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Who profits from innovation in global value chains?: a study of the iPod and notebook PCs

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This article analyzes the distribution of financial value from innovation in the global supply chains of iPods and notebook computers. We find that Apple has captured a great deal of value from the innovation embodied in the iPod, while notebook makers capture a more modest share of the value from PC innovation. In order to understand these differences, we employ concepts from theories of innovation and industrial organization, finding significant roles for industry evolution, complementary assets, appropriability, system integration, and bargaining power.

1. Introduction

The power of innovation to reward pioneers with exceptional profits is well known. Yet, as recognized in various strains of the business strategy literature, the value generated from the innovation is generally shared by the innovator with some combination of component suppliers, intellectual property owners, providers of complementary products and services, competitors, and consumers. This is all the more true as firms focus on a set of core activities and rely on a network of allies and suppliers to help them create and produce innovative products. In such innovation networks, a key question for managers and students of firm strategy is who captures the most value from innovation, and why?

This article addresses the question of who benefits financially from innovation in global value chains by looking at specific products: higher-end iPods and notebook computers. We apply a novel methodology for measuring value captured by firms across the supply chains for a pair of globally innovated products that combine technologies from the United States, Japan, and other countries, and are all assembled in China. This product-level approach allows us to break out the financial value embedded in each product and clarify how it is distributed across the primary participants in the supply chain.

Our analysis shows that the gross margins (GMs) of Apple for its high-end iPod products are generally higher than those earned by notebook PC makers, although not so high as to be considered “supernormal.” Other indicators such as operating profits and stock price performance suggest that Apple has captured a great deal of value from the innovation embodied in the iPod, while notebook PC makers capture a more modest share of the value of innovation in their supply chains.

In order to understand the differences in the profits from innovation between Apple and the notebook PC makers and their suppliers, we frame our analysis using a nested approach that draws on theories from two major business strategy traditions: profiting from innovation (PFI) and industrial organization (IO). These theories are prescriptive rather than predictive, so we are not testing them, but using their concepts to frame the analysis of our data. Specifically, we look at (i) the ability of lead firms to profit from their own innovations based on criteria identified by Teece (1986) and related studies in the PFI tradition along with (ii) the bargaining power of participants in the supply chain as a determinant of how the profits from innovation are divided, from the IO tradition (Porter, 1980). The PFI framework is based on the perspective of a focal firm and is not directly concerned with the profitability of other actors in the supply chain. The IO approach, concerned primarily with industry structure, is well suited to thinking about the bargaining power that determines the range of profit outcomes we observe along the supply chain.

For the lead firms, we apply the PFI framework and discuss how Apple built its iPod profit engine by keeping vital complements such as software in-house, dynamically innovating a business model that leveraged key external complements, and using proprietary technology to keep rivals at a distance. Within its supply chain, Apple has strong bargaining power thanks to the large market opportunity it provides.

By contrast, notebook computer makers are part of a business ecosystem that they coordinate yet do not control. Two suppliers—Microsoft and Intel—stand out for making supernormal profits. These two were able to wrest control over key software and hardware standards from IBM in the late-1980s and have protected their positions ever since (Dedrick and Kraemer, 1998). Possessing tremendous bargaining power, they capture a large share of PC industry profits, leaving less for brand name vendors and others in the supply chain. We estimate that PC makers earn normal margins on the mid-priced notebook models analyzed here, as do many of their suppliers. The lead firms leverage the huge supply of complementary assets for Wintel PCs (software, peripherals, Internet content, services, etc.), while allowing Microsoft and Intel to shoulder much of the cost of sustaining the ecosystem that supplies those assets by dealing with compatibility issues and investing in the core operating system and microprocessor technologies.[1]

[1]“Wintel” is industry shorthand for the standard that features Microsoft’s Windows operating system running on an Intel-compatible processor.

The following section of the article frames the analysis using concepts from the fields of innovation management and IO. We then present the methodology we use to analyze the distribution of profits for individual innovative products, and use that methodology to derive the gross profits for two models of iPod and notebook computers. We next compare the distribution of profits from innovation for iPods and notebook PCs across the supply chains of those products, using supplier data on gross and operating profits. Finally, we analyze why the differences occur using concepts from the IO and innovation literature.

2. Theories of innovation, profits, and the supply chain

An innovation can take many forms, from disembodied technology to a new product or process. We are concerned here with innovations that are tied to products manufactured by extended global supply chains. In the case of the iPod, the initial model was innovative in terms of its design and user interface, with subsequent models introducing various modifications, such as the video playback capability in the Video iPod analyzed in this article. Within 2 years of the first iPod sale, Apple also created a new business model for digital music, as we will discuss further below.

As an innovative product moves from concept to the market, the lead firm must assess the constellation of complementary technologies to identify those that might be sufficiently specialized to its innovation and which fit with its own capabilities to justify internal provision (Jacobides *et al.*, 2006). For the remaining complements, it must arrange for provision from supply chain partners.[2] The lead firm must also define its value proposition for customers and assess the competitive environment for its offering as part of creating a comprehensive business model (Chesbrough and Rosenbloom, 2002). The product price divides the available surplus (the difference between willingness to pay for a product and the actual cost of providing it) between the producers and the consumers. That price, in turn, minus the total cost of production and distribution, determines the value that is available to be distributed among the supply chain participants.

Value capture within the supply chain can be thought of as a two-level process: (i) the determination of producer surplus and (ii) the division of that surplus among the supply chain partners. We apply a different analytical approach to each level: the analytically rich innovation framework to the producer surplus and the simpler bargaining perspective from IO economics for the division of the surplus across the supply chain.

[2]We use "supply chain" to mean the physical flow of goods, from materials through distribution and sale of the final product. We use "value chain" to refer to all the functions of a firm, including its support activities. And "global value chain" refers to all the functions, from initial concept to the provision of complementary products, needed to achieve a satisfactory user experience.

2.1 Profiting from innovation

In an outsourced supply chain, a lead firm coordinates a partner network to develop and manufacture an innovative product and to maximize the market value of its innovation. The lead firm bears the primary responsibility for maximizing the profits that it divides with its partners and suppliers.

In the classic strategy literature, the ability of lead firms to maximize producer surplus and capture the highest value from their innovation depends first on preventing rivals from eroding profits. Firms can avoid this outcome by erecting barriers to entry that persist over time and charging higher prices that bring "supernormal profits" or "economic rents" (Porter, 1991). These barriers, or isolating mechanisms (Rumelt, 1987), can include government regulations (e.g., cable TV franchises), patents, control over raw material sources, branding, or advantages due to a unique location.

In dynamic, highly networked industries, such as information technology and electronics, additional factors come into play. Each innovation at the core of a new product offering is likely to require access to and coordination with other innovations to provide value to users. The technologies at the heart of electronic products have a high rate of change, so entry barriers are often short-lived, and management must be capable of recognizing and responding to changing market characteristics (Teece *et al.*, 1997).

These features of high-technology industries have made them a special focus of a stream of literature on PFI. One of the most-cited studies in this literature, Teece (1986), identifies three important factors that influence the distribution of profits from innovation.

