**The Performance Impact of Core Component Outsourcing: Insights From The LCD TV Industry**

Madhu Viswanathan

(madhu_viswanathan@isb.edu)

Prokriti Mukherji

(prokriti.mukherji@kcl.ac.uk)

Om Narasimhan

(o.narasimhan@lse.ac.uk)

Rajesh Chandy

(rchandy@london.edu)

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Madhu Viswanathan is assistant professor at Indian School of Business, Hyderabad, India Prokriti Mukherji is a lecturer in marketing at Kings College, London, Om Narasimhan is the Professor of Marketing and Deputy Head of Department, London School of Economics. Rajesh Chandy holds the Tony and Maureen Wheeler Chair at the London Business School, where he is a Professor of Marketing. We would like to thank conference participants at AMA, San Diego, Marketing Science, Vancouver, and UTD-FORMS for helpful comments and Stephanie Lenway and Tom Murtha for generous use of their data.

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## ABSTRACT

Firms in technology markets often outsource the manufacture of core components – components that are central to product performance and comprise a substantial portion of product costs. Despite the strategic importance of core component outsourcing, there is little empirical evidence (and many conflicting opinions) about its impact on consumer demand.

We address this gap with an examination of panel data from the flat panel television industry, across key regions globally. Results from our estimation indicate that core component outsourcing reduces the firm's ability to be on the technological frontier; this hurts demand, because our estimates suggest that consumers care about firms being on the frontier. On the other hand, such outsourcing also reduces costs. Finally, we find that outsourcing increases the intensity of competition in the marketplace. We assess these (often opposing) effects, and conduct thought experiments to quantify the performance impact of core component outsourcing.



*Keywords*: High technology markets; outsourcing; technology frontier.

## INTRODUCTION

In 2004, Sony was the third largest selling brand of LCD TVs in the United States by market share[1]. Remarkably, none of the core components of the TV (such as the LCD screen) was manufactured by Sony; all were outsourced from other firms. Similar stories on core component outsourcing (defined as sourcing from outside suppliers, components that are central to product performance and comprise a substantial portion of the costs of these products) are common in other industries, including electronics, pharmaceuticals, automotive, and food and beverage production (Tully 1994; Varadarajan 2009).

Nevertheless, some fundamental questions about this practice remain unanswered. From a marketing viewpoint, perhaps the most fundamental concern is the impact of outsourcing on consumer demand. There is a fair amount of theoretical literature, along with some empirical evidence, that has suggested that outsourcing can help reduce costs (Anderson and Weitz, 1986; Roodhooft and Warlop, 1999). There has been almost no empirical examination of the countervailing conjecture that core component outsourcing can lead to a reduction in innovation, and a decline in brand value and differentiation (e.g., Bettis et al. 1992; Quinn and Hilmer 1994). Reflecting these opposing forces is a strand of the literature that counsels more sanguinity about the likely effects of core component outsourcing, suggesting that the cost reduction afforded by core component outsourcing would allow firms to focus resources on other (e.g., non-product) aspects of their marketing strategies (Helper and Sako 1995; Nishiguchi 1994).

Most of the above has been, at best, conjecture. As Bengston (2008, p. 373-74) notes, “Despite the popularity of outsourcing there are few systematic and large-scale studies [on] the actual effect of outsourcing on firm performance. The few results are furthermore contradictory.” Indeed, those firms that do not outsource core components often have strong opinions about the wisdom of their decision. For example, Yoon Boo Keun, president of Samsung's TV business (which does not outsource any of its LCD screens) believes that outsourcing core components such as the LCD screen for LCD TVs is “tantamount to abandoning your brand" (*BusinessWeek* 2010). His counterparts from Panasonic, and Toshiba, each of whom have outsourced this core component to others such as Samsung, presumably did not share his sentiments. Diametrically opposing views on the performance impact of core component outsourcing seem common.

It is not entirely surprising that studies looking at the impact of outsourcing on consumer demand are relatively scarce. One can, following prior literature, point to two ways that outsourcing can affect demand: a) through a reduction in the firm’s costs, and quite possibly final prices; b) through a reduction in the innovation ability of the firm, an attribute which could be of some significance to consumers. However, measuring these effects is another matter altogether, and is fraught with

[1] Samsung and Sony entered into an arrangement to jointly produce LCD screens at the end of 2004 and started production soon after the end of our data period (Sony 2005)

significant complications that might help explain the conflicting conclusions in research and practice. Perhaps the most obvious challenge is the fact that any effect on consumers is likely to be indirect. Few customers are aware of the provenance of the components in products they buy, even if these components are central to the performance of these products, and even if these components comprise a substantial portion of the costs of these products. Moreover, firms often use mixed strategies when outsourcing core components: they outsource core components in some of the products within their product lines, and eschew outsourcing in other products within the same product lines. To return to the TV example, only 42% of Philips LCD TVs involved outsourced LCD screens; the others were manufactured in-house. Any comprehensive attempt to assess the impact of core component outsourcing on consumer demand therefore requires a plausible framework to assess the process by which core component outsourcing across different products from the same firm might affect demand. Apart from modeling issues, this, as we will note below, imposes data requirements that are not easy to surmount.

Our paper presents an initial attempt at overcoming these challenges; developing a conceptual framework, putting together a data set with the required characteristics, and implementing an empirical methodology that helps assess the impact of core component outsourcing on various performance outcomes. Specifically, we seek to make three contributions to the literature.

First, we specify and test a process by which outsourcing affects consumer demand. More specifically, we assess consumer response to outsourcing-induced reductions in costs and technological performance, which manifest themselves in the form of (potentially) lower prices and negative brand spillovers due to lowered technological performance.

Second, we explicitly model competitive interactions in our model. Depending on the particulars of the situation, competitive response can either enhance or diminish a firm's profits. Almost none of the prior literature on outsourcing considers the role of competition explicitly. This is a major omission, as it displays a lack of verisimilitude - most industries are fairly competitive, with competitive pressures often cited as a reason for outsourcing. Further, insights from models that do not incorporate competition could lead to erroneous conclusions on the efficacy or otherwise of a firm's outsourcing strategy. Our work explicitly considers strategic behavior on the part of all the firms.

Third, we develop a model that explicitly helps achieve the two contributions above, i.e., we build a detailed model of consumers who choose the product that gives them the highest utility, and a supply side where competing firms make outsourcing decisions and pick prices with a view to maximizing profits. We combine this with a model of how outsourcing affects the marginal cost and technological performance of the firm's products.

We build and test our framework using a unique data set from the flat panel television market spanning three major regions – North America, Europe and Japan, over a two-year period (2004-

2005). Our data contains unusually detailed information on prices and product attributes, as well as on outsourcing decisions for these products. The rich information on product sourcing decisions across many technologies allows us to correct for the possibility that unobserved firm level attributes and unobserved market characteristics can affect both the use of particular sourcing decisions and the outcomes of these decisions.

***Conceptualization***

Our conceptual framework consists of three pieces. These can be thought of as covering i) firm-level effects; ii) consumer effects; and iii) competitive effects.

*Firm-level implications*. The first piece deals with the firm-level implications of the outsourcing decision, and itself has two related components: i) the impact of outsourcing on the firm's technological performance, and ii) the impact of outsourcing on costs. Prior literature suggests the main tradeoff that is at the heart of our paper: outsourcing could reduce technological performance, a negative effect; on the other hand, it could help reduce the marginal costs of the firm, a positive effect.

The negative technology effect could occur for two reasons. First, the notion of absorptive capacity, tied to the resource-based view of the firm, suggests that by outsourcing, firms reduce their ability to develop internal knowledge, reducing their (absorptive) capacity to assimilate external knowledge (Cohen and Levinthal 1990; Fichman and Kemerer 1997; Leiblein et al. 2002). These problems are more acute in high technology industries, where downstream suppliers often control vitally important new technology. Therefore, internalizing these technological capabilities affords firms control and access to the knowledge necessary to build a portfolio of cutting-edge products (Afuah 2001). Second, the transaction cost economics literature suggests the danger of lockout, i.e., suppliers might be unwilling to supply cutting edge technology unless firms pay a premium for it (Teece 1987).

