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Who Profits from Innovation in Global Value Chains? A Study of the iPod and Notebook PCs

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I. Introduction

The power of innovation to create economic value and reward pioneers with exceptional profits is a deeply-held belief of inventors, entrepreneurs, investors and the public. Innovation can enrich companies and individuals and sometimes disrupt entire industries. Yet many studies have shown that the value from innovation is often captured by someone other than the original innovator, whether by imitators, suppliers of key components, intellectual property owners, or providers of related products and services.[1] In an era when new ideas are brought to the market by networks of specialists rather than by one company, a key question is who captures the most value from innovation in such a structure, and why?

Many of the best examples of such a dispersed innovation network are to be found in the electronics industry. For decades, the industry was dominated by large companies like IBM, HP, Toshiba, Fujitsu and Philips that designed and built their own products, often using internally-produced components and proprietary technologies developed in large R&D labs. Even as Silicon Valley-type startups flourished in personal computers, software and semiconductors, the large vertically integrated companies created and captured a large share of the value of innovation in electronics into the 1990s.

Since then, there has been a shift by firms in many industries to focus on core competencies and outsource other activities, creating global production networks or value chains that cross corporate and national boundaries (Dedrick & Kraemer, 1998; Gereffi et al., 2005). In the prominent case of the electronics industry, this has taken the form of modular production networks, in which the interfaces between firms are clearly codified (Sturgeon, 2002).[2] Companies that formerly manufactured most products in-house, as well as start-ups that never had manufacturing capabilities, have outsourced production, and even product development, to turn-key suppliers known as contract manufacturers (CMs) and original design manufacturers (ODMs).

Today, the creation and production of a successful product in one of these global value chains spreads wealth far beyond the lead firm, i.e. the company whose brand appears on the product, and who bears primary responsibility for conceiving, coordinating, and marketing new products. While the lead firm and its shareholders are the main intended beneficiaries of the firm's strategic planning, other beneficiaries include partners in the firm's supply chain. Firms that offer complementary products or services may also benefit, possibly even more than the lead firm.

This paper addresses the question of who benefits financially from innovation in global value chains by looking at specific products. This product-level approach allows us to break out the financial value embedded in an innovative product and clarify how it is distributed across the many participants in the supply chain from design and branding to component manufacturing to

[1] See Mitchell (1991) and Rosenbloom and Christensen (1994) for discussions of how newcomers and industry incumbents fare following the introduction of innovations.

[2] Baldwin and Clark (2000) called these modular clusters, but their work abstracts from the spatial distribution of the activities.

assembly to distribution and sales. We apply a novel methodology for measuring the distribution of value across the supply chains for two models from Apple's iPod family and notebook PC models from Lenovo and Hewlett-Packard (HP). These are all examples of globally innovated products, combining technologies from the U.S., Japan, and other countries. They all are assembled in China, mostly by Taiwanese CMs and ODMs.

Our analysis of these four products shows that the gross margins of Apple for its high-end iPod products are generally higher than those earned by HP and Lenovo for notebook PCs, but not so high as to be considered "supernormal." A key reason for the difference is that Apple's control of the core software, proprietary standards and complementary infrastructure of the iPod enables it to retain greater profits, whereas a large share of the PC industry profits are siphoned off to Microsoft and Intel, whose ownership of valuable standards allows them to charge a considerable price premium. Other "winners" (earners of above-average profits) include suppliers of key logic microchips, while suppliers of other high-value inputs like hard drives and high-resolution displays face severe competition that limits their margins to much lower levels even though they produce two of the highest value components in an iPod or notebook PC.

We consider these results in the context of the theory on profiting from innovation. While the theory is largely confirmed by our research, we also note several distinctions, such as the commoditization of manufacturing. Also, contrary to recent suggestions in the literature, we find no evidence of a causal link between product and industry architectures. Instead, there is a vast electronics "industry architecture" that can easily support product-level value chain configurations ranging from modular to integrated. As posited by Pisano and Teece (2007), a critical capability in this environment is system integration.

We begin by reviewing the literature on profiting from innovation for insights into the basic elements that determine which entities ultimately capture a significant share of the profits from an innovation. These insights frame the analysis and guide the interpretation of results. Subsequent sections describe the framework for measuring and mapping the financial value created along a supply chain (Linden et al., 2007b), apply it to our four products, and analyze the comparative results. Finally, we offer implications of the analysis for firms and managers.

II. Profiting from Innovation

Much of the literature on profiting from innovation builds on Teece's (1986) analytical model and asks "which entities ultimately capture significant shares of the available profits from a particular innovation" (Teece, 2006: 1136). Here we review Teece's model and its implications for capturing value in the electronics industry.

The Teece Model of Profiting from Innovation

Teece's original model has three basic elements: stages of technical evolution, an appropriability regime, and complementary assets. In addition, researchers have identified "industry architecture" as another key strategic variable (Jacobides, et al., 2006; Pisano & Teece, 2007).

The key evolutionary question is whether the market has embraced a *dominant design* (Abernathy & Utterback, 1978; Anderson & Tushman, 1990). In the early stages of an industry, a variety of product solutions may be introduced with no clear leader. Once the market has chosen a winning set of product characteristics (e.g., form factor, function set), less design heterogeneity is possible and competition becomes more price-based. The early phase often amounts to standards-based competition (David & Greenstein, 1990), in which groups of firms promoting alternative offerings in a single product space try to build sufficient market presence to become the dominant standard.[3]

The second issue highlighted by Teece is *appropriability*. Pisano and Teece (2007) discuss the strategic aspects of appropriability regimes such as intellectual property rights and industry standards organizations that can limit competition in a technology segment and protect firm profits.

In cases where innovation is distributed across multiple companies, the most profitable company will be one with control of "one or more of the standards by which the entire information package is assembled" (Morris & Ferguson, 1993: 87). The classic case here is the IBM PC, which became the first widely adopted PC and the dominant design for the industry, but in which more profits were ultimately captured by Intel and Microsoft than IBM.

The third foundational element of the Teece model is *complementarity*. For many electronics products, a key factor is the availability of goods that enable or enhance their functionality. For instance, computers need software, and DVD players need pre-recorded movies. Without one, the other has no value to the user. Complements need not be indispensable, as in the instance of fashionable cases for an iPod. The innovating firms must decide whether to produce the complement itself or to rely on others to do so (Jacobides, et al., 2006).

Complements differ in terms of asset specificity. Generic complements, such as most electronics components, are readily redeployable. Unilaterally specialized complements, such as accessories using the iPod's unique connector, are dependent on the main product, but not vice-versa. Co-specialized complements, such as plastic moulds for unique product enclosures, involve mutual dependence.

The role of complementors has assumed a special place in the innovation literature, because firms today must work with widely distributed innovation networks to bring new ideas to market. Innovators need to coordinate to varying degrees with a large number of allied firms to ensure a supply of complements, while also positioning themselves to capture as much as possible of the value that is created.

The most recent extension of the model is to the overall industry structure, or *architecture*. An industry architecture is defined as a set of technical and social interfaces that provide a framework in which firms in an industry interact (Jacobides et al., 2006). Firms may be able to shape the architecture of their industry by internalizing a vital complementary activity or by supporting competition and innovation among complementors.

[3] In some cases, multiple standards may co-exist in the market after a dominant design (e.g. a product architecture) has become apparent. Examples include the competition between IBM-compatible and Macintosh PCs, or between different video game standards.

This phenomenon of leveraged innovation has been given a variety of names, such as platforms (Gawer & Cusamano, 2002), keystones (Iansiti & Levien, 2004), small footprints (Baldwin & Clark, 2006), and architectural advantage (Jacobides, et al., 2006). In each case, the focal firm is able to realize profits by providing a high-appropriability product or service that becomes a key element of the innovations of other firms. Examples include Intel's processors and Sony's PlayStation consoles.

Applying the Model to the Electronics Industry

Dominant designs, appropriability, complementarity, and industry architectures are all well represented in the electronics industry.

The overarching question facing innovators and their allied firms is how to ensure that they are part of a widely-adopted technology platform so that there is a substantial profits "pie" to share in, while also trying to maximize their share of that pie. No one wants to capture the largest share of a small or disappearing pie, as Sony did with the Betamax but no one wants to capture a declining share of a large pie as happened to IBM, which finally sold its unprofitable PC division in 2004. The Betamax case illustrates the importance of establishing a dominant standard that can generate ongoing profits for the entire innovation network. The IBM case shows that winning a standards battle does not guarantee success if a defensible appropriability regime is not maintained and the innovator loses market power.

Within the electronics industry, market power can be situated almost anywhere in the value chain of a particular product, from upstream component suppliers to branded lead firms, or even to service providers such as mobile phone carriers. Borrus and Zysman (1997) dub this phenomenon "Wintelism" in a nod to the paradigmatic case of Microsoft's Windows software and Intel's processors as the leading profit engines in the PC industry.

