2000s. Between 2000 and 2015, export performance

[7] This is due to sector growth, as well as to the closure of Intel's plant in 2014.
[8] The remaining firms came from five economies: Colombia, Germany, Ireland, Japan and Puerto Rico.

Figure 4. Costa Rica in the medical devices global value chain



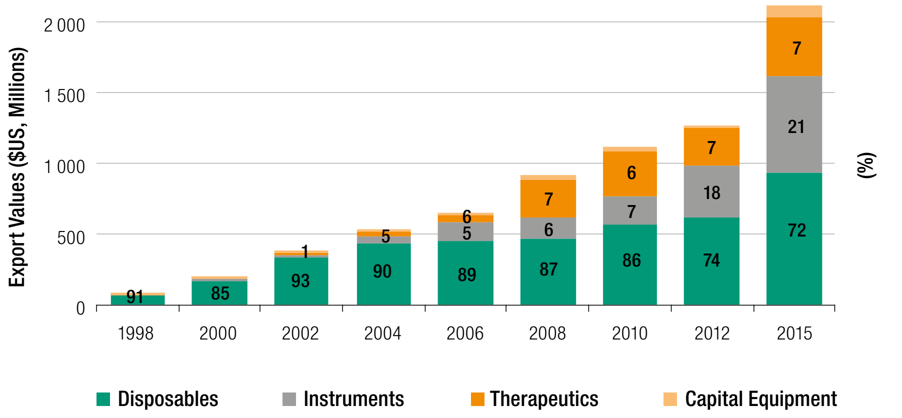
Sources: Imports and exports (2014) of medical devices (AE080) companies (28 establishments). UN Comtrade export data. Costa Rica SUT 2014. Firm interviews, 2012. For the HS product codes used for the four main export categories, see Table A-1. For more detail on the methodology, see Frederick (2017).

Note: Components data: From top to bottom based on share of purchases for medical devices overall; shading based on capabilities. Arrows show top inputs by product category.
Assembly/Production data: Numbers of exporters with >50% of exports in category and number of firms with capabilities, but not a majority (<50% of exports); category shares of exports; export value as of 2015.

underwent very steady and significant expansion in overall value, from just under US$400 million in 2002 to over US$2 billion in 2015. This increase derived from product and functional upgrading, as well as market diversification, as global firms gained confidence in the ability of their Costa Rican subsidiaries to meet the quality and regulatory requirements of multiple markets. There was both an expansion of exports of early products and a shift in export composition in terms of technological content (figure 5). In 2002, about 90 per cent of medical device exports were in the low-tech disposables category, but by 2015, the other three higher-tech categories accounted for 56 per cent of exports. This changing composition shows that Costa Rica was moving toward product categories of higher technological content (*product upgrading*). At the same time, the value-added content of exports continued to rise, increasing by 32 per cent between 2012 and 2015 alone, illustrating that a broader set of activities was being undertaken in-country (*functional upgrading*). Simultaneously, Costa Rica diversified its export destinations. In 2005, 93 per cent of exports were to the United States, while in 2015 this had dropped to 72 per cent as exports to Europe and Japan increased.

With few pre-existing local firms, this growth and upgrading was the result of FDI, supported by considerable efforts on the part of CINDE as well as by Costa Rican investment incentives. Between 2000 and 2014, a series of large GVC lead firms,

Figure 5. Costa Rica's medical exports by product category: 1998–2015
(Millions of dollars and per cent)



Source: UN Comtrade (2017).

including Boston Scientific, St. Jude Medical and Covidien (Medtronic), established "efficiency-seeking" export-oriented manufacturing plants in the country. Figure 6 disaggregates these investors into four waves: pre-2000, 2001–2004, 2005–2008, and 2009–2014. A very clear pattern of FDI succession emerges that underpins the technological upgrading of Costa Rica's exports: the companies that invested pre-2000 were predominantly in the low-tech, cost-driven disposables category. In each successive period, companies with higher-level technology entered Costa Rica. In addition, several established firms continued to expand their capabilities through reinvestments. Each wave of investment appeared to build on the last. During interviews, when asked why companies came to Costa Rica, managers repeatedly emphasized that they were encouraged by the positive experiences of the earlier investors. This mirrors the demonstration effects of Intel's investments in the electronics sector.