We examine the idea of technological performance through the lens of a *technology frontier*, defined as the most advanced commercial manifestation of a core technology as embodied in products in the market (Anderson and Tushman 1990; Levinthal 1998; Tushman and Anderson 1986). It is important to clarify that the technological frontier is not something that is only a possibility (e.g., manned Mars flights as the frontier for space tourism); it is embodied in a product that is currently available to consumers. Following the discussion above, we suggest that *outsourcing reduces the ability of a firm to attain the technology frontier*.

The positive effect of outsourcing on costs could also occur for two reasons. First, and most obviously, one avoids a large fixed cost expenditure on plant and equipment if one outsources (Bettis et al. 1992; D'Aveni and Ravenscraft 1994; Gilley and Rasheed 2000). Second, a considerable literature has suggested that outsourcing firms can benefit from the high-powered incentives of the market place (Chesbrough and Teece 1996; Monteverde 1995; Teece 1996), leading to lower marginal cost production and reduce investments in plant and equipment (Bettis et al. 1992; D'Aveni and Ravenscraft 1994; Gilley and Rasheed 2000; Quinn 1992). The latter argument is related to that on core competence (Prahalad and Hammel, 1990), in that a firm could outsource manufacturing to another firm with a greater degree of competence in that function.

Following the argument above, we suggest that *outsourcing reduces marginal costs* and refer to this as the *efficiency effect*[2]. While previous literature has suggested such an effect, our econometric estimation helps us quantify its magnitude, while accommodating a hitherto unaccounted for set of demand and supply side factors.

*Consumer Implications*. The second piece of our framework gets to the heart of our research question and examines the impact of the effects mentioned above on consumer demand. It does so by modeling a consumer with a set of preferences of her own. We argue that a firm's position on the technological frontier positively influences consumer perceptions of its products. More formally, we hypothesize an *aura effect*, whereby consumers use distinctive attributes from one product in a firm's product line to make inferences about other products in its product line (Dacin and Smith 1994; Sullivan 1990). The existence of this effect acts as an inducement for firms to try getting on the frontier.

A rich literature in marketing has suggested that in complex situations where product quality is difficult to ascertain, consumers use other product attributes (such as price and brand name) to infer quality (e.g., Del Rio et al. 2001; Jacoby et al. 1971; Keller 1998, 2001). In high technology markets, a firm's position at the technological frontier is a characteristic that signals the technological edge a firm possesses over its competitors. Firms go to great lengths to advertise and generate positive word-of-mouth for their leading-edge products, e.g., displaying their latest technological breakthroughs in trade shows and industry events to grab the attention of members of the media and of early adopters. Being on the technological frontier creates additional 'buzz' for the firm, leading to a positive reinforcement of the firm's image as a technological leader. These arguments suggest that a firm's position on the technological frontier creates an aura effect that is used by consumers to evaluate products. If a firm's position on the technology frontier offers an aura, then following the arguments in prior literature, we suggest that it should generate positive spillover effects on the overall evaluation (and thus demand) of other products sold by the firm.

*Competitive Implications*. The third piece of our framework is the effect of competition on everything discussed in the first two pieces above, i.e., on the potential costs and benefits of outsourcing. Some prior literature has suggested that competitors' responses to a focal firm's outsourcing strategies might diminish the positive impact of outsourcing for the focal firm (Bettis et al. 1992; Gilley and Rasheed 2000; Quinn 1992). However, to the best of our knowledge there has

[2] Note, however, that nothing in our framework *presupposes* the existence of cost reduction – this is an empirical matter that our data and technique are well-suited to shed light on.

been no empirical test of this effect. Clearly, competition matters greatly when consumers pick a product from amongst various alternatives; in a situation of differentiated competition, the response of competitors will directly impact consumer choice, prices, and profits. The magnitude of this effect, which we call the *strategic effect*, is determined by how 'close' competitors are in attribute space. There is a positive aura effect because of which everyone wants to locate at the frontier (minimal differentiation), and a strategic effect from wanting to avoid the intense price competition that ensues as firms get closer to each other in attribute space, which causes firms to move away from the frontier (maximal differentiation). Our econometric specification builds on a game theoretic framework that allows for strategic response by competitors (Berry, Levinson, Pakes 1995).

In sum, our framework suggests three effects of the firm's decision to outsource (or not) core components of its products. The three effects in the case of a move from in-house production to outsourcing are: i) a reduction in the marginal cost of production (*efficiency* effect); ii) a reduction in the likelihood of being on the technological frontier, thus lowering the firm's attractiveness to consumers (*aura* effect); and ii) an impact on prices through the new configuration in product attribute space of the firm relative to its competitors (*strategic* effect). It is the net impact of these effects that determines whether and when the firm is better off making the move to core component outsourcing.

The paper closest to our research question is by Sun and Li (2011), who examine the impact of consumers' onshore and offshore experiences on service duration and customer retention. Firms, in their paper, use a dynamic programing approach to learn about heterogenous consumer preferences, and balance short term costs with long term customer retention to maximize long term profit. Our paper differs from theirs in several ways. First, as we explain above, the competitive implications of outsourcing actions is a key part of our research framework. Second, there are several differences in context between their situation and ours (service centers vs. HDTV market). Chief among them is that consumers in their context get assigned to their representative (product) while consumers in our context have to make an active choice decision. Finally, our focus on outsourcing and demand through its impact on innovation and costs is markedly different from their focus on outsourcing and customer retention due to differences in consumer heterogeneity. While these differences lead to very different conceptual and modeling approaches, they also provide very different (albeit complementary) managerial insights. For instance, Sun and Li have much to say on the dynamics of customer response to the outsourcing decision; our paper is silent on that but speaks to the impact on innovative ability as well as costs, and the competitive response to the outsourcing decision.

Our research is embedded in the LCD TV context; as such, it behooves us to speak to the issue of generalizability. We do so along two dimensions – conceptual and methodological.

Conceptually, our research examines the impact of core-component outsourcing on demand through its impact on price and position on the technology frontier. While our focus on the technology frontier is dictated by the industry being studied, it can be applied to other product features, or even something as broad as an overall quality dimension. Similarly, our focus on core-component outsourcing is governed by the variation available in our data but the idea can be extended to both other forms of outsourcing (e.g., OEM outsourcing).

In terms of methodology, it is fair to say that there are pieces of our model that are very particular to the context being studied (e.g., the notion of how outsourcing affects ability to get on the technology frontier), and others that are fairly generalizable (e.g., the demand estimation). This is very similar to most work in the empirical industrial organization tradition, wherein there are context-specific features overlaid on standard models (e.g., Bresnahan 1989; Gentzkow and Shapiro 2010; Reiss 2011).

***Preview of Results***. Outsourcing comes, not surprisingly, with a significant saving in fixed costs. The number is of the order of $455 Million for Liquid Crystal Display (LCD) and $277 Million for Plasma Display Panel (PDP) plants. Further, there is a significant efficiency effect – our estimates suggest that core component outsourcing reduces the marginal cost of production, leading to a cost saving of almost 21% on average. On the flip side, we find that outsourcing negatively impacts a firm's ability to get on the technological frontier; it is 17% less likely that a firm will get to the technological frontier if it switches from producing in-house to outsourcing the core components in its products. Our estimation confirms the aura effect due to a firm's position on the frontier, i.e., a firm's proximity to the frontier has a positive effect on demand. More precisely, moving 10" more on the technology frontier results in almost $3.2 million in additional demand. Finally, we offer novel insights around the strategic effect. For example, we find in one of our thought experiments that if a firm hitherto engaged in production in-house outsources, it hurts the profits of firms that are already away from the frontier, because of enhanced competition due to reduced differentiation. We also analyze a joint venture between Sony and Samsung and find that it would lead to reduced profits for both parties, while benefitting some competitors.