The flip side of Wintelism is that most firms even in a successful value chain have little market power. Beyond the elite high-earners, the electronics industry is populated by a vast array of companies whose components and services can serve a variety of end markets, from cheap consumer products to mission-critical medical devices, and who compete aggressively with each other for every design win. The presence of all these competing suppliers allows lead firms to use a multi-sourcing strategy (or the threat of doing so) to drive down price. In its turn, the presence of multiple lead firms with access to the same low-cost supply base leads to fierce competition. On average, there is little difference in the returns earned by systems firms and component suppliers in the electronics industry.[4]

Complementarity is a reality throughout the electronics industry, especially outside the small number of firms, primarily in Japan, that have remained vertically integrated. Systems firms must assemble a partner network for everything from components to distribution and differentiate themselves through design, software, branding, distribution know-how, or other

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[4] Our analysis of financial data for the top 300 electronics firms from 1999 to 2004, as reported in the Electronic Business EB 300 listings from 2000 to 2005 (accessed at http://www.edn.com/), showed the average gross margin for systems firms to be 35 percent versus 33 percent for component suppliers.

means. Component suppliers compete by providing support infrastructure (software, reference design kits, etc.) to speed their customers' products to market.

The architecture literature to date can be difficult to apply in practice because it tends to be vague as to level of analysis. In some cases it seems to encompass an entire industry, in others, just the value chain of a single lead firm. Even the definition of industry is open to interpretation. For example, it is possible to speak of "the electronics industry," "the PC industry," "the notebook PC industry," or "the hard disk drive industry." Each of these is a subset of the one preceding it, but with different dominant firms and different dynamics.

Another confusion in this literature surrounds the relationship between industry architectures and dominant designs. For Pisano and Teece (2007), product architecture leads to industry architecture: "there is a strong connection between the architecture of the industry and the architecture of physical products and technologies. The computer industry evolved from a 'vertical' to a 'horizontal' architecture *because of* the modular technological architecture of the PC" (p.283, emphasis added). For Jacobides, et al. (2006), the causality seems to flow the other way: "Our approach suggests that dominant designs may be the result of particular industry architectures" (footnote 16 on p.1211). We will revisit this issue after presenting our research.

Our research expands the winner-take-all narrative that characterizes much of the profiting from innovation literature by developing a much finer view focused on the "relative" profitability of different participants in the industry value chain. We do this by measuring the distribution of profits from two widely adopted electronics products: notebook computers and portable music players. We use product teardowns to estimate the value captured by the most important firms in the innovation and production networks of each product. We then explain "why" these particular firms capture such value using an industry-level analysis and the profiting from innovation concepts.

III. Methodology: Measuring Who Captures Value in Global Value Chains

In this section, we describe a generic value chain, which we use as the basis for introducing a method of calculating value capture by the companies in the chain.

Value Chain Analysis

Within a value chain, each producer purchases inputs and then adds value, which becomes a cost of the next stage of production. The sum of the value added by everyone in the chain equals the final product price. The natural starting point for estimating these values is a map of a value chain showing the activities (manufacturing, design and branding, and distribution, sales and service) involved in passing from component suppliers to final customers (Figure 1).

Figure 1: Generic Electronics Value Chain

Componen t suppliers → CM/ODM → Brand name vendors → Distributors → Retailers → Customer s

Manufacturing	IP, design, marketing	Distribution, sales, customer service

Although each product incorporates a large number of components (in the case of a notebook computer, thousands), the large majority are low-value parts, such as capacitors and resistors that cost less than a penny each. Although the suppliers of these components earn profits, they account for a small share of the total value added along the value chain, and typically compete with close substitutes, which eliminates the potential for above-normal profits.

Most electronics products also contain a few high-value components, such as a visual display, hard drive or key integrated circuits. These components, which are themselves complicated systems, are the most likely to embody proprietary knowledge that helps to differentiate the final product and to command a commensurately high margin. By virtue of their high cost, these few inputs will usually account for a relatively large share of total value added. Innovation is rapid in these components, and accounts for much of the steady technological improvement in final products such as the iPod or notebook PCs.

These complex components may have their own multinational supply chains. For example, an integrated circuit might be sold by a U.S. company but fabricated by a contractor in Taiwan and encased in its final package in Korea before being shipped to a product assembly plant.

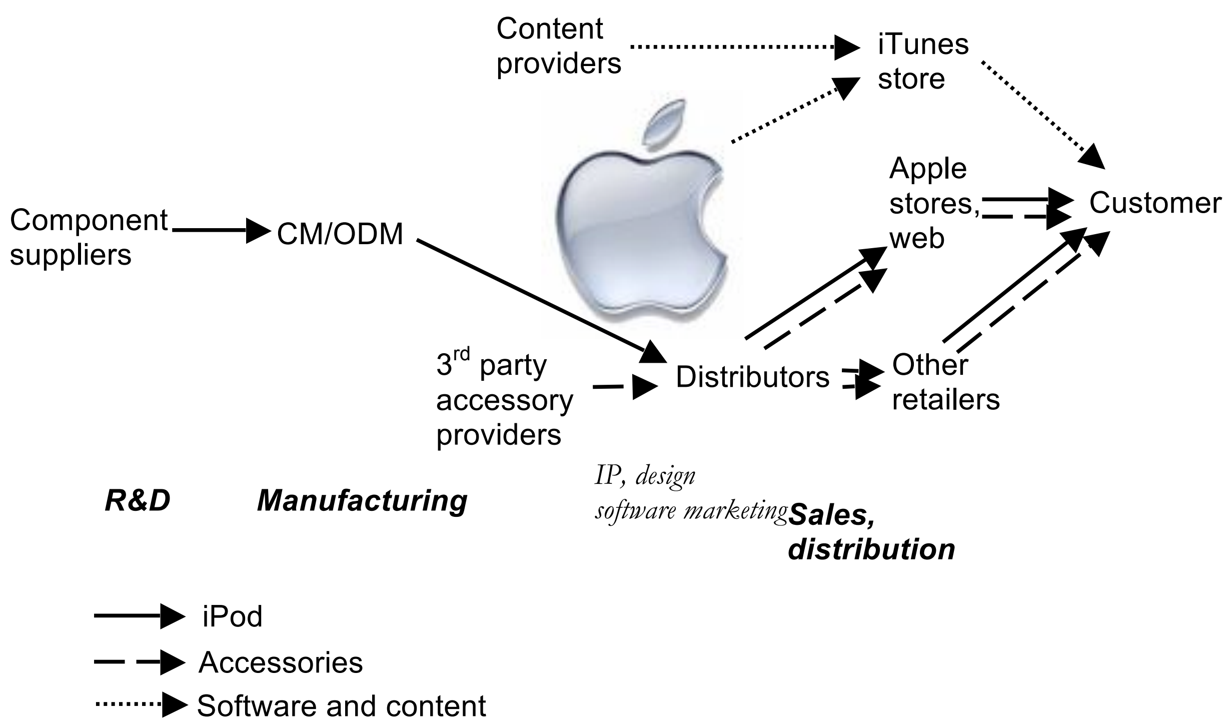
In the case of a non-integrated systems firm like Apple, the manufacture of these components into the final product is done by a number of large multinational contract manufacturers (CMs) or original design manufacturers (ODMs) such as Flextronics, Solectron, Foxconn, Quanta, and Compal who provide assembly services. These assemblers compete fiercely for high-volume opportunities, limiting their margins. Even large vertically integrated manufacturers such as Sony and Toshiba now outsource part of their production to these CMs and ODMs.

Product concept, branding and marketing is done by brand-name vendors. These lead firms contribute market knowledge, intellectual property, system integration and cost management skills, and a brand name whose value reflects its reputation for quality, innovation, and customer service, for good or ill.

Distribution is done by a few global wholesalers such as Arrow, TechData and IngramMicro, and many smaller national or local distributors. Sales are by large retail chains such as Best Buy, Circuit City, and Fry's, as well as by general retailers such as Costco and WalMart, and smaller local dealers. They operate on a fixed margin from the vendor and seek scale and reach, but price competition plus high capital and operating costs keep net margins low. Sales are also handled increasingly by the branded vendors directly online and in cases such as Apple and Sony, through their own stores. The lower cost of direct sales contributes to the lead firm's margins, and own store sales may contribute to cross-selling as well.[5]

Figure 2 expands this generic value chain for the iPod.

Figure 2. Value Chain for an iPod



Using maps like this as a guide, we calculate the value added at various stages of the value chain by estimating the selling price of that stage's output and subtracting the cost of all purchased inputs. The data and method are described fully in another report (Linden et al., 2007a) and briefly described next.

Data Sources and Analytical Approach

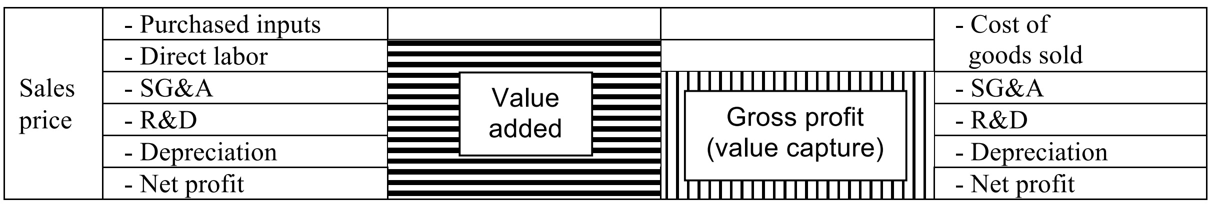
Product-level cost data are extremely hard to obtain directly from electronics firms, who jealously protect information about the pricing deals they have negotiated and often require the silence of their suppliers and contractors through non-disclosure agreements.