Local sourcing is low but growing; in 2014, approximately 9 per cent of intermediate goods inputs were purchased within Costa Rica, up from only 6 per cent in 2012.[9] The relatively low amount is due primarily to global supply chain limitations caused by scale and regulations; local MNE plants have little flexibility to source locally and as of 2012, there was only one Costa Rican OEM supplier. Any local sourcing is predominantly from foreign suppliers, and the presence of domestic Costa Rican firms in the industry remains limited. Domestic sourcing is concentrated in activities with economies of scope, which has allowed foreign suppliers to address the demands of the diverse range of medical device manufacturers in the country. In particular, these suppliers were concentrated in forward linkages in packaging and sterilization activities, supporting the distribution-based activities for final assembled products.

[9] Based on the Supply and Use Table (SUT) for 2014, intermediate purchases of medical device companies were worth US$1.3 billion, of which 64 per cent were goods and 36 per cent were services. Services are primarily royalties (20 per cent) followed by administrative office services (4.5 per cent). Top material purchases were plastic and/or rubber products (42 per cent), metal (22 per cent), electronics and electrical inputs (14 per cent), and medical-specific inputs (13 per cent). The United States accounts for approximately three-quarters of imports.

Figure 6. Firms in Costa Rica's medical devices sector, pre-2000 to 2014

Entry Year	Firm Characteristics	Main Product Category	Core Market Segments	Product Examples (FDA Class)	Select OEMs
Up to 2000 24 firms: 9 US 14 CR 1 German	6 OEMs 8 Components 1 Input distributor 7 Packaging 1 Finishing 3 Support services	Disposables	Drug delivery Women's health	Intravenous tubing (I) Mastectomy bras (I)	Baxter Hospira Amoena
2001–2004 13 firms: 9 US 3 CR 1 Colombia	4 OEMs 5 Components 1 Finishing 1 Logistics 2 Support services	Instruments	Endoscopic surgery	Biopsy forceps (II)	Arthrocare (Smith & Nephew) Boston Scientific
2005–2008 8 firms: 7 US 1 Puerto Rico	2 OEMs 4 Components 1 Packaging 1 Finishing	Therapeutics	Cosmetic surgery Women's health	Breast implants (III) Minimally invasive surgical devices (II)	Allergan Horizon
2009–2014 24 firms: 18 US 1 CR 2 Ireland 1 Japan 2 JVs (US-CR)	12 OEMs 7 Components 1 Input distributor 2 Sterilization 2 Packaging	Disposables Instruments Therapeutics	Cardiovascular drug delivery	Heart valves (III) Dialysis catheters (III) Guide wires (III) Compression socks (I)	Abbott Vascular St. Jude Moog Covidien Volcano Corp.

Source: Authors; updated from Bamber and Gereffi (2013).

c. Upgrading, knowledge transfer and local institutions

The upgrading patterns described earlier indicate that strong growth combined with increased capability development was the result of agglomerations of FDI leveraging Costa Rica as one of a few offshore production platforms. Costa Rica's ability to harness this FDI reflects (1) the country's human capital base, in particular, the capabilities of Costa Rican managers, as well as skills upgrading by Costa Rican employees; and (2) considerable efforts by CINDE, COMEX (Ministry of Trade) and other institutional actors to facilitate export-oriented investor operations. These two factors were continuously ranked by interviewees as very important to investment decisions.

The medical devices industry relies on a relatively small but highly skilled workforce. In Costa Rica, growth created some 17,500 manufacturing jobs between 2000 and 2015. By 2012, 10–20 per cent of the workforce was comprised of engineers and 10-15 per cent of technicians. The remaining 60–80 per cent of direct production workers initially drew from the unskilled labor pool that had served the apparel sector. However, even these positions have begun to require a minimum of technical high school education, i.e., nine years primary and secondary education followed by three years of technical education. Management draws heavily from former Intel employees, and by 2012, the majority of foreign-owned plants were managed by Costa Ricans. Several interviewees suggested that this factor further contributed to the willingness among MNE subsidiaries to work with local authorities to overcome challenges. Overall, based on analysis of the interviews, there were very few foreign workers on staff in any MNEs located in Costa Rica.