## DATA & MEASURES

### *Empirical Context*

A comprehensive test of the effects noted above imposes some data requirements; some of these requirements have, as we noted earlier, bedeviled previous attempts at empirical analyses on outsourcing. First, it requires data on core component outsourcing decisions – ideally at the level of each product in the relevant firm's product line. Because the decision to outsource is considered sensitive by many firms, this data is rarely available in a comprehensive manner. Second, it requires data on consumer response to each of the products offered by key firms in the industry. Moreover, because many firms today – especially in the technology sector – produce products for global markets, the ideal data context would also include consumer response across key regions across the globe. Third, it requires comprehensive data on a variety of drivers and outcomes of core component outsourcing – in particular on the technology frontier, as well as on prices, brands, and relevant technology characteristics. Moreover, to test the competitive (strategic) effects and the aura effects noted earlier, this data should be available for all key players in the industry and for all products in the respective product lines of these players. Ideally, this data should also be available over multiple points in time, so that heterogeneity due to unobserved brand-level and time-level factors can be accounted for.

An empirical context that fulfills all of the requirements noted above is the global flat panel television market. Additionally, this market is also important from an economic perspective. With revenues of over $24.2 billion in 2007 (*DisplaySearch* 2007), this market remains one of the largest in consumer electronics, estimated to be $147 billion in 2020 (*Global Industry Analysts* 2020).

The flat panel television market (in the time period of our data, i.e., 2004-2005) was dominated by Liquid Crystal Display (LCD) and Plasma Display Panel (PDP) technologies. Plasma technology first appeared in the market in 1997. The strength of plasma is the ability to produce large flat panels measuring just four-inches deep with better than 720 progressive resolution capability. The weakness of plasma is that it is expensive to produce, uses phosphors that can cause pixels to age and burn unevenly, and produces a heavy panel that requires a custom installation. LCD technology, plasma's main rival, has been used in high-end projectors for many years.

The manufacture of flat panel displays is a technically challenging, expensive and risky process. For example, the seventh generation of Thin Film Transistor (TFT) LCD fabrication plants required an investment of between $1.5 billion and $2 billion per plant (Hart 2008). The investment is risky for a variety of reasons: i) uncertainty about the future demand for LCD and plasma televisions of various sizes, ii) uncertainty about how many competitors will enter the fray and when, and iii) uncertainty about future technological trajectories. The alternative to making these large investments is to outsource production.

The principal groups involved in component manufacturing can be categorized into contract manufacturers like AU Optronics, Quanta Display, and Chunghwa Picture Tubes, and TV manufacturers like Samsung who also supply to rival brands like Sony[3]. The key difference between the groups is that the contract manufacturers generally do not build finished TV sets while the TV manufacturers do. A majority of the contract manufacturers are based out of Taiwan. That said, actual manufacturing locations vary depending on labor costs, with both contract and TV manufacturers operating plants all over the world. Competition is intense in component manufacturing, with contract manufacturers competing not only among themselves but also with TV manufacturers to supply screens to brand owners (*Wall Street Journal* 2004). There are several firms (37 in our data) in the HDTV retail consumer market who compete not only with products in the HDTV segment but also

[3] In our data, whenever we observe mutual alliances for manufacturing jointly, we treat the decision as being insourced.

with product offerings from other technologies (CRT, RP_CRT). The availability of several competing products across different sizes and technologies forces firms to be extremely competitive on retail prices (*EPA* 2006).

***Data***

Our data, which comes principally from *DisplaySearch* reports, contains average quarterly retail price and sales information at the brand, technology (both LCD and plasma) and size levels for flat panel televisions sold in North America, Europe, Japan, China and an aggregated region referred to as the "Rest of World" (ROW), from October 2004 to October 2005. Details on the variables along with their descriptive statistics are given in Table 1. On the supply side, our data has information on whether the core components (as described in the measures section below) for each of the products in each firm's product line were outsourced or produced in-house. We supplement this core dataset with information on local wage levels, the Consumer Price Index, and outsourcing strategies that firms in our sample used for other technologies.

We construct our dataset by matching shipment and revenues of TVs to prices. These prices roughly coincide with the sales-weighted average of prices paid at the retail point of sale. We arrive at the final sample used for estimation as follows. First, of the five regions (North America, Europe, Japan, China, and Rest of the World) for which we have data, the first three account for over 86% of the revenue from flat panel televisions in our sample period. We therefore restrict our sample to these three regions. Figures 1a and 1b show the quantity sold in these regions by brand and technology. Note that LCD is the more popular technology in all three regions. Within these technologies, Sharp is the largest selling LCD brand in Japan and North America, while it is outsold by Philips in Europe. Similarly, Panasonic is the largest selling plasma brand in Japan and North America, but is outsold by Philips in Europe. Second, while our display sizes range from 10" to 62", the individual shares for each size are often very small. The average market shares across different sizes ranged from a maximum of 0.9% for 12" TVs to a minimum of 0.05% for 42" TVs. We therefore aggregate the individual size level variables into five discrete categories[4]. Third, there are 37 brands in our data, but most of them are small - the eight largest brands account for 75% of the total quantity sold. For ease of estimation, all brands other than these eight largest brands are combined into one composite brand. The average market share of the combined brands was around 0.86%. All this leaves us with 50 unique products (where a product is a combination of brand-technology-size) across markets. Not all products are available in all markets. Table 2 shows the distribution of products across different markets. Tables 3-5 show temporal patterns in products, market share, outsourcing in our data. These

[4] We run a series of robustness checks with different definitions of the product and consequently different data aggregations. In particular, we considered a specification with *no aggregation* on either brand or size, and another with no aggregation on size but aggregation on brand. The results are broadly unchanged and reported in the online appendix.

tables confirm that there is very little variation in these variables over time. Our final sample for analysis is an unbalanced panel comprising 383 observations.

A final issue relates to the specification of the outside good, which requires a definition of the total market size. We define the total market size as the number of televisions (of any technology, not just LCD and plasma) sold in that market, where a market is a region at a particular time.

***Measures***

There are two constructs that are central to our research questions. First, since we want to examine the existence and magnitude of the aura effect that accrues to a firm that is on the frontier, we need a measure of the technological frontier for each firm. Second, since we hypothesize that this frontier is affected by whether the firm outsources production or not, we need a measure of core component outsourcing. We now discuss these two measures.

*Technology Frontier*: In many high technology industries, in the short to medium term, the locus of technological performance is along a single central dimension. For example, Christensen (1997) notes that in the disk-drive industry, the primary basis for technological performance improvements was the size of the hard disk (the size of the hard disk shrank from 8.5” to 5.25” to 3.5” to 1.4” over the 1978 to 1993 period, thus moving the technological frontier in the industry accordingly). Other authors (e.g., Tushman and Anderson 1986) have also used a single dimension to describe the technology frontier in an industry (e.g., seat-miles capacity of the most capable plane flown to describe the frontier in the aircraft industry; central processing unit (CPU) speed of the fastest model to describe the frontier in the minicomputer industry).