For many electronic products, lists of components and their factory prices are available from industry analysts. These "teardown" reports capture the composition of the product at a specific point in time. A teardown report can be used to estimate a product's value added by subtracting the input prices from the wholesale price, which must be estimated with additional research.

[5] Apple's 10-K for the period ending for fiscal year ending September 30, 2006, states: "The Company's direct sales, primarily through its retail and online stores, generally have higher associated profitability than its indirect sales" (p.30).

To estimate the value captured by suppliers, we use firm-level gross profit in dollars. The ideal measure, value added, isn't readily available because publicly-listed companies do not generally reveal the amount of their wages for "direct labor" (workers who are involved in converting inputs to a salable product). Instead, the wage bill is hidden within "cost of goods sold" or "cost of sales." Therefore the number we use, "gross profit," is the difference between "net sales" and "cost of goods sold." Gross profit data are readily available from annual reports in the case of public companies. Figure 3 shows the difference between value added and gross profit. The horizontally-striped area includes the components of value added and the smaller vertically-striped area includes the components of gross profit, or value captured by the firm.

Figure 3. Components of Value Added and Gross Profit



Gross profit does not equal the full value added, since it excludes direct labor. The difference can be large or small, depending on the labor intensity (or outsourcing practices) of the firm. Instead, it measures the value the company (excluding its direct workers) captures from its role in the value chain, which it then can use to reward shareholders (dividends), invest in future growth (R&D), cover the cost of capital depreciation, and pay its overhead expenses (selling, general, and administration).

To estimate market power, we also look at gross margin (gross profit divided by net sales). Market power for a supplier is the ability to charge more than the long-run competitive price level, which is a product's average variable cost.[6] In the economist's ideal "perfectly competitive market," prices are driven to this long-run level so that all firms earn zero economic profits. The accounting profits reported in companies' public financial reports, which we will be using here, do not reflect all costs related to a firm's use of capital, so "normal" accounting profit even in a highly competitive market will be positive even though the corresponding "economic" profit is zero.

To determine whether or not unusually high or low profits are present, we need to compare the returns of individual firms to some "normal" profit margin. To estimate a normal margin, we calculated the average gross margin for 270 of the leading global electronics firms for 2004 as reported in Electronic Business' EB 300 listing, which was 32.8 percent.[7]

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[6] Average variable cost is variable costs (total costs minus fixed costs, or, equivalently, the costs that vary with the level of output) divided by the number of units produced.
[7] http://www.edn.com/article/CA630171.html?partner=eb Japan data were for fiscal year ending in March 2004. 30 firms, mostly Chinese, did not provide "Cost of Sales (% of revenues)" data. The median gross margin for the 270 firms was 28.6 percent, and the collective gross margin (the sum of gross profits divided by the sum of revenues) was 32 percent.

The standard deviation of the gross margin was 19.55 percent, so, assuming a normal distribution, the range of 13.2 to 52.3 percent should cover about two-thirds of the sample, which it does.[8] Gross margins above this range are supernormal, and margins significantly lower are subnormal.

Inside Portable Electronics

Apple's iPod is essentially a portable computer dedicated to media processing. As such, it shares general features with a range of related products, including notebook computers, cell phones, and PDAs. These features include a display, a storage medium, microprocessors, system memory, an input interface, a battery, printed circuit boards (PCBs), a physical enclosure, and software. They all also require assembly services, which are today mostly outsourced.

Using Portelligent teardown reports (Portelligent 2006, 2005b), we compared the key parts in one model of Apple's iPod (30GB Video iPod from 2005) and a Hewlett-Packard notebook computer (nc6230, also from 2005). Table 1 shows how the two systems compare in terms of their key inputs as a percentage of factory cost (the total of the inputs).

Table 1. Comparison of Inputs as Percentage of Factory Cost: 30GB Video iPod and HP nc6230 notebook

	Video iPod	HP nc6230
Software	Not Applicable	12%
Storage	51%	13%
Display	16%	16%
Processors	9%	27%
Assembly	5%	3%
Battery	2%	5%
Memory	4%	4%
PCBs	2%	3%
Enclosure	2%	1%
Input Device(s)[9]	1%	2%
Subtotal for key components	90%	86%
Hundreds of other components	10%	14%
TOTAL	100%	100%
Total Parts	451	2,196

Note: iPod software was developed in-house by Apple so there is no software license fee in the bill of materials.
Source: Authors' calculations

[8] 71 percent of the sample is within one standard deviation of the mean, with nearly the same number of firms above and below that range.
[9] "Input Device(s)" vary by product. For a notebook computer, it is the keyboard and trackpad (or other pointing device). For the iPod, it is the scroll wheel.

One major difference is that software does not figure in Apple's bill of materials. The iPod's software was developed in-house, which spares Apple from paying license or royalty fees on each unit sold. In contrast, software licenses for the operating system and applications are a major part (11 percent for the HP nc6230) of the bill of materials for notebooks.

Another key difference is that the iPod's limited-purpose microprocessors are relatively inexpensive as a share of costs (9 percent) compared to the notebook's general-purpose processor chipset (27 percent). By contrast, the iPod's storage system, a hard-disk drive, accounts for half of the factory cost compared to just 12 percent total in the notebook for the hard disk and DVD drives.

Interestingly, the display module in each system worked out to 16 percent and the assembly services (including component insertion, board test, and final assembly) to 5 percent of the total.[10] The circuit board, enclosures, and means of input account for a relatively small share in each case. The hundreds of other components that occupy supporting roles in the two devices only amount to 11 to 15 percent of the total input cost.

The details for these and two similar products (an earlier-model iPod and a Lenovo ThinkPad) are presented in four tables in the Appendix. These tables show specific parts detail for the hard drive, the display assembly, the processor chips, the battery, and memory chips.

The tables omit details for the PCBs, case, and input devices, as well as a host of smaller parts. Functionally, these parts might be very important for a particular product,[11] but their cost is relatively low. Their inclusion would not materially affect the results we report below.

IV. Findings: Value Capture and Market Power along the Supply Chain

As the component breakdowns above make clear, many companies contribute to every iPod and notebook personal computer (PC). However, the price of the component a company provides does not correspond directly to the value that it captures, which is determined by the supplier's cost of goods.

We use the parts lists in Appendix tables A-1 to A-4 to estimate firm-specific value capture and market power for the iPod and notebook value chains. These estimates are shown in the right-hand column of the Appendix tables.

Our basic procedure for deriving these values uses the gross profit rate of the company that supplies the part for the year the product was manufactured. For a few smaller parts, we have had to make an educated guess about the firm that supplied the part and a representative gross profit rate (marked with asterisks in the tables). These estimates, limited to the batteries in three of the products and the monochrome display in the 2003 iPod, do not materially affect the patterns of value capture discussed below because of the relatively small amounts involved.

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[10] See below for a discussion of how the assembly total was estimated from Portelligent data.
[11] For example, the iPod's case entails design finesse, requires great precision in its manufacture, and is a key part of the Apple brand image, but it's a small proportion (2%) of the bill of materials.

The Video iPod--Illustration and Analysis

We illustrate this approach to estimating value capture using the Video iPod (Appendix Table A-2), starting with the inputs and moving on to the later stages of the value chain.

Inputs

We begin with the hard drive, supplied by Toshiba. The use of company-wide gross profit may be inaccurate for a company like Toshiba that makes a wide range of products, from memory chips to power-generating facilities, but it can suffice for a first approximation. According to Toshiba's income statements, its gross margin for the fiscal year ended March 2006 was 26.5 percent of net sales.[12] As points of comparison, the 2005 gross margins of the two top firms specializing in hard drives, Seagate and Western Digital, were 23.2 percent and 19.1 percent, respectively, confirming that this is a fiercely competitive industry.[13] Using Toshiba's overall gross margin, recognizing that it is on the high side for the hard drive industry, the value captured by Toshiba from the Video iPod is about $20.

The Toshiba drive was a standard part with a standard ATA interface with little leverage despite the fact that Toshiba was the only major producer at the time Apple started up its iPod project (Sherman, 2002). Hitachi brought out a 1.8-inch drive in 2003,[14] but failed to gain much leverage in the market (17 percent market share to Toshiba's 70 percent) and announced in late 2007 that it would discontinue its 1.8-inch line. Although Toshiba's chief rival is exiting, Apple may maintain market power by threatening to eliminate hard drives in all iPod models in favor of the "flash" memory chips used in the iPod's Nano, Shuffle and Touch lines.