The first is *industry evolution*, and, in particular, whether the market has embraced a dominant design for a new innovation (Abernathy and Utterback, 1978; Anderson and 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, less design heterogeneity is possible and competition becomes more price-based. The early phase often amounts to standards competition (David and 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. A dominant design is, however, conceptually distinct from a standard (Gallagher, 2006), as evidenced by the case where multiple standards co-exist in the market after a dominant design (e.g., a product architecture) has become apparent. Examples include the competition between mobile phone standards or between different video game standards.

The second issue is *appropriability*. This is defined by Teece (1986: 287) as "the environmental factors, excluding firm and market structure, that govern an innovator's ability to capture the profits generated by an innovation." Appropriability hinges mainly on the nature of the technology and the available legal mechanisms to protect an innovator. It explicitly deals with firm strategy and organization as a means to appropriate value from innovation (Winter, 2006).

The third element of the Teece framework is *complementarity*. For many electronics products, widespread acceptance depends on the availability of related goods that enable or enhance their functionality. For instance, computers need software and DVD players need pre-recorded movies. Innovating firms must decide whether to produce such complements internally or to rely on others to do so (Teece, 1986). Given consumer expectations of interoperability and the speed of change in the electronics industry, even the largest firms today must work with widely distributed alliance networks to bring new ideas to the market. Innovators need to coordinate to varying degrees with a large number of firms, sometimes including competitors (Brandenburger and Nalebuff, 1996), to ensure a supply of complements in order to maximize the total value proposition, while also positioning themselves to capture as much as possible of the value that is created by the network.

These factors interact with each other. For example, when appropriability is low (i.e., when imitation is easy), innovators shaping their supply chain are more likely to see their advantage erode unless they keep specialized complements in-house or otherwise under control (Pisano, 2006). A common thread linking dominant design, appropriability and complementarity is the presence of *standards*. A dominant design often emerges from market-based standards competition, or, in the case of a formal standard-setting procedure, political maneuvering within an industry association. The nature of standards, which can vary in terms of technical openness, availability for licensing, and so on, helps to define the appropriability regime. Control of the key standards for a product manufactured by a modular supply chain can reside in different levels of the product architecture, and there is a competition to prevent control from shifting to another layer (West and Dedrick, 2000). The classic case here is the PC, where the standards of the now-dominant design were originally set by IBM at the system level, but eventually usurped by Microsoft and Intel at the microprocessor and operating system levels.

An important adjunct of the original PFI framework that has particular relevance in the present study is system integration. This capability has become a key strategic function as industries become decentralized (Prencipe *et al.*, 2003). With innovation happening in different parts of the industry, a central actor 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).

As will be seen later in Section 6, these concepts help to explain why Apple is able to capture more value from its iPod innovation than PC makers are able to capture from notebooks.

2.2 Bargaining within the supply chain

The division of the producer surplus among the supply chain partners depends upon the relative bargaining power of the participants (Porter, 1980; Bowman and Ambrosini, 2000). A lead firm must decide based on strategic concerns, such as competitive conditions in input markets, which activities to undertake in-house and which to turn over to an outside supplier (Chesbrough and Teece, 1996; Jacobides *et al.*, 2006). Once it has decided on the composition of its supply chain, the lead firm bargains with its suppliers and partners in the supply chain over the distribution of profits. Buyer bargaining power is greater when there are only a few large buyers than when there are many smaller ones. Similarly, a seller's bargaining power is higher in a monopoly or oligopoly situation than in a highly competitive market.

Other factors influence bargaining power as well. For instance, access to proprietary information, such as a seller's cost structure or a buyer's inventory situation can provide bargaining power (Seidmann and Sundararajan, 1997). After a supplier is chosen, high switching costs from one supplier to another can give a seller greater bargaining power, a situation known as an *ex post* small numbers bargaining situation (Williamson, 1975). Specialized knowledge is another source of bargaining power, as only a few suppliers may have a particular expertise required by the buyer, which also leads to small numbers bargaining.

As will be seen in Section 5, these bargaining concepts help to explain why Apple is able to capture a greater share of the profits within its supply chain than PC makers are able to capture within theirs—even though they share much of the same general supply chain.

3. Methodology: measuring who captures value in global value chains

Our supply chain perspective is similar to that adopted in studies such as Gereffi (1994), Gourevitch *et al.* (2000), and Kaplinsky and Fitter (2004). However, these earlier studies used an industry-level approach, whereas we are pursuing a product-level focus to estimate the value captured by the lead firm and its most important suppliers for a single model (Appendix A briefly introduces supply chain analysis). The products we analyze here in detail are Apple's Video iPod, released in late-2005, and the model nc6230 notebook computer released by Hewlett–Packard (HP) in early-2005. We also analyzed an earlier model of the iPod and a Lenovo notebook computer that generated similar results. We summarize those results below, but do not analyze those supply chains in detail.

To model the value captured by a lead firm and its suppliers at the product level, we need to know the product's cost structure. However, 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' "teardown" reports, which capture the composition of the product at a specific point in time. These 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.

On the basis of the teardowns from Portelligent (Portelligent, 2005b; 2006), Table 1 shows the key inputs in one model of Apple's iPod (30GB Video iPod) and an HP notebook computer (nc6230). Although a notebook computer, with its programmability and multiple functions, may seem radically different from an iPod, the latter is essentially a portable computer dedicated to media processing. This comparability is underscored by the similarity across the two products of each functional input as a percentage of the lead firm's manufacturing cost.

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

Table 1 Comparison of inputs as percentage of factory cost: 30GB video iPod and HP nc6230 notebook

	Video iPod (in %)	HP nc6230 (in %)
Software	NA	12
Storage	51	13
Display	16	16
Processors	9	27
Assembly	3	3
Battery	2	5
Memory	4	4
PCBs	2	3
Enclosure	2	1
Input device(s)[a]	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.

[a]"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.

or royalty fees on each unit sold. In contrast, software licenses for the operating system and applications are a major part (11%) of the bill of materials for the H–P nc6230.

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

Further details for these and two similar products (an earlier-model iPod and a Lenovo ThinkPad) are presented in Appendix Tables A1, A2, A3, and A4.

To estimate the value captured by the suppliers, we consider three firm-level measures of profit: GM, operating margin (OM), and return on assets (ROA). GM is the ratio of gross profit (the difference between "net sales" and "cost of goods sold") to net sales. GM tells what share of a firm's sales price is retained after the direct costs of making its goods or services are deducted; it is the measure that comes closest to the product-level profit that we analyze for the lead firm. OM is the ratio of operating profit (which subtracts overhead costs including research, development, sales, general, and administrative expenses from gross profit) to net sales. OM shows the success of a firm's overall productive and innovative activity. Return on assets (ROA), the ratio of net profit (or loss) to total assets (an accounting value reported on a firm's balance sheet), shows the firm's economic efficiency in the use of capital from its shareholders and creditors.