In the case of flat panel televisions, display size was the primary dimension on which technological performance differed across players during the period we study. As display size increases, it creates new challenges for equipment manufacturers; large glass substrates require special handling technologies because of the tendency of glass to sag when transported horizontally. Large display sizes also cause a shift towards enhanced production technology (more efficient and cost efficient) and new tools and equipment for handling the larger sizes (Hart 2008). While these are ‘supply side’ reasons for the importance of display size, there exist equally compelling demand side reasons. Firms actively advertise leadership in TV size, and both consumer electronics shows and retailers feature the largest sizes prominently. The biggest (by size) TV product launches at technology trade shows like Consumer Expo Show (CES) often garner a lot of media exposure (e.g., on CNET, CBSnews.com, FoxNews.com and *Engadget*; see CES 2009, CES 2011). This suggests that during the period covered by our data, consumers were likely aware of the largest size currently available, as well as the identity of the firm selling it. Further, while a number of technological attributes such as resolution and refresh rate are cited by industry observers as important determinants of product performance, there was little differentiation between brands on these attributes during the period we study. For instance, on both pixel resolution (number of pixels) and refresh rates, there is almost no variation across firms, region and time[5]. In contrast, size is an important attribute that firms do differ on. Given these demand and supply factors, we define the *TechnologyFrontier* variable as the maximum display size a firm *can* produce, based on supply chain (production data) information. Figure 2 is a snapshot of supply chain data for three brands (Sharp, Samsung and Sony) in period 2 for LCD technology (the sheet for plasma technology is very similar). The highlighted rows represent the technology frontier for that brand for LCD technology. To see how the sheet ties into our definition of a company-specific technology frontier, consider three examples. First, Sharp, which does not outsource out all. Notice in the first three rows that the LCD supplier for all of Sharp's TVs is Sharp itself. Its technology frontier is the biggest size it is currently able to produce, which is 65". Next, consider Samsung, which outsources partially - the LCD supplier for the 15" Samsung TV is BOE Hydis, while the other sizes are made by Samsung itself. The technology frontier for Samsung happens to be 46". Finally, consider Sony, which outsources completely – all of its LCDs are supplied by CMO or Samsung. Its technology frontier is 46", because that is the maximum size it can produce. As is evident, the term sheet is the basis for our definition, and permits a unique measurement of the technology frontier for each firm. The measure has the merit of accurately reflecting the firm's current technological capability, in that we know this is the best the firm can do currently. Additionally, it doesn't vary by market, and is consequently less likely to suffer from market targeting or competitive reasons. Note that this does not preclude the existence of other quality attributes, unobserved to us in the data, that might influence consumer perceptions of the technological frontier. It is important therefore to control for quality that is observed to consumers but unobserved to us, and we do so in our estimation.

Our *TechnologyFrontier* measure indicates the position of each firm on the technological frontier at a particular point in time. Note that the measure is at the *firm* and *technology* level. It is important to emphasize that the technological frontier is defined by what is actually realized in the market and not a notion of a possible goal to reach. Figure 3 shows the variation of different brands on this measure. There are interesting patterns, in that Samsung, Panasonic and LGE are higher on the *TechnologyFrontier* in PDPs than the other firms, while Sharp has the highest position in LCD TVs.

*Core Component Outsourcing*: The data contains detailed information on the ownership structure of the major components of flat panel televisions. We are therefore able to identify the owner of the final product (brand owner), as well as the supplier of the core component, namely the display screen. We use this information to create our measure of outsourcing. We operationalize outsourcing at two levels - the product level and the firm level. The product level measure captures the fact that the decision to outsource is taken at the product level. The firm level measure captures the relation

[5] As a check, we redid the estimation with pixel resolution as the key technological performance differentiator; the impact of *TechnologyFrontier* turns out to be insignificant. We also ran a specification with our current measure of *TechnologyFrontier*, but with resolution as an additional covariate. This also left our results qualitatively unchanged (see online appendix), with pixel resolution still being insignificant.

between outsourcing and the firm's position on the technology frontier. At the product level, a product is considered to be produced in-house and is assigned a value of 0 if a firm that is the brand owner is also the screen supplier for that product. In instances where the display screen is not manufactured in-house, the measure is assigned a value of 1. For example, Panasonic is the brand owner and display screen manufacturer for its 37" plasma TV and is therefore assigned a value of 0 on the outsourcing measure. Toshiba, on the other hand, puts its brand name on a 37" plasma TV obtained from external suppliers and is assigned a value of 1 on the measure. In cases where the product is manufactured both in-house and externally, we assume that it is outsourced if it has multiple external suppliers.

To obtain the firm level measure of outsourcing, we calculate the average outsourcing of all products produced by that firm at a particular time. In the above example, Panasonic manufacturers all its plasma products in-house and is assigned a value of 0. Toshiba, on the other hand, outsources all its components and is assigned the value of 1.

***Model-free Evidence***

We are interested in examining the relationship between outsourcing and demand through its impact on prices and technological ability. Our dataset contains unique information on core component outsourcing at the level of each product in the relevant firm's product line, along with consumer sales, prices, brands, and relevant technology characteristics for key players in three regions across the globe for four quarters. This rich variation allows us to examine the relationship between core component outsourcing, price and the technology frontier. Figures 4a, and 4b show the relationship between our measures of core component outsourcing, price, technology frontier and quantities sold. Greater core component outsourcing is accompanied by lower price (Figure 4a) and lower position on the technology frontier (Figure 4b). The figures in general are consistent with what our conceptual framework would suggest, i.e., we would expect outsourcing to lead to lower costs, manifested in lower prices to the consumer. We would also expect it to lead to lower technological ability, in the form of a lower frontier.

While the figures in general are consistent with our expectations, they don't control for various factors that are likely to be important, such as region, time, brand, technology, or size. They also do not account for the endogeneity problem that arises because both prices and the technology frontier are endogenous. We address these issues in a preliminary fashion with a reduced form specification that is light on assumptions.

***Reduced Form Analysis***

As a first step, we address the endogeneity issues along with controls for various factors by estimating a three stage least squares regression (3SLS), with i) quantities sold, ii) prices, iii) *TechnologyFrontier* and iv) *Core Component Outsourcing* as endogenous variables. The four equations in our 3SLS can be usefully thought of as a series of 2SLS estimations. Identification requires at least one regressor that affects the endogenous variables exclusively. In our estimation, we assume that raw material costs affect prices but not quantities or the *TechnologyFrontier*, while firms' outsourcing strategies in CRT, RPTV technologies are assumed to affect *Core Component Outsourcing* but not prices, *TechnologyFrontier* and quantities sold. Finally, quantity sold is affected by price and *TechnologyFrontier* but not by *Core Component Outsourcing* directly. Table 6 shows the results of this estimation. *TechnologyFrontier* has a positive impact (0.17, $p<0.01$) on quantities sold while prices have a negative impact (-0.05, $p<0.01$). More importantly, as hypothesized, both prices and *TechnologyFrontier* are affected negatively by core component outsourcing (-4.85, $p<0.01$ and -38.22, $p<0.01$ respectively).

The combination of model-free evidence and reduced form analysis does reinforce our research premise, but it falls short of quantifying the mechanism behind the outcomes observed. Further, the evidence above cannot speak to any competitive effects, since competition was not explicitly modeled. A satisfactory resolution requires a structural model, which we turn to next.

## MODEL AND ESTIMATION

To start with, it is useful to ask what a reasonably complete modeling of the phenomenon we are interested in (i.e., outsourcing and its impact) would entail. Based on our discussion so far, there would have to be i) a modeling of the decision by the downstream firm to outsource; ii) a modeling of the impact of this decision on immediate, firm-specific outcomes, such as marginal costs and technological ability; iii) a modeling of competitive interaction between the firm and others selling the same final product; and iv) a modeling of demand specifying how the end consumer picks between products. In what follows, we describe each of these components of our model in detail. For each component, we discuss the behavioral foundations, link it to an econometric specification, and discuss our estimation strategy, with specific discussion around the use of instrumental variables, when warranted.