Moving to the next-most expensive input, the supplier probably didn't fare much better. The display used in the Video iPod was supplied by Toshiba-Matsushita Display, a joint venture. The estimated factory price was $23.27, and the average gross margin for Toshiba and Matsushita was 28.7 percent, which would translate into $6.68 of captured value.[15]

Although smaller display sizes have tended to be more profitable than notebook and TV displays because there are so many smaller niches for different sizes and resolutions, the segment is still overcrowded, with Korean and Taiwanese entrants pursuing the Japanese market leaders. Toshiba-Matsushita Display saw its market rank fall from second at the beginning of 2005 to third by the end of the year, having been displaced since then by Sanyo-Epson, another Japanese joint venture.[16] Toshiba's Annual Report for the period ending March 2006 described the business environment facing Toshiba-Matsushita Display as "very tough... characterized by rapid price deterioration" (p.26). The corporate gross margins of Sanyo (19 percent), Epson (18

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[12] Gross profit rate calculated from data at http://www.toshiba.co.jp/about/ir/en/finance/pl.htm.

[13] Calculated from Edgar Online data accessed at http://finance.yahoo.com.

[14] "Hitachi Introduces 1.8-Inch Mobile Hard Disk Drive," Hitachi Press Release, January 6, 2003.

[15] Matsushita margin of 31% for fiscal year ended March 2006 calculated from data at http://finance.yahoo.com/q/is?s=mc&annual. Toshiba margin was already discussed in the hard drive analysis.

[16] "Korean suppliers target small-to-medium-size display market, says iSuppli," DigiTimes.com, October 20, 2005 for first-quarter data and "iSuppli: Sharp and Sanyo Epson retain top spots in small- to medium-size LCD market," iSuppli Press Release, July 21, 2006 for fourth quarter data.

percent), and the sector leader, Sharp (23 percent), were even lower than those for Toshiba and Matsushita, so the 28.7 percent used here may be on the high side.

The first inputs where we find some evidence of market power are the two primary microchips from U.S. companies Broadcom and PortalPlayer that control video playback and manage the iPod's functions, respectively. Their gross margins in 2005 were 52.5 percent and 44.8 percent, respectively, leading to an estimate of $6.60 in combined value captured.[17] Broadcom's is high enough to land in the supernormal range (more than one standard deviation from the mean) for the electronics industry.

PortalPlayer, a Silicon Valley start-up founded in 1999, was a key partner in the iPod development process (Sherman, 2002). PortalPlayer provided the main microchip and an accompanying reference design that controlled the iPod's basic functionality, handling critical tasks like digital music processing and the user's database management.[18]

If PortalPlayer had any market power with Apple, it was dissipated by Apple's centrality to PortalPlayer's success. In 2005, Apple's subcontractors for iPod assembly accounted for 93 percent of PortalPlayer's sales.[19] PortalPlayer's above-average gross margin may therefore represent Apple's acknowledgement of its supplier's fragility; 2005 was only PortalPlayer's second year of profitability.

Although there is some short-term co-specialization, Apple is no more than one product revision (about 18 months) from being able to replace even a key supplier like PortalPlayer with acceptable switching costs. This is in fact what happened in 2006 as Apple began designing iPods without PortalPlayer's processors in them. The chip company fell on hard times and was acquired by Nvidia, another chip company (Clarke, 2006).

Broadcom, on the other hand, was a well-established chip supplier by 2005, when Apple selected it to add video playback to the iPod line. Moreover, Broadcom had over a billion dollars in annual revenue and a diverse customer base, so it wasn't dependent on Apple's business. Broadcom's strength lies in its proprietary technologies for designing chips and the efficiency (in terms of power usage, speed, etc.) of the algorithms the chips use to accomplish tasks such as decoding compressed video.

In the case of the lithium-ion battery, Portelligent was not able to identify the supplier, nor were we able to do so through our own research. The market for lithium-ion batteries is dominated by three Japanese companies, Sanyo, Sony, and Matsushita, who collectively account for more than

[17] Gross margins from http://finance.yahoo.com/q/is?s=BRCM&annual and PortalPlayer's 10-K for the year ended December 31, 2005.
[18] A "reference design" is a generic design for a complete system, in this case a portable digital music player, that often includes a menu of features that can be customized according to the wishes of the client, or, as was more likely in this case, that can give some guidance to the client's engineers as they develop their own system using, for example, a PortalPlayer-supplied software development kit.
[19] Portal Player's 10-K for the year ended December 31, 2005.

half the market.[20] Their respective gross margins in the fiscal year ending March 2006 were 18 percent, 31 percent, and 31 percent[21] Because Sanyo's low margin appears to be due to problems in its non-battery lines of business,[22] we assigned a gross margin of 30 percent to the Video iPod battery.

A similar analysis was performed for the three types of memory chips from Samsung (main system memory; 28 percent gross margin), Spansion (non-volatile flash memory for retaining settings between uses; 10 percent gross margin), and Elpida (memory support for the video processor; 24 percent gross margin).[23] The memory chip sector is notoriously volatile because of the difficulty of synchronizing demand and supply. Spansion's gross margin was particularly low because of weak revenue in 2005 as prices for Spansion's NOR-type flash chips plummeted 28 percent in response to excess supply.[24]

There are hundreds more parts in a Video iPod, with a total combined cost of $22.79. Due to lack of space, we will not enumerate the additional parts here. The few that are most likely to earn a supernormal rate of return are some of the specialized microchips and customized mechanical parts such as several connectors that allow the iPod to achieve its tiny dimensions. These margins are impossible to determine by looking at financial statements alone, since the parts are so small relative to the suppliers' total sales.

Manufacturing services

Our estimate of the value captured by suppliers of manufacturing services (the placing of components on circuit boards, board testing, and final product assembly) required a different approach. A fair amount of component insertion and final product assembly of electronics goods is outsourced to specialist suppliers of manufacturing services, especially by U.S. companies.

All iPod manufacturing is outsourced to Taiwanese companies with factories in mainland China. Apple's initial manufacturing partner for the iPod was Taiwan's Inventec Appliances, which continues to handle the hard drive-based iPod models.[25]

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[20] 2002 market data from Institute of Information Technology, Japan, reported in NIST (2006). Subsequent mentions in the press (e.g. Tim Culpan, "Sony Battery Recall to Cause Shortage Until June, Makers Say," Bloomberg.com, October 12, 2006) suggest that this is still the case.

[21] Calculated from data at http://www.hoovers.com/sanyo/--ID__41882,target__financial_information--/free-co-samples-index.xhtml, http://finance.yahoo.com/q/is?s=SNE&annual, and http://finance.yahoo.com/q/is?s=mc&annual.

[22] Based on a review of business segment data in Sanyo Financial Statements: http://www.sanyo.co.jp/ir/e/library/pdf/financialstatements/fs-2006.pdf

[23] 2005 gross margins from http://samsung.com/AboutSAMSUNG/ELECTRONICSGLOBAL/InvestorRelations/FinancialInformation/AnnualFinancialSummary/Income.htm, http://finance.yahoo.com/q/is?s=SPSN&annual (Spansion), and http://investing.businessweek.com/businessweek/research/stocks/financials/financials.asp?symbol=6665.T&dataset=incomeStatement&period=A&currency=US%20Dollar (Elpida).

[24] Spansion 10-K for the year ended December 25, 2005, "Net Sales Comparison for Fiscal 2005 and Fiscal 2004."

[25] Levy (2006), Chapter "Origin."

The reported gross margins of contract manufacturers tend to be small (Inventec Appliance's margin for 2005 was 9 percent[26]), but this is misleading because they carry some of the components in their Cost of Goods Sold. To count them against Inventec's revenue and again as part of Apple's factory cost would constitute double-counting.

As a first approximation, we will treat assembly services, as estimated by Portelligent, as pure profit. Because we are not discussing the profitability of assembly services further, estimating an amount for Inventec's direct costs would not change the analysis that follows.

The actual labor involved in a single iPod is limited and low-paid. Portelligent estimated that the final assembly of this model of iPod required about 10 minutes, and according to reports from Apple when it was defending itself against allegations that one of its subcontractors was abusing workers, the maximum hours per week at the factory were 60 and the minimum monthly wage was about $100, which works out to less than a penny per minute (Kurtenbach, 2006).

As with key components, Apple would incur some switching costs to change manufacturing service providers. However, these costs can be minimized by synchronizing them with a product revision, hence the power in the relationship is once again mostly on Apple's side.

Distribution and retail

Once the product is manufactured, there is still a great deal of value to be captured. The retail price of the 30GB Video iPod at the time of Portelligent's analysis was $299. Based on our research, we estimate a 25 percent wholesale discount for each unit, with 10 percent for distribution and 15 percent for retail for both iPod models.[27]

As with assembly services, we will again assume that payments for distribution and retail are pure profit without any implications for the analysis that follows. Both the distribution and retail sectors are intensely competitive, with small reported margins. However, the incremental cost of shipping or selling a single iPod is quite small, so we have not used a corporate-level margin statistic.

Apple--the residual claimant on value

Applying all these estimates to the retail price, we were able to arrive at an estimate of Apple's gross margin on each 30GB Video iPod sold. Apple is the lead firm in the iPod value chain, incurring costs for R&D, marketing, coordination of the entire value chain, and other overhead costs such as warranty.[28] It is the residual claimant for value capture, as detailed in Table 2, in that it is the only company that bargains with all other actors in the value chain.