GMs or OMs above a "normal" level reflect the ability to charge more than the long-run competitive price level, which is a product's average variable cost. 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 began by calculating the average GM, OM, and ROA for 270 of the leading global electronics firms for 2004 as reported in Electronic Business' EB 300 listing, which were 32.8%, 11.5%, and 5.2%, respectively.

The standard deviation of the GM was 19.5%, so, assuming a normal distribution, the range of 13.3% to 52.3% should cover about two-thirds of the sample, which it does (71% of the sample is within one standard deviation of the mean, with nearly the same number of firms above and below that range). GMs above this range are defined as supernormal, and margins significantly lower are subnormal.

The standard deviation of the average OM was 13.5%, giving a "normal" range of 25.0% down to −2.0%. The fact that a negative OM can be within the normal range illustrates the fact that many companies in the industry operate on very thin margins, and each year some are likely to lose money. In 2004, 18 firms of the 196 for which data were available in the EB 300 had negative OMs.

The standard deviation of the average ROA was 7.1, giving a "normal" range of 12.3% to −1.9%. The same thin-margin logic that applies to OM applies even more

Table 2 Three performance measures

Measure	Definition	"Normal" range, 2004
GM	Gross profit over sales	52.3 to 13.3%
OM	Operating profit over sales	25.0 to −2.0%
ROA	Net profit over total assets	12.3 to −1.9%

Source: See text.

so to ROA because its numerator, net income, reflects subtractions from operating income, particularly taxes.

We estimated the product-level GMs for lead firms, which we use to compare the value capture of Apple for two iPod models and of Lenovo and HP for notebook PCs. Company-wide OMs are available for all publicly-traded firms in the supply chain, and can be used to compare value capture at the firm level after subtracting the costs of R&D, and the sales and administrative costs a firm incurs to achieve its GM. If a high GM is completely consumed by the cost of R&D and marketing, then it is not a sign of above-normal profits. This is better measured by OM after those costs are taken out. Software companies capitalize some of their development costs to be expensed over the life of the product. For this reason, ROA, which includes these capitalized costs in the denominator, is a useful metric for comparing software and manufacturing companies.

By examining all three measures, we can avoid faulty conclusions that might result from the use of just one. Table 2 summarizes the preceding discussion.

4. Lead firm gross profit

Given the factory cost, in order to estimate gross profit per unit, we need to know the wholesale price at which the lead firm releases its products to a distributor, who then adds an amount to that price when charging a retailer. Other supply chain configurations occur, but we will reason from this basic model of distribution and retail as follows.

The retail price of the 30GB Video iPod at the time of Portelligent's analysis was $299. On the basis of our research, we estimate a 25% wholesale discount for each unit, with 10% for distribution and 15% for retail for both iPod models.[3]

[3]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

Table 3 Derivation of Apple's GM 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.

Applying these estimates to the retail price, we were able to arrive at an estimate of Apple's GM on each 30GB Video iPod sold. Apple is the lead firm in the iPod supply chain, incurring costs for R&D, marketing, coordination of the iPod's global value chain, and other overhead costs such as warranty. It is the residual claimant for value capture, as detailed in Table 3, in that it is the only company that bargains with all other actors in the supply chain.

Apple's estimated gross profit on these units would be $80, which works out to a GM of 36% of the $224 estimated wholesale price. As a point of comparison, Apple's reported corporate GM for all products in the year ending September 30, 2006 was 29%.

For the notebook computer, lower discount rates were used for our estimation of distribution and retail because a notebook PC is a much more expensive product than an iPod and the costs of distribution and retail do not rise proportionately to the price. Our estimates of notebook computer distribution and retail discounts are 5% and 10%, respectively. Applying these discounts, our estimate of the wholesale price received by HP is $1,189 against our estimated factory cost of $856. The difference of $333 gives HP an estimated near-average GM of 28%. This estimated notebook GM, which does not reflect warranty and other direct expenses, is higher than HP's overall GM of 24.3% in the fiscal year ending (FYE) October 31, 2006.

Similar estimates of value capture were made for an older model of iPod and a Lenovo ThinkPad. The earlier-generation iPod earned a slightly higher margin (40%) than the later version (36%), while the ThinkPad-branded notebook earned slightly

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).

Table 4 Lead firm-estimated GMs for four products[a]

Product	Retail price (in $)	Estimated wholesale price (in $)	Estimated gross profit (in $)	Gross margin (gross profit as percentage of wholesale price)
30GB third-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
HP nc6230, 2005	1,399	1,189	333	28

Source: Authors' calculations; see text.

[a]The product-specific gross margins in Table 3 are calculated as described in the text discussed in 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.

more (30%) than the competing HP model (28%). However, for each pair of products (Table 4), the margins are so close as to be within the uncertainty range of our estimates.

Apple's iPod GMs are generally higher than those for the two notebook models, but these would be partly dissipated by Apple's extra overhead costs. 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 capabilities, 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.

HP, on the other hand, has transferred a great deal of the responsibility for its development engineering to its original design manufacturers (ODM) contractors, while Lenovo relies more on internal engineering capabilities that it acquired along with the ThinkPad brand when it bought the IBM PC division. Both HP and Lenovo carry out the critical task of establishing initial specifications that balance market demand and technology trends.

5. Distribution of profit along the supply chain

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

Table 5 Profit margins of primary firms in the video iPod supply chain, 2005

Function	Supplier	Gross margin (in %)	Operating margin (in %)	Return on assets (in %)
Controller chip	PortalPlayer	44.8	20.4	19.1
Lead firm	Apple	29.0	11.8	16.6
Video chip	Broadcom	52.5	10.9	9.8
Primary memory	Samsung	31.5	9.4	10.3
Battery	TDK	26.3	7.6	4.8
Retailer	Best Buy	25	5.3	9.6
Display	Toshiba–Matsushita Display	28.2	3.9	1.8
Hard drive	Toshiba	26.5	3.8	1.7
Assembly	Inventec Appliances	8.5	3.1	6.1
Distribution	Ingram Micro	5.50	1.3	3.1
Minor memory	Elpida	17.6	0.1	−1.0
Minor memory	Spansion	9.6	−14.2	−9.2

Note: Shaded cells are outside the "normal" range for that profit measure.
Source: Calculated from corporate reports for the fiscal year that includes December 2005; data for Toshiba–Matsushita Display, a 60/40 joint venture, are weighted averages of consolidated data for Toshiba and Matsushita.

We measure value capture along the supply chain using GM, OM, and ROA, described above. Our measures are calculated from the company-wide values in corporate financial reports.

The use of company-wide data for our purposes is not as good as product-specific data would be, but product-level data simply are not available for component suppliers. In the case of a focused company like the chip-maker Broadcom, company data is a good approximation because such companies target a similar level of profitability for most projects they undertake. In contrast, a company like Samsung that makes everything from microchips to major household appliances has a wide range of profit margins across its divisions. We note cases where, based on industry knowledge, we believe the corporate numbers do not accurately reflect the bargaining power of suppliers for a particular component.