Our modeling approach is as follows (see **Figure 5** for a flowchart of the model and estimation strategy). In **stage 1**, firms decide on outsourcing strategies for all their products. They do this by considering the strategy that yields them the highest expected profits[6]. Firms have common knowledge of all factors that affect outsourcing decisions but the econometrician doesn't observe these shocks. The estimation output of this stage is the fixed cost of manufacturing in-house. In **stage 2** (consisting of two parts), the outsourcing strategy chosen earlier results in a realized technology frontier (**2a**) as well as impacts the firm's marginal cost of production (**2b**). At this stage, both demand and cost shocks are realized. These shocks, while observable to firms, are unobservable to the

[6] Firms don't observe individual realizations of demand and cost shocks but are aware of the distribution of these shocks. In addition, firms' outsourcing decisions are affected by two more shocks, one a mean zero measurement shock and two, a firm-technology level structural shock. While firms don't observe the measurement shock they are aware of the firm-technology level structural shock. Our assumptions are consistent with other papers using this methodology (Pakes et al. 2015, Ho et al. 2012, Lee 2013).

econometrician. Mapping on to our conceptual framework, 2b would give us an estimate of the efficiency effect. In **stage 3**, firms set prices, conditional on their outsourcing decision. Finally, in **stage 4**, consumers purchase and 'consume' the product (stage 4 estimation gives us the magnitude of the aura effect). In this stage there are two unobservable variables with respect to the econometrician, a product-time-region level unobservable and a product-level shock. One can think of the first three stages as constituting our supply model, and the fourth stage as specifying the demand model. Note that the model is estimated in reverse order, i.e., stage 4 is estimated first. The estimates from stage 4 are used to obtain both the price-margins and the marginal costs, which are used as inputs in stage 1 to obtain the fixed costs of sourcing. It is important to note here that while we have specified a sequence of stages, we do not model any dynamics in the process. Further, we should clarify that while our sequence has firms deciding on outsourcing, leading to a realization on the technology frontier, it is impossible to unambiguously observe this sequence, or to assess the intended positioning on the technology frontier that decision makers in each firm might have in mind.

Overall, our estimation procedure leads to the estimation of the following number of parameters across the four stages. In Stage 4 (the demand specification) we estimate 18 linear parameters and 5 non-linear parameters; 19 in Stage 3, wherein the firm sets prices; 13 parameters in stage 2 (marginal cost estimation) and 3 parameters in stage 1 (outsourcing decisions).

***Identification.***

Our identification strategy builds on features in our data. Briefly, in Figures 4a and 4b, we show that outsourcing has a negative relationship with both price and technology frontier. As discussed earlier, our reduced form analysis, in the form of a simultaneous 3SLS model treating quantity sold, *TechnologyFrontier*, price and outsourcing as endogenous variables also yields results that are in line with our hypotheses, e.g., that *TechnologyFrontier* has a positive impact on quantities sold while prices have a negative impact. More importantly, both prices and *TechnologyFrontier* are affected negatively by outsourcing.

Formally, identification of parameters of interest occurs through the natural variation in the data between sales, price and outsourcing (this is line with standard identification arguments made in this literature (BLP 1995, Nevo 2001, etc.)). In particular, the coefficients on price ($\alpha$) and TechnologyFrontier ($\beta$) in the demand estimation are identified with the variation in sales along with the variation in price and outsourcing respectively. The inclusion of region, time and brand fixed effects in the estimation absorbs all unobserved quality differences between products and sales, outside of outsourcing and price (Rossi 2014). In our context, outsourcing affects both price and technology frontier in the demand estimation. To separately identify the impact of outsourcing from that of price in the demand model, we require an exclusion restriction. In other words, we need variables that affect price independent of outsourcing's impact on price. These would, in our context, be factors like raw materials and technology used. Finally, the coefficient on outsourcing in the cost equation is identified by the variation of costs with respect to outsourcing, the price elasticity from the demand equation, and the price-cost relationship as defined by our pricing game. While the marginal costs are not directly observable, the variation in marginal costs is a function of the variation in price and quantities sold (marginal costs are obtained as an inversion of these two variables). Our figures suggest that this variation is indeed present. Finally, the fixed costs are identified by the variation in outsourcing both within a firm and across firms along with the structural assumptions on how the game is played (demand, price etc.). Figure G3 (in the online appendix) shows the variation in outsourcing both across and within firms on our measure, and does suggest reasonable variation.

***Stage 1: Outsourcing decision***

One can think of the outsourcing decision, at its most basic, as being made with the objective of profit maximization. Focusing on just the cost side, this would entail a firm comparing the cost of procuring the product from outside versus the cost of making it in-house, and picking the lower cost option.

Formally, the problem facing a firm *j* with $\Phi_j$ set of products is given by:

$$max_{\boldsymbol{o_j}} \Pi_{jt}(\boldsymbol{p}, \boldsymbol{\xi}, \boldsymbol{\epsilon}, \boldsymbol{o_j}, \boldsymbol{o_{-j}}) = max_{\boldsymbol{o_j}} \left( E\left[\pi_{jt}(\boldsymbol{p}, \boldsymbol{\xi}, \boldsymbol{\epsilon}, \boldsymbol{o_j}, \boldsymbol{o_{-j}})\right] - C_j(\boldsymbol{o_j})\right) \quad (1)$$

where $\boldsymbol{o_j}$ is a vector of outsourcing decision variables with a cardinality that is equal to the number of products in the firm's product line. For example, for a firm with *k* products, $o_j = \underbrace{\{1,0,1, \dots ,1\}}_{k}$ with the *k*th element representing the outsourcing decision of the *k*th product. $\boldsymbol{o_{-j}}$ are the outsourcing strategies for all other firms. All the bold faced letters $(\boldsymbol{p}, \boldsymbol{\xi}, \boldsymbol{\epsilon})$ are vectors of the corresponding *p*, $\xi$ and $\epsilon$ variables.

Profits depend on products offered, optimal prices as specified through equation (1), the structural error terms and the outsourcing strategies of other firms. The firm makes outsourcing decisions once every time period for each product across all regions for a particular technology (in other words, firms make sourcing decisions conditional on the technology chosen). Further, we assume that firms are aware of each other's objective functions (i.e., the objective functions are common knowledge).

We assume that firms make their outsourcing decisions before the realization of demand and cost shocks. These shocks are in the form of random shifts in demand and supply, e.g., a TV show on nature in Japan that increases demand for high definition TVs, or a sudden increase in oil prices in Japan that raises the cost of production and shipping. These shocks are random, mean zero, and unobservable to the firm (at the time of making the outsourcing decision). The expectation above is over the realization of demand and cost shocks. Let $v_o$ denote the difference between the realized profits given by equation (1) and profit expectations. We assume that $v_o$, usefully thought of as capturing measurement error, is unobserved by the econometrician and partially observed by the firm. In addition, $v_j$, a structural cost shock, captures firm-technology factors that affect the costs of outsourcing and insourcing; we assume that $v_j$ is identical across firm-technology combinations, observable to the firm but unobserved by the econometrician. Further, all firms are aware of the value of this shock (common knowledge). These assumptions are consistent with other papers using this methodology (Pakes et al. 2015, Ho et al. 2012, Lee 2013). Note that $v_j$ cannot accommodate private information shocks between firms, or different shocks for outsourcing and insourcing. Further details on assumptions regarding $v_o$ and $v_j$ are provided in the online appendix.

Denoting $r(\boldsymbol{o}_j)$ as the estimate of the observed profit that comes from the demand and cost estimates, the relationship between expected profits and $r(\boldsymbol{o}_j)$ is given by:

$$E[\pi_{jr}(\cdot)] = r(o_j) + v_o \tag{2}$$

Finally, there is a fixed cost, $F_j$, associated with the decision, i.e.,

$$C_j(\boldsymbol{o_j}) = \frac{\sum_{k\in\Phi_j} I\left(o_j^k=0\right)F_j}{\sum_{k\in\Phi_j} I\left(k\in\Phi_j\right)} + v_j \tag{3}$$

where $o_j^k$ represents the $k^{th}$ element of vector $\boldsymbol{o}_j$. We normalize the fixed cost of outsourcing to zero, which implies that $F_j$ is the fixed cost associated with insourcing. There are two things to note about our model specification. First, $r(\boldsymbol{o}_j)$ captures the notion that firms are uncertain about their profits $\pi_{jr}(\cdot)$ in this stage. Second, the profits of outsourcing one product in the portfolio depend on the outsourcing strategies of other products in the portfolio.