The shift to a more diversified and sophisticated product portfolio was accompanied by a shift to more highly skilled and better paid jobs. The higher qualifications in the labor pool helped to raise average wages. In 2015, the average annual salary in firms that were primarily exporting disposables was US$12,448, compared with US$13,986 in those primarily exporting medical instruments, and US$14,687 in those primarily exporting therapeutic devices. Average salaries in all categories of firms exporting medical devices were higher than those for the total economy, at approximately US$9,748 (Central Bank of Costa Rica, 2016). According to interviewees, finding qualified human capital is the biggest challenge for firms aiming to continue to increase output and expand to new markets; consequently, local educational institutions have been receptive to providing industry-specific training. Examples include the development of an introductory course for medical devices regulation for operators by the National Technical Institute; a six-month international training program for packaging technicians; and a postgraduate degree in regulatory affairs at the Costa Rica Institute of Technology.

The second key dynamic that facilitated firm upgrading in the sector was the identification by lead firms themselves of critical "GVC gaps" in Costa Rica's technical capabilities, which was followed by targeted FDI recruitment efforts by national development institutions (CINDE and COMEX). One example is the co-location in 2009 and 2012 of two sterilization plants in Costa Rica, which allowed for market diversification through direct exports. This occurred after a critical mass of MNEs pointed out the value-adding advantages for the medical devices sector of creating this forward-linkage capability. CINDE's post-arrival services for investors created an environment that contributed to inter-firm collaboration. Finally, spatial clustering of the firms in a small number of industrial parks created an additional layer of institutional support for the industry. These parks facilitated collaboration among park members to overcome constraints.

5. Discussion

Costa Rica has demonstrated substantial progress on various metrics of upgrading in the electronics and medical devices GVCs, but the results remain uneven (see table 2). In terms of export competitiveness, the quantity (volume) of Costa Rica's exports increased significantly in both sectors, but the quality (technological content) rose most visibly in medical devices. In terms of local linkages, the backward linkages for medical devices have increased only modestly (from 6 per cent to 9 per cent between 2012 and 2014), and in electronics they remain negligible. Changes in the skills and wages in the workforce are relatively high in both sectors, but electronics, led by Intel, was clearly the pacesetter, with an average annual compensation of nearly US$40,000 in 2014 (compared with US$18,300 in medical devices).

We summarize our findings by highlighting the impact of the five main determinants of FDI-generated spillovers mentioned earlier.

Industrial Policy: Costa Rica's decision to attract high-tech FDI in the 1990s and 2000s was successful due to a combination of factors: political and macroeconomic stability; legacy investments in education and infrastructure from past development policies; proximity to the U.S. market; Costa Rica's FTZ regime, which offers very beneficial conditions to MNE investors; and supportive institutions such as CINDE and COMEX that have proven very effective in targeting FDI promotion. Nonetheless, the success of this investment strategy in the electronics and the medical device GVCs differs: electronics was dominated by a single company, Intel, involving neither local suppliers nor other major MNE investors, whereas the medical devices GVC has a large number of MNE subsidiaries in diverse product categories.

GVC Characteristics: Electronic components is a very scale-intensive and cost-driven sector, which is concentrated in a few Asian countries (e.g., China and Viet Nam). Thus, as a small country with comparatively high minimum-wage levels that is located far from the Asian production network, Costa Rica has virtually no

Table 2. Upgrading metrics in the electronics and medical devices sectors

Type of Upgrading		Medical Devices			Electronics		
		2012	2014	2015	2012	2014	2015
Overall GVC Performance	Gross Output (US$, Millions)	1,397	1,798	2,066	697	456	134
	Value Added (US$, Millions)	537	666	711	475	344	60
	Exports (US$, Billions)	1.3	1.7	2.1	2.3	2.0	0.3
	Contribution to Total GDP (All)	1.30%	1.50%	1.40%	1.10%	0.70%	0.10%
	Number of Firms	23	28	35	14	14	12
Product Upgrading	Share of Exports by Product Category	D: 49% I: 29% T: 21% CE: 1%	--	D: 44% I: 32% T: 20% CE: 4%	--	--	--
Backward Linkages (Products)	Share of Goods Sourced Domestically	6%	9%	--	1%	2%	--
Social (1)	Total Employment	11,882	13,940	16,290	4,475	4,329	1,758
Social (2)	Avg. Total Compensation/ Emp. (US$)	17,488	18,324	18,891	34,389	39,603	17,098
Definitions		AE080			AE074-75		