Tables 5 and 6 identify significant subgroups of supply chain participants along the Video iPod and nc6230 notebook supply chains, shown in descending order of OM. The firm-level GM, OM, and ROA are shown in the right-hand columns. Cells where the value lies outside the "normal" range for that measure are shaded.

For a few inputs where we did not know the specific firm that was the primary supplier, we have used the data for one or more representative firms, as detailed below. Whether the specific firm is known or not, these data are intended to be

Table 6 Profit margins of firms in the HP nc6230 supply chain, 2005

Function	Supplier	GM (in %)	OM (in %)	ROA (in %)
Operating system	Microsoft	84.8	36.6	17.3
Processor plus logic and wireless chips	Intel	59.4	31.1	17.9
DDR SDRAM (graphics memory)	Hynix Semiconductor	37.3	24.9	17.7
Cardbus and battery charge controllers	Texas Instruments	48.8	20.8	15.4
Ethernet controller w/transceiver	Broadcom	52.5	10.9	9.8
Memory board (main memory)	Samsung	31.5	9.4	10.3
Retailer	Best Buy	25.0	5.3	9.6
I/O controller	Standard Microsystems	46.0	4.2	2.7
DVD–ROM/CD–RW drive	Matsushita	30.8	4.1	1.9
Battery pack	Unknown	24.0	4.0	2.4
Lead firm	HP	23.4	4.0	3.1
Display assembly	Toshiba Matsushita Display	28.2	3.9	1.8
Hard drive	Fujitsu	26.5	3.8	1.8
Assembly	Unknown	6.1	2.4	4.6
Distributor	Unknown	7.7	1.5	1.9
Graphics processor	ATI Technologies	27.6	1.1	1.0

Note: Shaded cells are outside the “normal” range for that profit measure.
Source: Calculated from corporate reports for the fiscal year that includes December 2005; battery gross and operating margins are the average of the FYE 12/05 or 3/06 data for the five leading makers of notebook batteries (combined market share of ~90%); assembly gross and operating margins are the average of the FYE 12/05 data for HP’s four ODM partners; distributor gross and operating margins are the average of the data for four leading distributors.

indicative, not definitive. They give some idea of bargaining power and value capture along the supply chain, which we discuss below for lead firms and suppliers of key inputs.

The following discussion of bargaining power refers primarily to GMs and OMs. The discussion would not be substantially different if we used ROA. The three measures do not lead to exactly the same rank order, but they share a general ranking of firms into high, medium, or low groups.

5.1 Lead firms

The most striking contrast between the iPod and notebook supply chain margins is how high Apple ranks in terms of OM within its supply chain (second of twelve)

Table 7 Selected operating ratios

	GM (in %)	R&D/sales (in %)	OM (in %)
Apple, FYE 9/24/2005	29.0	3.8	11.8
HP, FYE 10/31/05	23.4	4.0	4.0

Source: Calculated from Apple 10-K for FYE 9/30/06, p. 74, HP 10-K for FYE 10/31/06, p. 42.

compared to HP (eleventh of sixteen). Apple's company-wide OM is 11.8%. This is probably lower than the value that could be attributed to this iPod model alone. Apple's company wide GM that fiscal year was 29%, which is less than the 36% GM we estimated for this model (see Table 3).

As discussed above, Apple negotiates with every member of the iPod supply chain. It is both the "guarantor of quality" (Jacobides *et al.*, 2006) to the consumer and the residual claimant for value after all expenses. It enhances both roles by working closely with its suppliers, and even its suppliers' suppliers.

HP, based on its company-wide GMs and OMs, appears far down the nc6230 list despite being the lead firm in its supply chain (Table 6). Our estimated nc6230-specific GM of 28% (Table 4) is only slightly higher than the 23.4% reported company-wide, so these numbers may be roughly representative of HP's value capture in the notebook market, adjusting for the fact that notebook margins are generally higher than those for the desktop systems that HP also sells.

At a company-wide level (Table 7), Apple has a much higher OM than HP in spite of a similar level of R&D expenditures. We discuss why this is so in Section 6 using the Teece model.

5.2 Main processor and software firms

As expected, the highest margins in notebooks are earned by Microsoft and Intel, with supernormal OMs of 36% and 31%, respectively. Their returns on assets are also above the normal range, which shows that Intel's multi-billion dollar factories and Microsoft's capitalized development costs do not offset the extraordinary profitability reflected in their GMs and OMs. Microsoft and Intel's ownership, maintenance, and vigorous defense 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 and Lenovo to differentiate their computers in the market. Network effects that favor these inputs make it hard for computer companies to find alternate suppliers.

For the iPod, Apple is responsible for its own software. The first-listed outside firm is the supplier of this model's key computer chip, PortalPlayer, with an OM of

20.4% in 2005. PortalPlayer, a Silicon Valley start-up founded in 1999, was a key partner in the iPod development process (Sherman, 2002), providing the main microchip that controlled the iPod's basic functionality, handling critical tasks like digital music processing and the user's database management.

If PortalPlayer had any market power with Apple, it was dissipated by its dependence on Apple for its revenues. In 2005, Apple's subcontractors for iPod assembly accounted for 93% of PortalPlayer's sales (PortalPlayer, 2005). PortalPlayer's above-average GM 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 with its processor supplier, 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).

5.3 Other microchip firms

There are three main categories of microchips: logic, memory, and analog. *Analog chips* tend to have high margins due to their specialized nature but make up a small share of the cost of an iPod or notebook.

Some *digital logic chips* are as specialized as analog chips, and command higher prices as well. They derive bargaining power from unique features of their implementation that reduce cost or improve performance. A prime example in the iPod is Broadcom's video decoder. Broadcom's GM of 52.5% is high enough to land in the supernormal range for the electronics industry. Its 10.9% OM is near the electronics industry average, but at the high end for iPod suppliers.

Unlike PortalPlayer, Broadcom 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 was not 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. This gives its products sufficient attractiveness to command relatively high margins.

In contrast, *memory chips* are more narrowly standards-based and subject to intense competition. The bargaining position of these firms is set primarily by supply and demand in the overall memory market, and their margins are determined by their ability to control their internal costs. The sector is notoriously volatile because of the difficulty of synchronizing demand and supply, which leads to cycles of glut and scarcity.

The iPod's main memory chips came from Samsung, which reported a 9.4% OM. Samsung has been the world's largest supplier of memory chips in recent years, which has allowed it to benefit from scale economies in addition to the cost benefits of its internal excellence in key aspects of manufacturing. The poor performance of the other memory suppliers in the iPod, Elpida (0.1% OM) and Spansion (−14.2% OM), reflect the volatility in the memory sector.

In the nc6230, we find Samsung again and also its fellow Korean memory giant, Hynix, which had an even better year, earning a 25% OM, which placed it third among the major nc6230 suppliers. This should be seen as an indication of the company's manufacturing prowess rather than an indication of bargaining power as such because all dynamic random access memory (DRAM) suppliers negotiate price based on general market conditions of supply and demand so that variations in margins are indicative of company cost structure.