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[26] Inventec Appliances Corporation Consolidation Financial Statements December 31, 2005 and 2004.

[27] A gross profit margin of "less than 15 percent" for non-Apple sales is claimed in Damon Darlin, "The iPod Ecosystem," New York Times, February 3, 2006, so Apple's wholesale discount would need to be at least this large. The distribution estimate is from an industry interview. A typical retail and distribution margin for another small consumer product, a $99 digital camera, is 24% (Siu Han and Adam Hwang, "Taiwan ODM/OEM digital camera makers to see more orders from Japan but shrinking net margins in 2008, says Asia Optical," DigiTimes.com, January 17, 2008).

[28] We examined whether warranty expenses were higher for Apple than for the notebook computer companies because of the iPod's full exposure to the consumer market (as opposed to the notebook

Table 2. Derivation of Apple's Gross Margin on 30GB Video iPod

Retail Price	$299	
Distributor Discount (10%)	($30)	
Retailer Discount (15%)	($45)	
Sub-Total (estimated wholesale price)		$224
Factory Cost	($144)	
Remaining Balance (estimated Apple gross profit)		$80
Apple Gross Margin ($80/$224)		36%

Source: Authors' calculations; see text.

Apple's estimated gross profit on these units would be $80, which works out to a gross margin of 36 percent of the $224 estimated wholesale price. As a point of comparison, Apple's reported corporate gross margin for all products in the year ending September 30, 2006 was 29 percent.[29] Apple's corporate number reflects various iPod-related costs such as warranty expenses that are not included in our analysis, and also reflects margins for non-iPod products.

Our $80 estimate of Apple's gross profit is greater than the price of any single input, so it is definitely greater than the value captured by any of its partners. And for sales through Apple's own web or store outlets, it also captures the retailer discount of $45, giving it a gross margin of 56 percent on those units.

Video iPod summary

To summarize the preceding analysis, Apple received a slightly above-average, but still "normal" gross profit of 36%. Only one of its key suppliers, Broadcom, appears to have achieved a gross margin in the supernormal range. Most of the other parts suppliers, including those for the hard drive and the display, probably earned "normal" profits or less. Subnormal profits were likely earned by one or two of the memory chip suppliers, who are among the most readily substitutable of the major inputs. In every relationship with its suppliers, Apple has the greater market power.

Hewlett-Packard Notebook PC

We can similarly dissect the gross margins earned from the Hewlett-Packard notebook computer model nc6230, whose key inputs are detailed in Table A-3. As expected, the leaders are Microsoft and Intel, with supernormal gross margins of 85 percent and 59 percent, respectively. Close behind Intel are other suppliers of logic chips, Broadcom (53 percent), Texas Instruments

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industry's mix of enterprise and consumer customers). Based on published data (http://www.warrantyweek.com/archive/ww20070508.html), Apple's overall warranty expense as a share of sales is lower than that for the major computer manufacturers for the period 2003-2006. We also interviewed a former Apple employee (February 2007), who indicated that, although warranty costs were considered too high in the iPod's early years, return rates were gradually brought to an acceptable level even as sales volume rose substantially.

[29] Calculated from data at http://finance.yahoo.com/q/is?s=AAPL&annual. Gross margin for the preceding year was also 29%.

(48 percent) and Standard Microsystems (46 percent). The supplier of a specialty memory chip, Hynix Semiconductor, also reported an above-average gross margin of 41 percent for the year.

Near-average gross profit rates were reported by suppliers of the optical drive (31 percent), main memory (30 percent), and the battery (30 percent). The lowest, but still near-average, margins were those of the graphics processor supplier, ATI Technologies (28 percent), display supplier Toshiba-Matsushita Display (28 percent), and the hard drive supplier, Fujitsu (26 percent).

Assembly, distribution, and retail services were treated as above, but lower discount rates were used for distribution and retail because a notebook PC is a much more expensive product than an iPod ($1,399 versus $299). Our estimates of notebook computer distribution and retail discounts are 5 percent and 10 percent, respectively. Following these discounts, our estimate of the wholesale price received by Hewlett-Packard is $1,189 against our estimated factory cost of $856. The difference of $333 gives Hewlett-Packard an estimated near-average gross margin of 28 percent. In dollar terms, our estimates for Microsoft and Intel's gross profits are $85 and $121, respectively, so HP earns the largest profit even though it's much lower when expressed in margin terms. The estimated notebook gross margin, which doesn't reflect warranty and other direct expenses, is higher than HP's overall gross margin of 24.3 percent in the fiscal year ending October 31, 2006.

Product Comparisons

Similar estimates of value capture were made for an older model of iPod and a Lenovo ThinkPad. The results are shown in Table 3. The earlier-generation iPod earned a slightly higher margin (40 percent) than the later version (36 percent), while the better-known ThinkPad-branded notebook earned slightly more (30 percent) than the competing Hewlett-Packard model (28%). However, for each pair of products, the margins are so close as to be within the uncertainty range of our estimates.

Table 3. Lead Firm Estimated Gross Margins for Four Products[30]

Product	Retail Price	Estimated Wholesale Price	Estimated Gross Profit	Gross Margin (gross profit as percentage of wholesale price)
30GB 3rd-Generation iPod, 2003	$399	$299	$119	40%
30GB Video iPod, 2005	$299	$224	$80	36%
Lenovo ThinkPad T43, 2005	$1,479	$1,257	$382	30%
Hewlett-Packard nc6230, 2005	$1,399	$1,189	$333	28%

Source: Authors' calculations; see text.

[30] The product-specific gross margins in Table 3 are calculated as described in the text accompanying Table 2. They are different from the gross margins for inputs listed in the Appendix tables, because those are company-wide values from published corporate reports.

Apple's iPod gross margins are generally higher than those for the two notebook models, but these would be partly dissipated by Apple's extra overhead costs.[31] As mentioned above, Apple's in-house software was critical to the iPod's success, but absent from the bill of materials. Apple's internal electrical and mechanical engineering capability, which determine important details like the quality of an audio circuit, the ability to pack components in a limited space, and the materials chosen for the case, add value to the raw components that make an iPod.

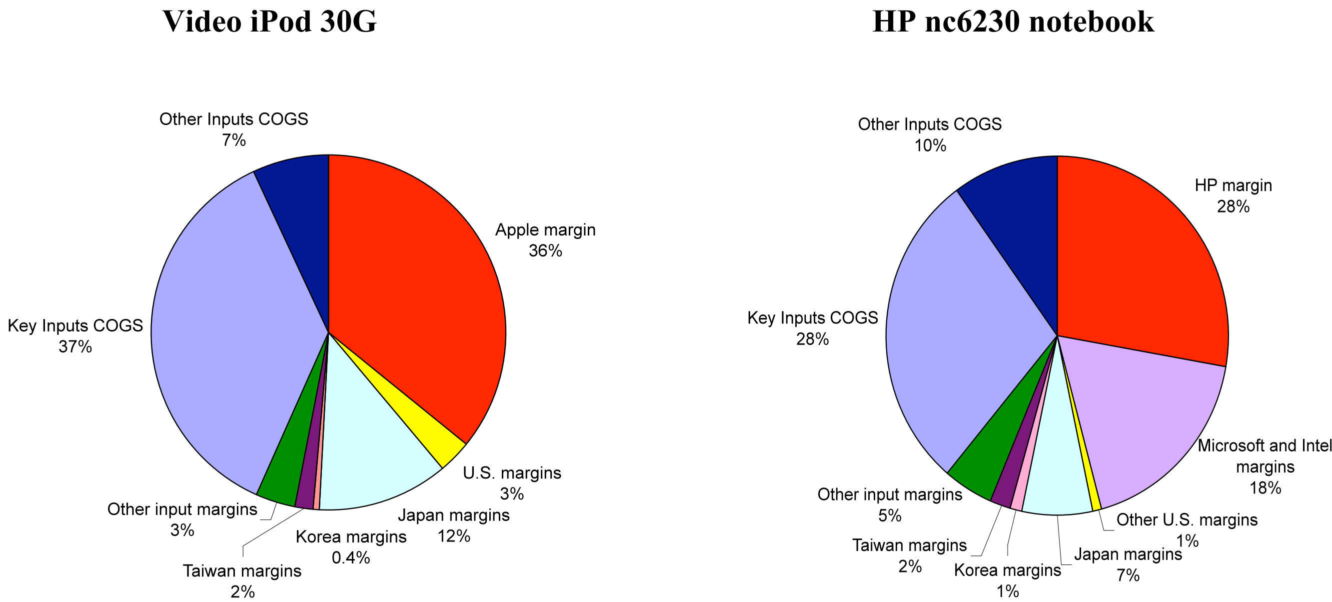
Other lead firms vary in the level of internal engineering capability they maintain. For example, HP relies more on ODMs for development engineering (mechanical and electrical engineering, PCB layout, and software engineering), whereas Lenovo relies more on the internal capability acquired with the IBM PC division (although Lenovo also outsources some models to ODMs). Both have their own design engineering capabilities for the critical task of establishing initial specifications that balance market demand and technology trends.