Sources: Imports and exports (2014) of medical device and electronics companies. UN Comtrade export data. Costa Rica SUT 2014.
Note: In 2015, the average total compensation per employee for all firms was US$11,365 (the average salary per employee was US$9,748). Values in table are for special regime and free zone companies.
D: Disposables, I: Instruments, T: Therapeutics, CE: Capital Equipment

chance to remain competitive in the A&T stage of this industry. Medical devices, by contrast, is a much more diversified sector driven by quality and regulatory compliance, in which proximity to the leading global market (the United States), economic and political stability, and intellectual property protection are prized. This allows Costa Rica to leverage capability development and institutional strengths, rather than scale, in specific segments to drive growth.

Strategies of GVC Lead Firms: A critical contribution of our study is its exploration of how the strategies of GVC lead firms created upgrading opportunities within Costa Rica. This topic was largely ignored by the previous studies of Costa Rica's high-tech upgrading, which instead focused on collecting social network data within clusters to identify knowledge linkages with domestic and foreign firms (Giuliani, 2008; Ciravegna and Giuliani, 2007). Intel's decision to set up an A&T plant was critical to the country's early success, but its decision to close this plant in 2014 eliminated this exporting option. More important for the long term, however, may have been Intel's strategy since the early 2000s of setting up and expanding engineering and R&D service centers in Costa Rica, which contributed to the growth of service exports and employment in the country. As in medical devices, competitiveness in this services niche is based on skill rather than scale.

Similarly, the strategies of GVC lead firms appear to be key for explaining the upgrading trajectory in the medical devices GVC. The technology-upgrading pattern shown in figures 5 and 6 came about in large measure because GVC lead firms were talking to one another and their headquarters about why Costa Rica was a good place to invest and expand their operations over time.

Position in GVCs: Costa Rica occupied different structural positions in these two GVCs that shaped its upgrading outcomes in both goods and services. In electronics, the possibilities for backward linkages were quite limited because the inputs to semiconductors are few and upstream segments are typically capital- and technology-intensive. However, the flourishing of service-sector employment in electronics showed great potential for knowledge-intensive linkages with Intel. In medical devices, exports from Costa Rica were finished products rather than intermediate goods. The diversity of medical device market segments that Costa Rica operates in opened more possibilities for technology transfers and knowledge spillovers. In addition, the number and diversity of MNE investors created more opportunities within Costa Rica to upgrade and move up the technology ladder across market segments, and to fill value chain gaps with relatively high-value manufacturing-related services, such as product sterilization.

Absorptive Capacity of Host Country: The country's political stability, rule of law, bureaucratic probity and highly skilled workforce are all advantages in attracting FDI. Equally important for the electronics and medical devices GVCs are the institutional coordination between CINDE and COMEX in implementing the country's industrial policy and attracting the right kind of FDI to support export-oriented growth. This inter-agency cooperation is a selling point across industries, and it can facilitate more extensive forms of public-private sector coordination in the future.

6. Conclusions: considerations for policy development

Promoting economic development through transnational knowledge networks is a challenge for all countries, but it is particularly important for small economies in high-tech, exported-oriented sectors. Our comparison of the electronics and medical devices GVCs in Costa Rica reveals important differences in terms of technology spillovers, even though both sectors are part of Costa Rica's high-tech upgrading strategy. The gains in electronics were very significant in one area – volume of manufactured exports; however, they were limited because the inputs from local suppliers were restricted to low-value activities associated with the operations of the plant. The disruption caused by the closure of the Intel plant in 2014 led to a large-scale layoff, although the skills of the electronics workforce were relatively high and could be readily absorbed by other export-oriented sectors of the economy. These findings have broader implications for policy development beyond the specific case of Costa Rica and these industries.