5.4 Hard drive firms

The Video iPod's hard drive, its single most expensive component, was supplied by Toshiba. We used Toshiba's company-wide GM for the fiscal year ended in March 2006, 26.5%. Industry interviews suggest that the GM on this unit is probably 20% or less because Toshiba is a relatively low-volume producer that does not maximize its economies of scale, and Seagate and Western Digital, two larger disk drive producers, had GMs of 23.2% and 19.1% in the FYE June 30, 2006.

The Toshiba drive was a standard part with little leverage despite the fact that Toshiba was the only major producer at the time Apple started up its iPod project (Sherman, 2002). Toshiba's OM in FYE March 31, 2006 was just 3.8%. A large gap between GMs and OMs is a pattern we see frequently in Japanese firms. By comparison, Seagate and Western Digital had OMs of 9.5% and 8.4%, despite having lower GMs than Toshiba.

The nc6230 hard drive came from Fujitsu, one of the smallest hard disk drive suppliers, with about 7% of the market in unit terms in 2005 (Chan, 2006). The fierce competition of the drive market and Fujitsu's relatively small scale are likely to have kept its margins on this unit low. Fujitsu's company-wide margins in the year ending March 2006 were 26.5% gross and 3.8% operating.

5.5 Other Japanese-supplied parts

Among all the suppliers, Japanese companies are the most prevalent in the supply chain. In the iPod, Japanese suppliers provided the hard drive, the display, the battery, and one of the memory chips. Apart from the memory company, Elpida, which had poor performance at the gross as well as the operating level, their GMs fell between 26.3% and 28.2%, close to Apple's 29%. OMs, however, fell between 3.8% and 7.6%, which was well below Apple's 11.8%.

In the nc6230, Japanese companies supplied the optical disc (CD/DVD) device, the display, and hard drive. Their OMs are between 3.8% and 4.1%, similar to the 4% earned by HP. Their GMs are between 26.5% and 30.8%, which is more than HP's 23.4% GM.

Across all these companies, the two measures of profit are highly correlated, with OM being about a third of the GM. If a Japan "dummy variable" is introduced into a regression of OM on GM, the dummy's coefficient shows that Japanese identity knocks off more than 3% points from a firm's OM. This represents a major loss of value for the Japanese firms relative to the 8.7% average OM for all firms in the sample.

Although this low OM represents poor value capture in the shareholder sense, it does not represent weak bargaining power within the supply chain. Japanese firms have long-tolerated inefficient cost structures for a variety of business and societal reasons, such as maintaining employment. More recently, a change in shareholder structure has increased pressure to improve performance in terms of returns to shareholders (Sapsford and Fackler, 2005).

We present a more detailed analysis of batteries, displays, and the CD/DVD drive in Appendix B.

5.6 Assembly firms

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 (Levy, 2006). Despite a low GM of 8.5%, careful cost control and limited research expense (2% of sales) helped Inventec Appliances achieve an OM of 3.1%.

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.

For the nc6230, we did not know the specific assembler. To estimate assembly profitability, we averaged the margins of the four ODMs (Compal, Inventec, Quanta, and Wistron—all Taiwanese) reported to be supplying HP with notebook computers in 2004 and 2005 (Tzeng and Hwang, 2003; Lin and Shen, 2006). The average GM was 6.1% and the average OM was 2.4%. The highest OM in this group was 4.6%, but the rest were 2.3% or less.

Despite the contribution of the ODM firms to the development process for the notebooks they manufacture, contract manufacturing is a notoriously competitive and low-margin business with vendors able to switch suppliers from one model to another.

5.7 Retail firms

After a product is manufactured, there is still a great deal of value to be captured from distribution and retail. On the basis of our research, we estimate a 15% discount to retailers for the Video iPod, which would more or less be the retailer's GM on any single unit since the firm's overhead is spread over a store's worth of products. Our teardown estimate of the nc6230 retailer's GM was 10%. These margins are retained by the lead firms when they are able to sell directly to end users, which Apple does in large volumes through its Apple stores and website.

Looking at representative firms in the electronics retail sector, Best Buy, which sells both consumer and office goods, had a GM of 25% and OM of 5.3% in fiscal year 2005. Circuit City, associated more with consumer electronics like the iPod, had a GM of 24.5% but an OM of only 1.9% after overhead costs were deducted. The GM of an office equipment retailer, Staples, was 28.5%, and its OM was 7.7%. These retailer margins, while far from stellar, are large enough to suggest that the big retailers exert some power in the electronics supply chain despite the well-known fierce competition in the sector.

5.8 Distribution firms

The picture is less positive for distributors, which use low-margin, high-turnover business models. We estimated a 10% share of the retail price of the iPod for distribution, which works out to an estimated GM of 11.8% for the distributor ($30/$254). We allowed 5% of the nc6230 retail price for distribution, which works out to a 5.9% GM ($69/$1,189).

Ingram Micro, which is involved in distributing both iPods and HP computers, had GM of 5.5% in the fiscal year 2005. This fell to operating profits of 1.3% after overhead costs were deducted. These values are probably dominated by computers and other IT products and services, which are Ingram's main business. The average for four leading computer distributors (Ingram Micro, Tech Data, Avnet, and Bell Microproducts) in 2005 was 7.7%. The corresponding average OM of these four distributors was 1.5%.

6. Explaining why some lead firms capture more value

We now explain the value captured by lead firms like Apple and HP. The technology trajectory of the PC industry has been well studied over its long history, so we begin by reviewing the evolution of the iPod. After that we compare the market positions of Apple and HP in terms of the factors identified as important in the literature on PFI.

6.1 Evolution of the iPod business model

Digital audio players had been marketed by small companies as early as 1998, but they suffered from low capacity, high cost, and complex interfaces. The pre-iPod hard drive-based models used standard notebook PC drives, which kept the units too bulky for easy mobility. The iPod was the first unit to incorporate Toshiba's smaller drives to permit a strikingly thin design and also introduced a wheel-based interface for control and file navigation in place of the buttons that featured on the front of competing products.

The iPod is not just a hardware innovation but also 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. The initial iPod, introduced in Fall 2001, was integrated with iTunes only on Apple's own Macintosh platform, with no thought to Apple involvement in content delivery (Levy, 2006: 154). In 2002, a Windows-compatible iPod was released using third-party software, greatly expanding the available market. In October 2003, Apple added iTunes support for the Windows platform.

In April 2003, Apple, having painstakingly negotiated cooperation from all the major music labels, introduced the iTunes Music Store (iTMS), which was the first service to legally permit the downloading of single tracks by a wide range of major artists as an alternative to illegal downloading or buying a whole CD for one song. The iTMS (now called the iTunes Store) uses an exclusive system of digital rights management (DRM) called FairPlay, which limited the number of computers on which the purchased tracks can be played.

Apple's control of the underlying DRM system for the first legal music downloading service with a large library added user-switching costs to the iPod business model that helped keep Apple ahead of its rivals. To take advantage of this opportunity, Apple reportedly spent $200 million on advertising in the iPod's first 4 years, which was far more than the advertising of its music-player rivals at that time (Levy, 2006: 120). The advertising helped to expand the user base, and the switching costs associated with music purchased at the iTunes Store helped to ensure that buyers' second music player was also an iPod. The same logic applies to any iPod-specific accessories such as external speakers that use the iPod's "dock" connector; these also impose switching costs on future music player purchases.