For the makers of Intel-based computers, it is hard to get around the fundamental economics that siphon off a large share of industry profits to Microsoft and Intel. In the HP nc6230, for example, Intel and Microsoft combined have a gross margin of about 66 percent on components whose value equals about 30 percent of the wholesale price, which means their combined gross profit works out to 20 percent of the wholesale price. Microsoft and Intel's ownership and maintenance of valuable standards (operating system and processor architecture, respectively) allow them to charge a considerable premium for their components while making it harder for systems vendors like HP to differentiate their computers in the market. Network effects that favor these inputs make it hard for computer companies to find alternate suppliers.

If we compare the share of value capture (percent of wholesale price) in the Video iPod to that of the HP nc6230 (Figure 4), we see the following. First, between the lead firms, Apple's share of total value capture is significantly larger than HP's share; second, Microsoft and Intel grab a large share of the gross profits from the PC, leaving less for HP and everyone else in the value chain. We next look at how the iPod's evolution contributed to Apple's greater share of profits, and then explain the differences more generally in terms of the profiting from innovation literature in Section V below.

[31] For the company as a whole, a 29% gross margin for fiscal year 2006 falls to 10% net margin after all expenses.

Figure 4. Value capture in Video iPod and HP notebook as percent of wholesale price



Notes: Margins by country refer to gross margins associated with inputs produced by firms headquartered in that country (regardless of where the inputs were manufactured). COGS is cost of goods sold, including purchased inputs and direct labor.

Evolution and value capture of the iPod

As noted earlier, the iPod is not just a hardware innovation, but an integrated system comprising the iPod product family and closely integrated with its iTunes software and iTunes Store. Apple built up its iPod ecosystem in stages, as acceptance of the product justified additional effort. The initial iPod, introduced in Fall 2001, was integrated with iTunes only on Apple's own Macintosh platform. Two years later, Apple added support for the Windows platform, greatly expanding the available market. None of the technologies behind the iPod or iTunes were controlled exclusively by Apple, but the iPod, like the other music players at that time, was able to take advantage of a huge supply of complementary assets in the form of MP3 music files encoded from CDs or shared by users.

This changed in April 2003 with the introduction of the iTunes Music Store (iTMS) which painstakingly negotiated cooperation from all the major music labels, critical complementors that Apple recognized and courted. The iTMS (now called the iTunes Store) uses an exclusive system of digital rights management called FairPlay, which limits the number of computers on which the purchased tracks can be played. More importantly, FairPlay-encoded tracks will not play back on any portable players other than the iPod or Apple-licensed players such as Motorola's ROKR cell phone, since Apple has chosen not to license the system to other rivals.

The combination of Apple's iPod innovation, the first legal music downloading service with a large library, and its control of the underlying digital rights management system produced a network effect that helped keep the iPod ahead of its many competitors. To take advantage of this opportunity, Apple reportedly spent $200 million on advertising in the iPod's first four years, which was far more than the advertising of its music-player rivals at that time.[32]

The iPod case makes clear how a successful innovation creates the potential for a firm to retain a significant share of profits even when relying on a global network. Apple maintains control over its supply chain by controlling essential elements such as core software, a proprietary standard, and valuable brand image.[33] Table 4 shows how Apple's total gross profit compares to that of other firms in the value chain for sales inside and outside the U.S. According to International Data Corporation (IDC), about 40 percent of hard-drive-based iPod sales are overseas.[34] In the table, the gross margin for "Retail" has been subdivided to reflect our estimate of the share of Apple sales that are made through its website or its growing chain of Apple Stores.[35]

Table 4 shows that Apple, the lead firm in the iPod value chain, fares significantly better than any of its partners. The total value capture discussed so far, $80 for Apple, $75 for distribution and retail, and $39 for key inputs, totals $194.[36] Apple captures 53 percent of the measured value from U.S. sales and 47 percent from sales outside the U.S. – well beyond the 18 percent captured by all suppliers of key parts or the shares for distribution and non-Apple retail. These high shares underscore the importance of innovation and strategic management by a lead firm.

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[32] Levy (2006), Chapter: Cool.
[33] For related theoretical discussions, see Chesbrough and Teece (1996) and Jacobides, et al. (2006).
[34] Estimated from data for 2006 in "Worldwide and U.S. Portable Media Player 2007-2011 Forecast and Analysis, "IDC Report #206016, March 2007.
[35] Apple, as reported in various issues of AppleInsider.com's newsletter, has reported that about half of its overall sales are through direct channels, including its online and physical stores. We assumed this was most relevant for U.S. sales, with international sales being dominated by indirect sales in part due to the limited presence of physical Apple Stores outside the U.S.
[36] We haven't calculated gross margins for hundreds of smaller components costing $23. At the industry-average gross margin of 33 percent, they would add an additional $8 of value capture.

Table 4. The Distribution of $194 of Captured Value in a Single 30GB Video iPod

	Sales in the U.S.		*Sales outside U.S.*	
Value Chain Segment	**Apple**	**All other firms**	**Apple**	**All other firms**
Apple Gross Margin (development, software, marketing)	$80		$80	
Parts Suppliers (key inputs only, Table A-2)		$35		$35
Manufacturing (assembly, test)		$4		$4
Distribution		$30		$30
Retail*	$23	$22	$11	$34
TOTAL VALUE CAPTURE	$103	$91	$91	$103
PERCENT OF TOTAL	53%	47%	47%	53%

*"Retail" is split between Apple and other firms based on our estimate that one-half of all retail sales in the U.S. and one-quarter of all retail sales outside the U.S. are by Apple through its stores and online website.
Source: Authors' calculations; see text.

V. Explaining Why Some Firms Capture More Value

Our data show that lead-firm gross margins for iPods are slightly larger than for notebook computers. Yet the average difference of 9 percent, while noteworthy, is less than half the 19.55 standard deviation of large-firm gross margins reported earlier.

What explains the difference in value capture between iPods and notebooks? And why is it that Intel, Microsoft, and a handful of chip firms capture such high margins?

In order to answer these questions, we look at the different position of these players in the computing industry with respect to the key factors that can determine whether a firm will capture most of the value generated by its own innovative efforts. These include dominant design, appropriability regimes, complementary assets, and industry architecture. In the process, we show the relevance of these factors to the industry, while also providing new insights beyond the previous literature.

Dominant Design

The current physical configuration for notebooks (keyboard, palm rest, and pointing device) was established by Apple in the early 1990s. Since then, almost everyone in the industry has innovated within the dominant physical design and the Wintel standard (except Apple). As Teece (1986: 288) argued, "once a dominant design emerges, competition shifts to price and away from design," while innovation tends to shift to the component level (Anderson & Tushman, 1990; Clark, 1985), and to process innovation, both of which have happened in notebook PCs. This results in incremental innovation, with occasional supplier-generated discontinuities such as 32-bit and 64-bit processing, graphical interfaces, multimedia, and wireless connectivity. Those transitions have been managed by Intel and Microsoft with no threat to their position. This situation has made it very difficult for PC makers to differentiate their products, so competition has driven down their margins.

Apple's ability to innovate at the system level in the newly-emerging market for music players contrasts with the situation facing HP and Lenovo in the notebook PC market. The iPod was introduced before a dominant design was established for small digital music players, giving Apple a great deal of latitude in its design and integration choices. With its success, the highly integrated iPod/iTunes system became a dominant design, to the extent that Microsoft followed its example closely with the Zune after shifting from its more modular, Wintel-like "PlaysForSure" certification program that pushed Windows Media formats.

Appropriability

In PCs, IBM lost control over the key interfaces by the late 1980s, which undermined its ability to appropriate the value of the system design it had created. Microsoft and Intel capture a far larger share of profits than any iPod supplier and also have the highest margins in the PC industry. IBM's business-oriented ThinkPad line, introduced in 1992, was reportedly profitable, but any advantage it brought was unsustainable because of the ability of rivals to duplicate enough of its features over time, and IBM's loss-making PC business was finally sold to Lenovo. By contrast, Microsoft has achieved a very high level of user lock-in to Windows (Shapiro & Varian, 1999), while Intel has used a combination of aggressive IP protection, R&D resources and scale economies to maintain its position in the face of challenges from various competitors over the years. While they have sometimes dallied with other partners (e.g., Microsoft with AMD, Intel with Linux), the two have recognized a common interest in sustaining the two-way monopoly that has enriched both partners.

By contrast, Apple kept control over key elements of the iPod, particularly the user interface, and, as the iPod ecosystem expanded, the interfaces between the iPod, iTunes software and the online iTunes Store. Through this strategy, Apple has been able to capture by far the largest share of profits from its innovation in the iPod. They have so far defended this position through an appropriability regime that includes extreme secrecy, refusing to open up their digital rights management system to others, a carefully crafted brand image, and possession of a great deal of tacit knowledge in the areas of industrial design and user interfaces that others have tried and failed to imitate. Apple also has kept suppliers from gaining any significant market power by maintaining competition and being willing to switch key suppliers from one model to the next, as exemplified by the displacement of PortalPlayer's processors in favor of Samsung's in the most recent iPod models. Few iPod owners are probably even aware of what microchips power their music player, and even fewer care because Apple has maintained the role of "guarantor of quality" (Jacobides, et al., 2006).