Before we turn to the estimation strategy, it is useful to discuss what the model does and what it does not. What it yields is the fixed cost of outsourcing (to be more precise, it yields the fixed cost of insourcing, or equivalently, the fixed cost savings from outsourcing). We conceptualize the fixed cost as consisting of things like plant and equipment. As such, it depends above all on the technology used. This is in line with industry understanding of such costs; the popular press, in discussing the costs of building new manufacturing plants, emphasizes that the cost is almost entirely determined by the technology that is sought to be used, with very little depending on the identity of the firm building the plant (see the *BusinessWeek* 2005; *Engadget* 2005; *New York Times* 2004). In addition, we allow the fixed cost to vary based on firms' prior experience in a related industry and technology. For example, if Sharp uses LCDs in making calculators, then we allow Sharp to gain those benefits while making LCD TV sets. In sum, we let our fixed costs vary by technology and the firm's experience in a related industry. In LCD, 25% of the firms had related experience in other technologies; this number was 29% in PDP. Our modeling is similar to prior literature, which has generally assumed similar fixed costs across firms conditional on a set of covariates (Bresnahan and Reiss 1991; Seim 2006). Note that to facilitate interpretation and comparison, the fixed cost that we estimate should be treated as the cost of building a plant for insourcing divided by the expected number of years the plant will be functional. Firms incur this cost every period they operate this plant. Firms can calculate the expected profits from operating under a particular sourcing strategy and decide on their sourcing strategy. It is important to note two important assumptions in our model. First, we assume that temporal patterns for anything not explicitly endogenized (e.g., product entry and exits) are assumed to evolve exogenously. Second, we assume that firms make decisions on outsourcing every quarter and no long term consequences (dynamics) are incorporated while making these decisions.

It is important to ask (and is a big part of our paper) as to what factors would cause profits to differ between in-sourcing and outsourcing, and why the calculus would differ across firms. The arguments we noted earlier suggest that there are two immediate supply side consequences to outsourcing – a possible reduction in marginal cost (the efficiency effect) and a possible retardation of technological capability, as seen in a lower frontier (manifested in consumer terms in the aura effect). Both of these then feed, through a price setting model, into a demand model that determines final sales, and, given costs, profits. A behavioral foundation for why firms would pick one or the other strategy, therefore, has to suggest differences in these outcomes across firms, and indeed that is what we do shortly.

*Estimation of Outsourcing*: We use a moment inequalities estimator developed in Pakes et al. (2015) to estimate the fixed costs of outsourcing. The estimation is based on a "revealed preference" approach to recovering parameter values, and is ideal for our purposes because it places profit maximization front and center (Crawford and Yurukuglu 2012; Ho et al. 2012; Lee 2013). Briefly, each firm, conditional on other firms' outsourcing strategies, maximizes its expected profits by choosing whether to outsource or not for each product in its product line; any deviation from the observed sourcing decision results in lower profits. This is the necessary condition that is standard in all Nash equilibrium games and leads to a set of moment conditions in the form of inequalities that are the basis of the estimator. For example, if Sony is currently outsourcing production of all its components, the estimation proceeds on the basis that the profits from this strategy exceed that from every other strategy (e.g., a strategy that insources all components, or a strategy that insources some components and outsources others, etc.) that Sony can employ. In general, the procedure uses estimates from the demand, marginal costs and technology frontier equations to compute the new pricing equilibrium and subsequent profits for (outsourcing) decisions that the firm could have taken but chose not to. The difference between the observed decision and counterfactual decisions that are not observed is used to generate moments.

Let $o_j^k$ represent the current sourcing strategy for firm *j*, where the *k*th product is being outsourced, and $o_j^{k\prime}$ the new sourcing strategy for firm *j* where the *k*th product is being insourced. Then the following condition must hold:

$$E\left[\pi_{jt}(\boldsymbol{p},\boldsymbol{\xi},\boldsymbol{\epsilon},\boldsymbol{o_j^k})\right] - C_j(\boldsymbol{o_j^k}) \geq E[\pi_{jt}(\boldsymbol{p}',\boldsymbol{\xi}',\boldsymbol{\epsilon}',\boldsymbol{o_j^{k'}})] - C_j\left(\boldsymbol{o_j^{k'}}\right) \quad (4)$$

Substituting equations 2 and 3 in equation 4, we get

$$r\left(o_j^k\right) + v_o - \frac{\sum_{k\in\Phi_j} I\left(o_j^k = 0\right)F_j}{\sum_{k\in\Phi_j} I\left(k \in \Phi_j\right)} + v_j \;\geq r\left(o_j^{k'}\right) + v_{o'} - \frac{\sum_{k'\in\Phi_j} I\left(o_j^{k'} = 0\right)F_j}{\sum_{k'\in\Phi_j} I\left(k' \in \Phi_j\right)} + v_j$$

$$F \geq \frac{1}{\left(\frac{\sum_{k\in\Phi_j} I\left(o_j^k=0\right)-\sum_{k'\in\Phi_j} I\left(o_j^{k'}=0\right)}{\sum_{k\in\Phi_j} I\left(k\in\Phi_j\right)}\right)}\left(r\left(o_j^k\right)-r\left(o_j^{k'}\right)\right)+\Delta v \tag{5}$$

Similarly, if firm $j$ moved from insourcing its $k^{\text{th}}$ product to outsourcing, we would get

$$r\left(o_j^k\right)-r\left(o_j^{k'}\right)+\Delta v \geq \Delta F \tag{6}$$

As long as firms have correct expectations on average, $\Delta v$ will go to 0 as the sample size goes to infinity. Note that $v_j$ drops out of the equation, as this is a shock at the firm-technology level and is common to strategies within the firm. We obtain moments by exploring all the different sourcing strategies that firms could have utilized but decided not to, and then re-computing the competitive equilibrium for each possible strategy. The expectations are calculated over the distribution of demand and cost shocks. Practically, the demand and cost shocks are obtained from the residuals of the demand and marginal cost equations and the distribution is obtained by simulating 200 times over each draw of demand and cost shocks. For each draw, the competitive equilibrium (prices) is recalculated. Taking the average profits from these 200 simulations gives us one moment condition.

To illustrate the procedure for obtaining the moment conditions and to highlight the complexity involved, consider our earlier example where Sony is currently outsourcing production of all its three products. Changing the outsourcing strategy for Sony for one of its products from outsourcing to insourcing generates one moment. To obtain equation (5) for this one moment involves i) drawing a set of demand and cost shocks for all the products in all the markets, ii) calculating the equilibrium prices and demand estimates based on the drawn demand and cost shocks, and iii) repeating the simulation 200 times and taking the average net profits. Sony has three products and that generates $2^3$=8 moments for Sony. We calculate moments similarly for all the other firms in a given time period, obtaining a total of 213 moments. For each moment, we simulate and calculate the profits 200 times, recalculating the equilibrium in each instance. Stacking the 1, …, $J$ moments (the signs of equation (6) are reversed before stacking) that are generated together gives us the following equation for estimation:

$$P_J m(\theta) = \frac{1}{J}\sum_J r\left(o_j^k\right) - r\left(o_j^{k'}\right) - \Delta F \geq 0 \tag{7}$$

where $P_J m(\theta)$is the vector of moments stacked together. The identified set of parameter values is the set of parameters that satisfy the implied system of inequalities, i.e.,

$$\Theta_j = argmin_{\theta\in\Theta}\left|\left|(P_J m(\theta))_-\right|\right| \tag{8}$$

where $(\cdot)_- = \min\{\cdot, 0\}$. If there are no feasible parameters that satisfy all the inequalities, we use a method of moments methodology, minimizing the Euclidean distance by which the inequalities are violated (Ho et al. 2012; Pakes et al. 2015). To sum, the approach yields us estimates of the fixed cost of insourcing. Note that because the moment inequalities contains estimates from the previous three stages, it is necessary to account for the standard error from those stages. We use a sequential procedure that follows prior literature on this methodology (Pakes et al. 2015; Lee et al. 2013; Ho et al. 2012)[7]. Finally, it is important to note that we do not estimate the brand dummies (this poses no problems later for the counterfactual simulations, which do not require estimates of the dummies).