In sharp contrast, notebook computers are sold without any particular associated method of content delivery or brand-specific accessories. The manufacturer may pre-install software or services, but the customer ultimately decides which applications to use on the machine and which networks to join for accessing content. Nearly all PC accessories also conform to industry-wide interface standards that are supported by all brands. Users face no penalty from choosing a different brand of notebook PC at their next purchase.

6.2 Explaining differences in profits from innovation

Our data show that lead-firm GMs for iPods are larger than for notebook computers. The average difference of 9% would be coveted by any manager, but we also note that it is less than half the 19.5 standard deviation of large electronics firm GMs reported above, which means that the two numbers are not significantly different in the strict statistical sense.

What explains the difference in value capture between iPods and notebooks? And why is it that Intel and Microsoft capture such high margins in the PC supply chain?

In order to answer these questions, we look at the different positions of these players with respect to the key factors that can determine whether a firm will capture most of the value generated by its own innovative efforts. We will focus on the factors identified in the original Teece (1986) framework (industry evolution, appropriability, and complementarity) as well as other factors discussed above: system integration and business models.

6.2.1 Industry evolution and the dominant design

The current physical configuration for notebooks (keyboard, palm rest, and pointing device) was established by the early-1990s. Since then, almost everyone in the industry has innovated within the dominant physical design and, with the notable exception of Apple, within the Wintel standard. The innovation of HP and its suppliers in the nc6230 was limited to making the unit lighter yet more rugged by the use of a magnesium-alloy frame while Dell, HP's main rival in the notebook market, was still using all plastic. HP's rise to the top of the notebook ranking in the 2000s was driven primarily by price reductions made possible by the cost savings from its switch to outsourced manufacturing in the 1990s and the scale economies realized from its acquisition of Compaq in 2002.[4]

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 (Clark, 1985; Anderson and Tushman, 1990), 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 disruption of their position. This situation has made it very difficult for PC makers to differentiate their products, so competition has driven down their margins.

[4]Following a change in leadership in 2005, HP also improved the industrial design of its notebooks to enhance its consumer appeal, but the nc6230, marketed under the HP Compaq brand, was targeted primarily at budget-minded business users.

This can be seen starkly in terms of GM. In the HP nc6230, Intel and Microsoft combined have a GM of about 66% on inputs whose value equals about 30% of the wholesale price, which means their combined gross profit (i.e., the share of input price not directly related to the cost of providing the input) works out to 20% of the notebook's wholesale price. This leaves less for HP and everyone else in the supply chain since notebook PCs tend to target specific price points, which limits the potential for a positive-sum outcome.

Apple's ability to innovate in the then-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. iPod clones, such as the Digital Jukebox launched by Dell in 2003 to negative reviews, failed to dent iPod's market dominance.[5] The highly integrated iPod/iTunes system became a de facto dominant design, to the extent that Microsoft followed its example closely with the 2006 introduction of the Zune and the Zune Marketplace after shifting from its more modular "PlaysForSure" certification program that pushed Windows Media formats with loose ties to other companies' hardware and infrastructure.

6.2.2 Appropriability

Many of the individual innovations behind the components in electronic products enjoy high appropriability; thanks to patents or other barriers to imitation, but for system firms like Apple, HP, or IBM, the appropriability regime is weaker, which increases the need for control over specialized complements (Pisano, 2006). IBM lost control over the key system interfaces by the late-1980s to its chief suppliers, Intel and Microsoft, and it failed to create any in-house complement important enough to appropriate the value of the system design and dominant standard it had created. IBM's award-winning ThinkPad line, introduced in 1992, was a good seller, but IBM failed to innovate fast enough to prevent rivals from duplicating 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 and 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. With no PC maker having even 20% of the global market (versus over 90% for Microsoft and 80% for Intel), lead companies cannot do much to influence standards outcomes.

Unlike IBM, Apple kept control over key elements of the iPod, particularly the user interface, and 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

[5]See, for example, Lewis (2003): "Coming from the square world of Dell instead of the hip world of Apple, it's bigger, heavier, and clunkier than Apple's sleek, suave, elegant iPod . . . ."

share of profits from its innovation in the iPod. It has so far defended this position through an appropriability regime that includes extreme secrecy, refusing to open up the DRM system to others, and the 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.

Patented innovations have played a limited role in the iPod's continued success. Apple was even sued in 2006 over the iPod user interface by Singapore's Creative Technology, a pioneer in the digital audio player market. Apple settled within a few months for a one-time licensing payment to Creative of $100 million.

Still, Apple's control over key iPod standards, such as the dock connector interface for external devices, has enabled it to access the necessary complementary assets while appropriating a share of profits from that growth. In 2005, Apple introduced a royalty fee for certifying products that interfaced with the iPod via its dock connection (Fried, 2005).

6.2.3 Complementary assets

For many electronics products, a key factor is the availability of complementary goods and services that enable or enhance their functionality. Complements differ in terms of specialization. Generic complements, such as most simple electronics components, are readily redeployable to other supply chains. 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.

One vital complement in which Apple has invested for many years is its brand image. Apple has a reputation as a "cool" and exciting company whose product announcements are newsworthy for the general public. This image has been maintained by many years of careful advertising and brand management that extended back to the company's earliest years. The iPod's success was partly due to this image, and the iPod itself also did much to enhance Apple's brand appeal.

Apple also maintains the role of "guarantor of quality" for its customers (Jacobides *et al.*, 2006), so that few iPod owners are even aware of what microchips power their music player, unlike the "Intel Inside" awareness of the PC market. Apple has also kept suppliers from gaining any significant market power by multiple sourcing wherever possible and by being willing to switch key suppliers from one model to the next.

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 does most of its own final assembly. While outsourcing is not universal throughout the electronics industry, 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 (1–2 years) should conflict arise or another contract manufacturer offer a lower price.

Specialized complements are provided differently in the notebook PC and iPod ecosystems. In the notebook PC ecosystem, specialized hardware accessories and software programs are developed independently to meet published PC interface standards. Hardware peripherals have become quite generic, as they mostly rely on standard universal serial bus (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 highly specialized software in the iPod and the iTunes client software are developed by Apple internally. Unilaterally 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.

The iPod's most important complementary asset, content, 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. The presence of unofficial file sharing services made millions of tracks available free online (albeit illegally). 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.

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 that made sense to provide internally; 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.

6.2.4 System integration

A final profitability factor underscored by our analysis is the value of system integration skills. System integration proved to be important for both types of products that we analyzed, and we found that the integration can occur from the bottom up as well as the top down.

For the iPod, Apple's design expertise permitted it to generate a pleasingly thin product that offered users aesthetic, as well as practical, value. Although manufacturing was outsourced, Apple made the important engineering determinations that enabled the well-known iPod shape.