Targeted industrial policy can be used to attract investments in particular GVC segments without having in place all of the key elements that are often considered prerequisites. These include a local supplier base, local absorptive capacities and strong linkages with the educational sector. Industry and activity selection, however, have an important effect on the sustainability of investments. Industrial policy oriented towards GVC participation must be based on a thorough understanding of the offshoring drivers of lead firms.

Investment policies supporting functional upgrading and diversification can mitigate shocks caused by changes in lead-firm strategy or by exogenous variables. One of the most striking findings of this study is the key role played by high-value service activities as a complement to high-tech manufacturing in both of Costa Rica's high-tech GVCs. In the electronics sector, the addition of manufacturing-related and other professional services began in the early 2000s, relatively soon after the opening of Intel's assembly plant, but Costa Rica's centrality in Intel's global services strategy expanded considerably after 2014. In the medical devices sector, forward linkages from production into high value-addition services such as product sterilization drove market diversification and opened the door to functional upgrading into sales and distribution channels.

Human capital development policies are key to supporting upgrading; these can be closely linked to the firm. Experienced local management and skilled human capital can increase location attractiveness and drive embeddedness in lieu of (or in addition to) local supplier development. The waves of FDI in the medical devices sector established pipelines to MNE headquarters and other knowledge centers outside of Costa Rica that facilitated the rapid diffusion of new technologies that entered the country during this period (see figure 6). A key conduit between these two worlds were the Costa Rican managers of the MNE subsidiaries in the medical devices GVC, who used their local contacts and knowledge to identify potential suppliers and to reduce institutional barriers.

Finally, services-related upgrading can often be obscured by firm-level statistics. The benefits of FDI in a country can transcend the boundary of what standard statistical categories label as “manufacturing” or “services” activities, as illustrated by the case of Intel. By examining both firm-level and industry-specific dynamics, GVC analysis provides a lens to identify potential outcomes that would go unnoticed if one focused solely on product-specific trade data or industrial statistics. Intel’s entry into the R&D services “industry” and the subsequent increase in the services share of Costa Rica’s GDP was due to functional upgrading by an electronics manufacturing firm. Thus, the future of manufacturing-led development (Hallward-Driemeier and Nayyar, 2018) increasingly may rely on the growth of complementary, but hard to measure, high-value services.

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Appendix

Table A-1. Medical devices product categories by HS codes

Productw Category	Product Examples	HS Codes
Disposables	Needles, syringes, catheters, tubing, IV sets	901831, 901832, 901839
Instruments	Dental instruments, forceps, medical scissors, dialysis devices, defibrillators	901841, 901849 901850 901890
Therapeutics	Artificial body parts, hearing aids, pacemakers, crutches, implants, prosthetics	9021
Capital Equipment	MRI, ultrasound machine, x-rays, patient monitoring systems, blood pressure monitors	901811, 901812, 901813, 901814, 901819, 901820, 9022

Source: Authors.

Table A-2. Electronics GVC definition by HS Codes

Segment	Product Examples	HS Codes
3C Final Products	Consumer Electronics Cell Phones Computers	8469, 8470, 8471, 8472, 8519, 8520, 8521, 8525, 8527, 8528 85181, 85182, 85183, 85184, 85185 85171, 85172, 85173, 85174, 85175, 85176, 85178 90061, 90062, 90063, 90064, 90065 90091, 90092, 90093 844312, 844351, 84433 950410, 950450
Medical Final Products	Capital Equipment	901811, 901812, 901813, 901814, 901819, 901820, 9022, 902140, 902150
Industrial Final Products	Analytical Instruments	8526, 901210, 901410, 901420, 901480, 901600, 902410, 902480, 90271-5, 902780, 90281-3, 90291-2, 90301-4, 90308, 90321-2, 90328
Industrial Subassemblies	Parts of above	901290, 901490, 902490, 902790, 902890, 902990, 903090, 903290
3C Subassemblies	Parts of above	8473, 8522, 8529, 851770, 851790, 85189, 90069, 90099, 844399
Components	ICs	8532, 8533, 8534, 8540, 8541, 8542, 8523, 8524

Source: Frederick (2017). Background reports on the global electronics GVC prepared for the UN Statistics Division and UNIDO.
Note: If only four or five digits are listed, implies all six-digit codes are included.