***Stage 2: Outcomes of Outsourcing***

There are two outcomes of interest – the effect on marginal cost and the effect on the firm's ability to be on the technological frontier. Before we proceed, it is important to note that firms may target their position on the technology frontier or their intended marginal costs before the outsourcing decision is made, but, since both technology frontier and marginal costs are a function of outsourcing, one can still write down the firm choice as in equation 1. In other words, firms are fully cognizant of the consequences of outsourcing on the technology frontier and marginal costs. In addition to the actions of the firm, in stage 2, both demand and cost shocks are realized. These shocks are now observable to firms - the actual shocks are observable, not just their distribution - but are still unobservable to the econometrician.

*Marginal Cost*: One can think of insourcing as entailing a fixed cost (plant and equipment) plus a marginal cost (labor, electricity, raw materials). The fixed cost has already been estimated via our outsourcing model. The marginal cost needs to be explicitly modeled. It is important to realize that the marginal cost is likely to be firm-specific along two dimensions. First, a firm with higher R&D and operations capabilities, for example, might have a lower marginal cost of production. We capture such unobserved firm capabilities though a firm-specific constant in the marginal cost specification. Second, specifically considering outsourcing, the price at which the product is procured (the equivalent of its marginal cost of production, if one insources) might well vary across downstream firms – a firm with greater bargaining power is likely to get more favorable terms from upstream suppliers. In other words, even the impact of outsourcing on marginal cost may vary across firms. We explicitly model this dimension of firm-specificity by letting the coefficient of the outsourcing variable vary across firms. In addition to firm specific effects, outsourcing can have spillover effects on costs, i.e., outsourcing of one product can affect the marginal costs of outsourcing other products in the portfolio (both in a linear and non-linear fashion). For instance, manufacturing a 62" inch TV could reduce the costs of producing a 48" inch TV due to the nature of the process. These spillovers (economies of scope) need to be accounted for.

Formally, we assume that the marginal cost for a product in region *r* at time *t* is:

$$mc_{krt} = \gamma_{0j} I\{Brand\ j = 1\} + \gamma_{1j} Outsourcing_{krt} + \gamma_2 I\{Tech\ s = 1\}$$
$$+ \gamma_3 Size_{krt} + \gamma_4 I\{Region\ r = 1\} + \gamma_{5t} I\{Time\ t = 1\}$$
$$+ \gamma_6 PercentOutsourced_{krt} + \gamma_7 PercentOutsourced_{krt}^2 + \psi_{krt} \quad (9)$$

[7] We also try an alternative procedure to account for the standard errors (Eizenberg 2014), and find that the confidence intervals obtained are not unambiguously narrower, suggesting that the alternative is not superior. Details on the procedure we use in the paper, as well as the alternative just mentioned, are provided in the online appendix.

*Outsourcing*$_{krt}$ denotes the outsourcing status (1 being outsourcing while 0 is insourcing) while *Size*$_{krt}$ represents the size of product *k* in region *r* at time *t*. $PercentOutsourced_{krt}$ captures the percentage of outsourcing done by the firm. This variable captures the spillovers that firms can benefit from if they outsource multiple products. $I\{\cdot\}$ is the indicator function that takes the value of 1 whenever the denoted value is represented. $\gamma_{1j}$ is the impact of outsourcing on marginal costs; a negative value of $\gamma_{1j}$ would be evidence of the efficiency effect. $\gamma_6$ and $\gamma_7$ capture the spillovers that occur due to outsourcing. Our model accounts for brand, technology, region and time characteristics that could affect the marginal cost. If we let $\boldsymbol{Z} = \{Outsourcing, I\{Brand\ j{=}1\}, I\{Tech\ s{=}1\}, Size, I\{Region\ r{=}1\}, I\{Time\ t{=}1\}\}$ denote the vector of observed (to the econometrician) cost characteristics and $\boldsymbol{\gamma}$ the vector of coefficients associated with these characteristics, then the cost characteristics can be thought of as consisting of an observed set *Z* and an unobserved portion $\psi$.

*Estimation of Marginal Cost*: On the supply side, the specification of a Bertrand-Nash pricing game leads to a certain implied price-cost margin, which can be calculated once we have estimates of the demand-side parameters in place. We combine this calculation of the price-cost margin with observed prices to back out costs. We then regress[8] these costs on a set of cost characteristics, as indicated in equation 9 above. Denoting the price-cost margin as $PCM_{krt}$, we obtain the estimated pricing equation as:

$$mc_{krt} = p_{krt} - PCM_{krt} = \gamma_{0j} I\{Brand\ j = 1\} + \gamma_{1j} Outsourcing_{krt} + \gamma_2 I\{Tech\ s = 1\} + \gamma_3 Size_{krt} + \gamma_4 I\{Region\ r = 1\} + \gamma_{5t} I\{Time\ t = 1\} + \gamma_6 PercentOutsourced_{krt} + \gamma_7 PercentOutsourced^2_{krt} + \psi_{krt} \quad (10)$$

We model heterogeneity in outsourcing costs by allowing the coefficient of outsourcing $\gamma_{1j}$ to vary across brand as $\gamma_{1j} : N(\bar{\gamma}, \sigma_o^2)$, where $\bar{\gamma}$ is the mean cost of outsourcing in the population and $\sigma_o^2$ captures variation in costs across brands. The model to be estimated is a random coefficients model with randomness on the outsourcing parameter.

*Technology Frontier*: The impact of outsourcing on a firm's ability to be on the technology frontier is likely to vary across firms. For example, some firms might see a higher positive return from outsourcing while others see lower returns. These dissimilarities across firms could arise due to differences in absorptive capacities and internal learning. We explicitly model such firm-specificity in the *TechnologyFrontier* equation; formally, the closeness to frontier for a brand *j* at time *t* is specified as:

$$TechnologyFrontier_{jt} = \beta_{0j} I\{Brand\ j = 1\} + \beta_{1j} Outsourcing_{jt} + \beta_{2s} I\{Tech\ s = 1\} + \beta_{4t} I\{Time\ t = 1\} + \epsilon_{jt} \quad (11)$$

[8] We tried an alternate specification which endogenized the outsourcing variable using outsourcing strategies of the same firm in other technological areas, labor costs, etc. as instruments. Our results, shown in the online appendix, are qualitatively unchanged.

where $Outsourcing_{jt}$ is the average measure of brand *j*'s degree of outsourcing at time *t*, *Tech* is an indicator variable that takes the value 1 when the product is LCD and 0 otherwise. Similarly, *Brand* and *Time* are indicator variables that control for brand and time effects. A negative $\beta_1$ would suggest that outsourcing decreases a firm's ability to get to the technological frontier. We model heterogeneity in the impact of outsourcing on *TechnologyFrontier* by allowing the coefficient of outsourcing $\beta_{1j}$ to vary across brand as $\beta_{1j} : N(\bar{\beta}, \sigma_o^2)$, where $\bar{\beta}$ is the mean impact of outsourcing in the population and $\sigma_o^2$ captures variation across brands in the impact of outsourcing on the frontier. It is important to note that in our estimation the *Outsourcing* variable could potentially be endogenous, thereby biasing the results. We turn to this issue next.

*Estimation Of TechnologyFrontier*: We obtain the relationship between *TechnologyFrontier* and outsourcing through an instrumental variable (IV) regression. The use of an IV regression is to address potential endogeneity concerns arising from the fact that unobserved factors could influence observed outsourcing decisions. For example, firms that invest in R&D capabilities are likely to be closer to the frontier than those that don't and are also more likely to insource. Thus R&D capability is likely to be correlated with both the *Outsourcing* variable and the *TechnologyFrontier* variable, leading to a potential bias in our estimates if this factor is unaccounted for[9]. We tackle this using two sets of instruments, namely, the number of outsourced products in other categories, and the CPI and local wage levels in the different regions[10].