For notebook PCs, HP lets its manufacturing partners handle the bulk of physical design. HP retains responsibility for the product's look and feel and its responsiveness to customer needs (Parker and Anderson, 2002).

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 ecosystem. Intel moved into chipsets and even motherboards, setting standards for much of the hardware interfaces in the PC (Gawer and Henderson, 2007), such as PCI Express, while Microsoft has pulled more and more functionality into the operating system. 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. This limits the ability of PC makers such as HP to differentiate their products through significant design innovations. Many microchip vendors pursue a similar strategy to Intel's, offering complete reference designs, including recommended system layout and software, that can be implemented rapidly by customers with limited internal expertise (Linden and Somaya, 2003).

7. Conclusions

This article has applied a novel methodology for estimating and analyzing the profits of firms linked in a global value chain. Combining those results with insights from the business literature has provided insights into the opportunities and constraints facing firms in the electronics industry.

Because the electronics industry is a vast, open platform, a common set of complementary technologies is available to all firms. Lead 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 suppliers must find unique ways to improve their customer's value capture prospects through means such as new functionality, lower cost, or shorter time-to-market. While only a few firms in a supply chain, if any, can earn supernormal profits, many can earn normal margins, and the electronics ecosystem as a whole generates enough profits to support the continued rapid innovation that the electronics industry has seen for decades.

Our analysis makes it clear that the efforts and bargaining power of all the firms in a supply chain set the size of the value "pie" by determining the cost and capabilities of the final product. For instance, without a tiny hard drive or cheap flash memory or sophisticated software, there would not be an iPod as we know it, and without ODMs to make it in China, it would be more expensive and possibly less successful as a consumer product. In sharp contrast, the market power and high prices charged by Microsoft and Intel for their latest technologies have helped keep the cost of the notebook computers too high for most global consumers, which has driven the search for alternative configurations such as netbooks priced at a few hundred dollars.

Limitations of the profit estimation methodology include the need for access to teardown reports, internal company cost data, or other sources of component pricing. Our empirical approach also privileges detail over the wider picture, considering the supply chain to the exclusion of other complements and rival firms. Another limitation is the absence of specific product volume information; firms may accept 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 supply chain of a given model rather than multiple models, it also 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 has a different GM profile.

Despite these limitations, it is our hope that this methodology will be of use to researchers studying different industries to identify who profits from innovation. Our results show that profitable niches abound, in both a closed architecture such as Apple's iPod family and in the more open PC architecture. Studying the relative profitability of different participants in the supply chain will be of benefit both to scholars studying the profits from innovation and to managers looking to capture more profit for their firms.

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Appendix A

Supply chain analysis

Leading examples of dispersed innovation networks can be found in the electronics industry. For decades, the industry was dominated by large vertically integrated companies like IBM, HP, Toshiba, and Fujitsu that designed and built their own products, often using internally produced components and proprietary technologies. Since then, there has been a shift by electronics firms to focus on systems integration and outsource other activities, creating global production networks or supply chains that cross corporate and national boundaries. Companies that formerly manufactured most products in-house, as well as start-ups that never had manufacturing capabilities, have outsourced production and even aspects of product development to turn-key suppliers known as CMs and ODMs. They rely on outside component suppliers for production and innovation in core technologies such as semiconductors, displays, storage, batteries, and software.

Here we describe a simplified, generic supply chain, which we use as the basis for introducing a method of calculating value captures by the companies in the chain.

Within a supply chain, each participant purchases inputs and then adds value, which becomes part of the cost for the next stage of production. The sum of the value added by everyone in the chain equals the final product price paid by the customer. Figure A1 shows a generic supply chain for a product that is assembled by a contract manufacturer, warehoused by the lead firm, and then sold to the customers via distribution and retail channels. Many other configurations are possible.

Although each product incorporates a large number of components (thousands, in the case of a notebook computer, or hundreds, in the case of an iPod), the large majority are low-value parts, such as capacitors and resistors that cost less than a penny each. Although the reliability of such parts is vital to overall system quality and suppliers of these components earn profits, they account for a small share of the total value added along the supply chain. Moreover, they typically compete with close substitutes, which reduce 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 responsible for the final product's functionality and performance. They most likely embody proprietary knowledge that helps to differentiate the final product and can command a commensurately high margin. By virtue of their high cost relative to other components, these few inputs also account for a relatively large share of total value added.

Figure A1 Generic electronics supply chain

Many firms in the industry outsource assembly of these components into the final product to large multinational CMs such as Flextronics, Solectron, and Foxconn, or ODMs such as Quanta, and Compal, which also collaborate in product development. These assemblers compete fiercely for high-volume opportunities, limiting their margins. Apple outsources all final assembly, as does HP for notebooks. Lenovo keeps most of its notebook assembly in-house in facilities in China, and designs its Thinkpad products internally in the United States and Japan. Apple closely controls design and development in-house.

Lead firms coordinate the supply chain and handle product concept, branding, and marketing. These brand-name firms contribute market knowledge, intellectual property, system integration, and cost management skills, and a brand 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, with image-conscious companies 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 the cross selling of multiple products as well.[6]

Using maps like this as a guide, we calculate the value added at various stages of the value chain.

Appendix B

Japanese firms in the supply chain

There are many Japanese firms in the electronics supply base. As discussed in the main article, their OMs tend to be below average. Here we discuss more of the components provided by the Japanese firms.

Battery firms

In the case of the iPod's prismatic lithium-ion battery, Portelligent was not able to identify the supplier, nor were we able to do so through our own research. One of the leading makers of lithium-ion batteries for portable electronics, Amperex, is a Hong

[6]Apple's 10-K for the FYE 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).

Kong-based firm that was acquired by Japan's TDK in 2005. We have used TDK's company-wide OM, 7.6%, to represent the battery supplier's margin.

For the nc6230 battery profit margins, we averaged the GMs and OMs of the five leading makers of notebook battery cells, with a combined market share of ~90%.[7] Three of these, Sanyo, Sony, and Matsushita, are Japanese firms, and their OMs of 4% or less reflect loose cost control. The other two suppliers, Samsung and LG Chem, are Korean firms and had a 2005-OM of 9.4% and 5.7%, respectively.

These types of battery are typically produced to a custom size for each application, which may bring some short-term bargaining power for the supplier. But the field is sufficiently competitive that margins are not especially high relative to other types of components. As with most other components, the bargaining power lies with high-volume customers like Apple and HP.

Display firms

The displays, one of the costlier inputs in both the iPod and nc6230, were supplied by Toshiba–Matsushita Display, a 60:40 joint venture. The weighted-average OM for Toshiba and Matsushita was 4.2% for the FYE March 2006; GM was 28.2%.

Smaller display sizes such as that used in the iPod have been more profitable in recent years than standardized notebook and TV displays because there is a greater variety of niches for different sizes and resolutions, which allows for some differentiation by the supplier. The segment, however, 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 by Sanyo–Epson, another Japanese joint venture.[8] 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 GMs of Sanyo (19%), Epson (18%), and the display sector leader, Sharp (23%), were even lower than those for Toshiba and Matsushita, so the 28% used in the tables may be on the high side.