Complementary Assets

One aspect of complementarity where Teece's original formulation proved inaccurate is manufacturing. According to Teece (1986), "the notion that the United States can adopt a 'designer role' in international commerce, while letting independent firms in other countries…do the manufacturing, is unlikely to be viable as a long term strategy. This is because profits will accrue primarily to the low cost manufacturers." Yet in our group of products, only China-based Lenovo retains some final assembly, while HP and Apple outsource all manufacturing. While outsourcing is not universal throughout the electronics industry—Motorola and Nokia, for example, retain some final assembly, as do most of the major Japanese electronics companies—for the most part, manufacturing has become a generic complementary asset, in the sense that the manufacturing equipment can be converted from one product line to another with relative ease.

The lead firm and its manufacturing partner may share co-specialized assets to the extent that technologies have been transferred and the manufacturer has set up specific proprietary facilities as a result. But this level of asset specificity is unlikely to keep the partners committed to one another beyond a design cycle (one to two years) should conflict arise or another CM/ODM offer a lower price.

Specialized complements are provided differently in the notebook PC and iPod ecosystems. The specialized assets that are critical to the notebook PC include peripherals such as printers and cameras, expansion cards, and, most importantly, software applications. For the iPod, they include PC software to capture and manage content and transfer it to the device, and various add-ons such as speaker systems or car adapters.

In the mature notebook PC ecosystem, specialized hardware accessories and software programs are developed independently to meet the open PC interface standards. Hardware peripherals have become quite generic, as they mostly rely on standard USB or Firewire interfaces and only need specialized software drivers to run on different operating systems. With the vast majority of PCs running on Windows and Intel-compatible processors, a huge supply of complementary assets is available, generating much of the value to PC owners, and in some cases very high profits to the providers of these assets (e.g., HP printers, Adobe software).

For the iPod, Apple has employed a range of strategies to secure the necessary complements. The software in the iPod and the iTunes client software are developed by Apple internally. Specialized accessories such as speaker systems and car connectors that use Apple's patented iPod connector (for which Apple receives a license fee) are provided mostly by third parties, as are lower-cost (but not necessarily low-margin) accessories such as cases.

Apple's most important complementary asset, content for iPod use, is mostly generic (not iPod-specific) and comes from a variety of sources, only some of which required Apple's involvement. From the outset, consumers' CD collections provided a ready content source that could be encoded as unrestricted MP3s on a computer and transferred to the iPod, free of charge, and Apple provided a free encoder in its iTunes software.[37] The advent of unofficial filesharing services made millions of tracks available free online (albeit illegally).[38] In this case, the unwilling providers of complementary assets made no money directly, although they may receive some promotional benefits for their content.

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[37] Before iTunes, encoding software for the Macintosh needed to be purchased because of the license fee charged by the Fraunhofer Institute for the mp3 compression algorithm. Apple bore the license cost even before the iPod in order to increase the attractiveness of the Macintosh platform.
[38] Apple isn't unique in figuring out how to access free complements. Google figured out how to use the whole Internet to generate advertising revenue.

In addition, Apple provides access to millions of music tracks and other restricted content for paid download through its iTunes Store, with Apple receiving a small share of the profits. Then in 2004, the "podcasting" phenomenon of syndicated free audio content caught on, and Apple began cataloguing the thousands of podcasts in the iTunes Store in 2005.[39]

Another of the iPod's complementary assets, and one that can be too easily overlooked, is Apple's creation of its own brick-and-mortar retail channel. Absent the Apple Stores, the iPod could have been relegated to a couple of shelves in a large retailer without the effective sales efforts and attractive displays of the Apple Store. For the iPod, the Apple Store was a co-specialized asset; the iPod needed such distribution, and the Apple Store needed a hot product to drive traffic in order to succeed. This is consistent with Teece (1986), which pointed to retail distribution as an important complementary asset.

Industry Architecture

As mentioned earlier, the literature on profiting from innovation has searched for causality between industry and product architectures. As we pointed out, some of the confusion in this domain flows from the ambiguity of "industry."

The global electronics industry is frequently cited as the prototype of a modular industry architecture (Baldwin & Clark, 2000; Schilling & Steensma, 2001; Sturgeon, 2002), marked by a high degree of specialization, extensive use of outsourcing, and rapid innovation involving varying degrees of coordination among large numbers of companies to bring new technologies to market.[40] This stands in contrast to industries such as automobiles and aerospace, whose products are more integral and industry structures more vertically aligned. But while it is cited for its modularity, the broad electronics industry architecture is flexible enough to support both modular and integral product architectures.

If we compare notebook PCs to iPods, two iconic electronics products that rely on the same supply base for displays, drives, chips, mechanical parts etc., we see that they are quite different in terms of both product and value chain architectures. Notebook PCs are mostly modular, built on standard interfaces with mostly standard components. By contrast, the iPod is much more integral, both in terms of hardware customization and tight integration of hardware and software. This could mean that product architecture and industry architecture are not as tightly linked as some have suggested, or at least that there is not a clear causal relationship.

System Integration

Given the decentralized industry structure of the electronics industry, systems integration has moved beyond being a technical endeavor to become a key strategic function in highly innovative industries (Prencipe, et al., 2003). With innovation happening in different parts of the

[39] Despite the name, "podcasts" are unrestricted MP3 files, not limited to iPod use, but the use of the iPod-linked name and the iPod's dominance of the media player market were mutually reinforcing.

[40] In practice, the points of contact in the electronics industry are less arm's-length than in the ideal case, which gives rise to more interactive relationships that Gereffi, et al. (2005) call *relational value chains*. Whereas suppliers in modular networks make products to a set specification, the transactions in a relational network involve tacit knowledge or evolving specifications.

industry, someone must decide which technologies to incorporate into products, and then make those fast-changing elements work together in a product that is useful and affordable for customers. Pisano and Teece (2007) say that "A firm's ability to profit from innovation when there is considerable outsourcing depends importantly on whether the firm has world class capabilities in systems integration." Our analysis supports this, but we find that systems integration can occur from the bottom up as well as the top down.

The company determining the important aspects of a system is not necessarily the one whose brand name is on the outside of the final product. In PCs, Microsoft and Intel evolved from just providing an operating system and processor to become the systems integrators of the Wintel PC. Intel moved into chipsets and even motherboards, setting standards for much of the hardware interfaces in the PC (Gawer & Henderson, 2007), such as PCI Express, while Microsoft has pulled more and more functionality into the operating system. While the two sometimes disagreed, they generally cooperate to define how Wintel PC systems work, and to ensure compatibility across thousands of applications and peripherals. PC makers carry out systems integration at a functional level, but most of the important system-level decisions have already been made by Microsoft and Intel.

Other component suppliers have pursued a similar strategy, particularly vendors of microchips, whose ability to fit ever more transistors on a microchip has led to the so-called system-on-a-chip (Linden & Somaya, 2003). Such chips are sold not as stand-alone components but rather as "reference designs" that include recommended system circuitry, complementary components, an operating system, and software tools for developing customized applications. Although sophisticated customers like Apple will add their own engineering expertise, as they did with PortalPlayer's system-on-a-chip, less-sophisticated customers can use the reference design almost as delivered to reduce internal engineering overhead and reduce time-to-market.

VI. Practical Implications

The preceding analysis shows that Apple has benefited from following many of the prescriptions of the PFI model. While its iPod profit advantage isn't overwhelming, it has been enough to attract imitators who so far have fallen short. Yet our analysis of two Windows-based notebook computers shows that near-normal profits are available for products with little differentiation apart from a brand name and some marginal design differences, but lower ongoing requirements for R&D.

Because the electronics industry is a vast, open platform, the same set of complementary technologies is available to all firms. System firms, especially those working within a dominant design, must find ways to gain advantage through strategies such as branding, marketing, industrial design, rapid product development, business model, or channel strategy. Component firms must find unique ways to improve their customer's value capture prospects through means such as new functionality, lower cost, or short time-to-market.

A system or component firm that sets and controls a standard can earn above-average profits. Yet the opportunities to create a successful standard come only occasionally, usually before a dominant design is established. The examples of Microsoft, Intel, and Apple are notable for their rarity, and Apple's dominant position in digital music players contrasts with its marginal position in the PC industry. Still, while only a few firms in a value chain, if any, can earn supernormal profits, many can earn normal margins, and the system as a whole generates enough profits to support the continued rapid innovation that the electronics industry has seen for decades.

The efforts of all the firms in the value chain affect the size of the pie by determining the cost and capabilities of the products being sold. For instance, without a tiny hard drive or cheap flash memory or sophisticated software, there wouldn't be an iPod as we know it, and without ODMs to make it in China, it would be more expensive. Innovation means little if it doesn't result in successful products, and there are roles for many companies to transform an idea into a business. While most have little ability to influence standards outcomes and must compete on cost, quality and service like any other business, there are always new opportunities to profit from innovation in a dynamic industry such as electronics. Those most likely to do so apply systems integration skills to create value at the level of subsystem (e.g., TI, Broadcom), system (Intel), or ecosystem (Apple, Microsoft) in a way that creates some barriers to competitors from encroaching on their position.