CD/DVD player firms

The nc6230's DVD–ROM/CD–RW optical disc drive was supplied by Matsushita, the world's largest supplier of notebook-sized optical disc drives at that time. Its closest rivals were two Japan–Korea joint ventures: Hitachi–LG Data Storage

[7]Joseph Tsai, "Notebook vendors considering battery cells from China, says paper," DigiTimes.com, March 31, 2008.

[8]"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.

and Toshiba–Samsung Storage Technology, but Matsushita's shipments were growing faster.

Matsushita's GM in FYE March 2006 was an average 30.8%. Its OM was 4.7%, which is relatively low but still the highest of any of the nc6230's major Japanese suppliers. This reflects the benefits of several years of restructuring efforts aimed at improving competitiveness and profitability.[9]

[9]Ginny Parker Woods, 'Matsushita's Net Surges 38% Amid Strong Plasma-TV Sales,' *Wall Street Journal*, February 3, 2006, p. B6.

Table A1 Key inputs in the 30GB third-generation iPod, 2003

Type	Input	Supplier	Supplier HQ country	Estimated input price (in $)	Price as percentage of factory cost	GM (in %)	Estd. value capture (in %)
Storage	Hard drive	Toshiba	Japan	112.00	62	27.0	30.24
Processor	Controller chip	PortalPlayer	United States	6.18	3	41.4	2.56
Display	Monochrome display assembly	?	Japan[a]	5.81	3	14.0	0.81
Memory	SDRAM-32MB	Samsung	Korea	5.23	3	32.3	1.69
Battery	Battery pack	?	Japan[a]	3.46	2	27.4	0.95
		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		41.12

Source: Portelligent, Inc. (2003), company reports, and authors' calculations.
Display GM calculated from 2003 data for Wintek (Taiwanese display specialist that supplied Nano screens) via DigiTimes.
Battery GM calculated from FYE 3/04 data for TDK (consolidated) from TDK 20-F for FYE 3/06.

[a]Supposition.

Table A2 Key inputs in the 30GB fifth-generation iPod (Video iPod), 2005

Type	Input	Supplier	Supplier HQ country	Estimated input price (in $)	Price as percentage of factory cost	GM (in %)	Estd. value capture (in $)
Storage	Hard drive	Toshiba	Japan	73.39	51	26.50	19.45
Display	Display assembly	Toshiba–Matsushita	Japan	23.27	16	28.22	6.57
Processors	Video/multimedia processor	Broadcom	United States	8.36	6	52.5	4.39
Processors	Controller chip	PortalPlayer	United States	4.94	3	44.8	2.21
Battery	Battery pack	Unknown	Japan[a]	2.89	2	26.3	0.87
Memory	Mobile SDRAM Memory-32 MB	Samsung	Korea	2.37	2	31.5	0.75
Memory	Mobile RAM-8 MB	Elpida	Japan	1.85	1	17.6	0.33
Memory	NOR flash memory-1 MB	Spansion	United States	0.84	1	9.6	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		38.51

Source: Portelligent, Inc. (2006), company reports, and authors' calculations.

Data for Toshiba–Matsushita Display, a 60/40 joint venture, are weighted averages of consolidated data for Toshiba and Matsushita.

Battery GM calculated from FYE 3/06 data for TDK (consolidated) from TDK 20-F for FYE 3/06.

[a]Supposition.

Table A3 The most expensive inputs in the HP nc6230 notebook PC, 2005

Type	Input	Supplier	Supplier HQ country	Estimated input price (in $)	Price as percentage of factory cost	GM (in %)	Estd. value capture (in $)
Processors	Main chipset + Wi-Fi	Intel	United States	205.43	24.0	59.4	122.03
Processors	Graphics processor	ATI Technologies	United States	20.50	2.4	27.6	5.66
Processors	Ethernet controller w/transceiver	Broadcom	United States	2.01	0.2	52.5	1.06
Processors	Cardbus controller	Texas Instruments	United States	3.28	0.4	48.8	1.60
Processors	I/O controller	Standard Micro-systems (SMSC)	United States	1.42	0.2	46.0	0.65
Processors	Battery charge controller	Texas Instruments	United States	1.22	0.1	48.8	0.60
Display	Display assembly	Toshiba Matsushita Display	Japan	137.14	16.0	28.2	38.70
Software	Windows XP Pro OEM license	Microsoft	United States	100.00	11.7	84.8	84.80
Storage	60GB hard drive	Fujitsu	Japan	68.00	7.9	26.5	18.02
Storage	DVD–ROM/CD–RW drive	Matsushita	Japan	40.00	4.7	30.8	12.32
Memory	Memory board (512 MB)	Samsung	Korea	29.65	3.5	31.5	9.34
Memory	DDR SDRAM memory 2 × 32 MB	Hynix Semiconductor	Korea	5.68	0.7	37.3	2.12
Battery	Battery pack	Unknown	Japan[a]	40.52	4.7	24.0	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		332.80

Source: Portelligent, Inc. (2005b), company reports, and authors' calculations.

Battery GM is the average of the FYE 12/05 or 3/06 data for the five leading makers of notebook batteries (combined market share of ~90%).

[a]Supposition.

Table A4 The most expensive inputs in the Lenovo ThinkPad T43 notebook PC, 2005

Type	Input	Supplier	Supplier HQ country	Estimated input price (in $)	Price as percentage of factory cost	GM (in%)	Estd. value capture (in $)
Processors	Main chipset + Wi-Fi	Intel	United States	205.34	23.5	59	121.15
Processors	Graphics processor	ATI Technologies	United States	21.70	2.5	28	6.08
Processors	Microcontroller	Renesas	Japan	2.83	0.3	24	0.68
Processors	Power supply monitor/controller	Toshiba	Japan	2.11	0.2	26	0.55
Processors	Single chip LAN controller	Broadcom	United States	2.01	0.2	53	1.07
Processors	PC card controller	Ricoh	Japan	1.81	0.2	42	0.76
Processors	Power management ASIC	IBM	United States	1.42	0.2	40	0.57
Processors	Microcontroller	Philips	Europe	1.16	0.1	32	0.37
Display	Display module	Toshiba–Matsushita Display	Japan	138.32	15.8	28	38.73
Software	Windows XP Pro	Microsoft	United States	100.00	11.4	85	85.00
Storage	60GB hard drive	Hitachi	Japan	68.00	7.8	23	15.64
Storage	CD/DVD drive	Hitachi–LG Data Storage	Japan	40.00	4.6	25	9.80
Battery	Li-ion battery pack	Sony	Japan	41.06	4.7	37	15.19
Memory	Memory module	Hynix	Korea	29.68	3.4	41	12.17
Memory	32MB DDR SDRAM	Hynix	Korea	5.68	0.6	41	2.33
		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

Note: Assembly and test estimate excludes final assembly, which was done in-house by Lenovo.
Source: Portelligent, Inc. (2005a), company reports, and authors' calculations.