VII. Conclusions

We have demonstrated a method for estimating the value captured by companies in the supply chain of a specific product. Starting with industry analyst estimates of component pricing, we used additional firm-level data to calculate gross profit throughout the chain. This methodology may be used by researchers studying different industries to identify who profits from innovation.

Limitations of this methodology include the need for access to either internal company cost data or teardown reports, and the restriction of the analysis to the supply chain, excluding other complementors and rivals firms. Another limitation is the absence of product volume information; firms may trade off a lower gross profit against higher volume because it allows them to allocate overhead over a larger revenue base.

Because our method looks at the value chain of a given model rather than multiple models, it misses product variety. Leading companies like HP or Lenovo field a complete range of notebook computers from high to low-end, each of which may have different profit targets. According to Portelligent, the Lenovo model considered here may have been targeted "at the value-business market more than the traditional high-end ThinkPad buyer" with the HP notebook roughly similar. Consumer models might have told a different story. Similarly, the hard-drive-based iPods analyzed here were at the high end of Apple's media player line. Apple sells more units of the lower-priced, flash-based Nano, which will have a different gross margin profile.

Our results show the usefulness of our estimation method by demonstrating that profitable niches abound, in both a closed architecture such as Apple's iPod family, in which the lead firm sets all the interfaces, and in the more open PC architecture whose key interfaces are set by upstream suppliers. Seeing the relative profitability of different participants in the value chain will benefit both scholars studying the profits from innovation, and business people looking to capture more profit for their firms.

We analyzed our results further from the perspective of the “profiting from innovation” (PFI) model and found solid empirical support for the theory. Our analysis has been based on systematic, empirical analysis of the value captured by various participants along the value chain augmented by additional industry knowledge.

The analysis confirms the usefulness of the core constructs of technology evolution, appropriability, and complementary assets. It also suggests that the recent emphasis on system integration skills as an important factor in firms’ ability to profit from innovation is merited. On the other hand, the analysis shows the difficulty of applying the “industry architecture” branch of the PFI model in a causal model, and discussed implications for firms of the availability of a broad “electronics industry” supply base.

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Appendix

Table A-1. Key Inputs in the 30GB 3rd-Generation iPod, 2003

Type	Input	Supplier	Supplier HQ Country	Estimated Input Price	Price as % of Factory Cost	Supplier Gross Profit Rate	Estd. Value Capture
Storage	Hard drive	Toshiba	Japan	$112.00	62%	26.90%	$30.18
Processor	Controller chip	PortalPlayer	US	$6.18	3%	41.40%	$2.56
Display	Monochrome display assembly	?	Japan*	$5.81	3%	20%*	$1.16
Memory	SDRAM - 32MB	Samsung	Korea	$5.23	3%	32.30%	$1.69
Battery	Battery pack	?	Japan*	$3.46	2%	30%*	$1.04
		Sub-Total		$132.68	74%		
		Other Parts		$42.64	24%		
		Estimated assembly and test		$4.87	3%		$4.87
		Estimated factory cost		**$180.19**	**100%**		**$41.50**

* - supposition
Source: Portelligent, Inc., 2003 and authors' calculations.

Table A-2. Key Inputs in the 30GB 5th-Generation iPod (Video iPod), 2005

Type	Input	Supplier	Supplier HQ Country	Estimated Input Price	Price as % of Factory Cost	Supplier Gross Profit Rate	Est'd. Value Capture
Storage	Hard Drive	Toshiba	Japan	$73.39	51%	26.50%	$19.45
Display	Display Assembly	Toshiba-Matsushita	Japan	$23.27	16%	28.70%	$6.68
Processors	Video/Multimedia Processor	Broadcom	US	$8.36	6%	52.5%	$4.39
Processors	Controller chip	PortalPlayer	US	$4.94	3%	44.8%	$2.21
Battery	Battery Pack	Unknown	Japan*	$2.89	2%	30%*	$0.87
Memory	Mobile SDRAM Memory - 32 MB	Samsung	Korea	$2.37	2%	28.2%	$0.67
Memory	Mobile RAM - 8 MBytes	Elpida	Japan	$1.85	1%	24.0%	$0.46
Memory	NOR Flash Memory - 1 MB	Spansion	US	$0.84	1%	10.0%	$0.08
		Sub-Total		$117.910	82%		
		Other parts		$22.790	16%		
		Estimated assembly and test		$3.860	3%		$3.86
		Estimated factory cost		**$144.56**	**100%**		**$38.66**

* - supposition

Source: Portelligent, Inc., 2006 and authors' calculations.

Table A-3. The Most Expensive Inputs in the Hewlett-Packard nc6230 Notebook PC, 2005

Type	Input	Supplier	Supplier HQ Country	Estimated Input Price	Price as % of Factory Cost	Supplier Gross Profit Rate	Est'd. Value Capture
Processors	Main chipset + Wi-Fi	Intel	US	$205.43	24.0%	59%	$121.20
Processors	Graphics Processor	ATI Technologies	US	$20.50	2.4%	28%	$5.74
Processors	Ethernet controller w/ Transceiver	Broadcom	US	$2.01	0.2%	53%	$1.07
Processors	Cardbus Controller	Texas Instruments	US	$3.28	0.4%	48%	$1.57
Processors	I/O Controller	Standard Micro-systems (SMSC)	US	$1.42	0.2%	46%	$0.65
Processors	Battery Charge Controller	Texas Instruments	US	$1.22	0.1%	48%	$0.59
Display	Display Assembly	Toshiba Matsushita Display	Japan	$137.14	16.0%	28%	$38.40
Software	Windows XP Pro OEM license	Microsoft	US	$100.00	11.7%	85%	$85.00
Storage	60GB Hard Drive	Fujitsu	Japan	$68.00	7.9%	26%	$17.68
Storage	DVD-ROM/CD-RW Drive	Matsushita	Japan	$40.00	4.7%	31%	$12.40
Memory	Memory Board (512 MB)	Samsung	Korea	$29.65	3.5%	30%	$8.90
Memory	DDR SDRAM Memory 2x32 MB	Hynix Semiconductor	Korea	$5.68	0.7%	41%	$2.33
Battery	Battery Pack	Unknown	Japan*	$40.52	4.7%	30%*	$12.16
		Sub-Total		$654.85	76.5%		
		Other parts		$177.72	20.8%		
		Estimated assembly and test		$23.76	2.8%		$23.76
		Estimated factory cost		**$856.33**	**100.0%**		**$331.44**

* - supposition
Source: Portelligent, Inc., 2005b and authors' calculations.

Table A-4. The Most Expensive Inputs in the Lenovo ThinkPad T43 Notebook PC, 2005

Type	Component	Supplier	Supplier HQ Country	Estimated Factory Price	Price as % of Factory Cost	Supplier Gross Profit Rate	Estd. Value Capture
Main chipset + Wi-Fi	Intel	US	$205.34	23.5%	59%	$121.15	Main chipset + Wi-Fi
Graphics processor	ATI Technologies	US	$21.70	2.5%	28%	$6.08	Graphics processor
Microcontroller	Renesas	Japan	$2.83	0.3%	24%	$0.68	Microcontroller
Power Supply Monitor / Controller	Toshiba	Japan	$2.11	0.2%	26%	$0.55	Power Supply Monitor / Controller
Single Chip LAN Controller	Broadcom	US	$2.01	0.2%	53%	$1.07	Single Chip LAN Controller
PC Card Controller	Ricoh	Japan	$1.81	0.2%	42%	$0.76	PC Card Controller
power management ASIC	IBM	US	$1.42	0.2%	40%	$0.57	power management ASIC
Microcontroller	Philips	Europe	$1.16	0.1%	32%	$0.37	Microcontroller
Display Module	Toshiba-Matsushita Display	Japan	$138.32	15.8%	28%	$38.73	Display Module
Windows XP Pro	Microsoft	US	$100.00	11.4%	85%	$85.00	Windows XP Pro
60GB Hard Drive	Hitachi	Japan	$68.00	7.8%	23%	$15.64	60GB Hard Drive
CD / DVD Drive	Hitachi-LG Data Storage	Japan	$40.00	4.6%	25%	$9.80	CD / DVD Drive
Li-Ion Battery Pack	Sony	Japan	$41.06	4.7%	37%	$15.19	Li-Ion Battery Pack
Memory Module	Hynix	Korea	$29.68	3.4%	41%	$12.17	Memory Module
32MB DDR SDRAM	Hynix	Korea	$5.68	0.6%	41%	$2.33	32MB DDR SDRAM
		Sub-Total		$661.12	75.5%		
		Other parts		$192.21	22.0%		
		Estimated assembly and test		$21.86	2.5%		$21.86
		Estimated factory cost		**$875.19**	**100.0%**		**$331.94**

Source: Portelligent, Inc., 2005a and authors' calculations.