As always, it is important to justify the use of these instruments. We first give an intuitive reasoning for the validity of the instruments, followed by an empirical justification for them. The first set of instruments is the number of outsourced products at the firm level, in technologies not in our data. This includes the total number of products outsourced in rear projection LCD, Liquid Crystal on Silicon (LCoS) and Digital Light Processing (DLP) displays. We assume that the number of outsourced products in LCD and Plasma is correlated to the number of outsourced products in other technologies due to common firm-specific factors (e.g., tendency to outsource) but uncorrelated to the technology frontier. These technologies use different components, often made by a different set of core component manufacturers located in different geographical areas. This reduces the likelihood of there being common shocks to all these technologies, implying that we need to worry less about violating the independence assumption. Similarly, our second set of instruments, CPI and local wage levels, captures the cost-side determinants of outsourcing and is highly correlated with shifts in the labor market. Note that we explicitly include dummies for time, quarter, and technology, to avoid the issue of possible omitted variables that may be correlated with the instrument (Murray 2006).

[9] It is important to note here that firms know the true relationship between outsourcing and technology frontier while econometricians don't. The omitted variable bias correction is for econometricians to obtain the true estimate of the relationship that firms use when making the outsourcing decision. Further details on the assumptions involved are provided in the online appendix.

[10] The CPI and wage rates for different countries are obtained from the United States Bureau of Labor Statistics.

Empirically, establishing the credibility of instruments requires us to demonstrate their validity and test for their weakness. The standard test for validity is the *J*-test for over identifying restrictions, which tests whether all instruments are exogenous assuming that at least one of the instruments is exogenous. The intuition behind the test is that different sets of instruments should, if they are valid, lead to roughly similar estimates. The null is that the set of instruments is valid - we find that the null is not rejected for our set of instruments ($p > 0.1$), suggesting instrument validity. To check robustness, we also ran the regressions with different subsets of instruments, and the results were broadly similar. Having established validity, we next check for weakness of the instruments (i.e., is the explanatory power of the instruments sufficient to allow inference). To do this we look at the first stage results in Table E2 in the online appendix. The $R^2$ for this regression is 0.87, suggesting a good fit, and the F-test rejects the weak instruments hypothesis ($p > 0.1$). While this is the standard set of tests usually done, Murray (2006) recommends the use of a test by Stock and Yogo (2005). This is a conservative test for weak instruments that uses the first stage *F* statistic. The intuition is that instruments are defined to be strong if the *F* statistic is large enough that the relative bias in an IV regression is at most (say) 10%. The key to the Stock and Yogo test, therefore, is the definition based on relative bias, which in turn implies different critical values for the *F* statistic (see Table 1 in Stock et al. 2002). If the actual value exceeds this threshold, then the instruments are strong, else the instruments are weak. Our test (Table E2) exceeds the threshold at all levels of bias, suggesting that our instruments are strong. To sum, our instruments seem to be both valid and not weak.

***Stage 3: Pricing Model***

Our pricing model is one of differentiated Bertrand competition between multi-product firms, i.e., firms simultaneously choose retail prices for the entire range of products they manufacture. Prices are chosen to maximize joint profits over the entire product line for each firm. We specify the maximization problem and the associated first order conditions for a television manufacturer below.

Suppose there are *j* firms, each of which produces some subset, $\Phi_j$, of the $k$=1 ,…, K different products of televisions. The profits of firm *j* are:

$$\pi_{jrt} = \sum_{k\in\Phi_j} (p_{krt} - mc_{krt}) M s_{krt}(p) - C_j \qquad (12)$$

where $s_{krt}(p)$ is the market share of product *k*, which is a function of the prices of all brands, *M* is the size of the market, and $C_j$ is the fixed cost of production (the same as in equation 1).

The first order conditions are

$$s_{krt}(p) + \sum_{l\in\Phi_f} (p_{lt} - mc_{lt}) \frac{\partial s_{lt}(p)}{\partial p_{kt}} = 0 \quad \forall\, k\ \in \Phi_r \qquad (13)$$

$\Phi_r$ is the set of all products in region *r*. Written in matrix form, the price-cost margins for the manufacturer are

$$\boldsymbol{PCM}_{rt}^{j} \equiv (\boldsymbol{p_{rt}} - \boldsymbol{mc_{rt}}) = -(T_j \cdot \Delta_{lt})^{-1}\boldsymbol{s_{rt}}(p) \qquad (14)$$

The characters in bold are vectors and $\Delta_{lt}$ is a matrix of marketing response to price, with

$$\Delta_{lt} = \frac{\partial s_{lt}(p)}{\partial p_{kt}} \qquad \forall\, k, l \in \Phi_r \qquad (15)$$

and $T_j$ is the ownership matrix indicating the ownership structure of brand *j* given by:

$$T_j(k,l) = 1 \qquad \forall\, k, l \in \Phi_j \qquad (16)$$

The price response matrix $\Delta_{lt}$ is calculated as in Villas-Boas (2007).

*Estimation Of Pricing Model*: The price-cost margin (*PCM*) for each product is obtained from equation 14. In particular, we first use the demand estimates to obtain the predicted market shares and implied elasticities. Substituting the predicted market shares and elasticities along with the ownership matrix in equation 14 gives the *PCM*. Because the market shares and elasticities are values calculated from estimated quantities, it is important to incorporate the standard error of the estimates in the calculation. We do this using the delta method.

***Stage 4: Consumer Demand***

We model the demand side in as disaggregate a fashion as possible, while accounting for unobserved differences across consumers. Our approach follows Berry, Levinsohn and Pakes (1995) (hereon, BLP) in specifying a discrete choice random coefficient model of consumer utility. Each consumer chooses among different products to maximize her utility in each period. A product is defined as a combination of brand, size, and technology, e.g., an LCD television set made by Sony of size 32".[11] Formally, the utility of consumer *i* choosing a product *k* from region *r* at time *t* is:

$$U_{ikrt} = \alpha_{0i} + \beta_{0j} I\{Brand\ j = 1\} - \alpha_i Price_{krt} + \beta_{2i} Size_{krt} + \beta_{3i} I\{Tech_{krt} = 1\}$$
$$+ \beta_{4i} Technologyfrontier + \beta_{5r}\{Region\ r = 1\}$$
$$+ \beta_{6t}\{Time\ t = 1\} + \xi_{krt} + \epsilon_{ikrt} \qquad (17)$$
$$i = 1, \ldots, \mathrm{I};\ k = 1, \ldots, \mathrm{K},\ r = \{\text{NA, Europe, Japan}\},\ t = 1, \ldots, \mathrm{T}$$

where $I\{\cdot\}$ is the indicator function and represents membership in a set A, i.e.,

$$I\{x\} = 1 \text{ if } x \in A$$
$$= 0 \text{ otherwise}$$

$\beta_{0j}$ is consumer *i*'s time-invariant intrinsic brand preference; $Price_{krt}$ is the retail price of product *k* under region *r* at time *t*, with $\alpha_i$ the price sensitivity of consumer *i*; $Size_{krt}$ and $Tech_{krt}$ represent the size and technology used in product *k* in region *r* at time *t*; $TechnologyFrontier_{krt}$ is the technology frontier of product *k* in region *r* and time *t*; the *Region* and *Time* dummies account for region-specific differences and seasonal variations on consumer choice; and the $\beta$ coefficients measure the marginal impact of the relevant covariate on consumer utility (note, in particular, that a significant positive

[11] We perform a series of robustness checks (see online appendix) with various product definitions (e.g., different sizes and a more comprehensive set of brands). The results, while differing in magnitude, seem broadly consistent, suggesting that our product definition is relatively innocuous.

value for $\beta_{4i}$ would imply the existence of an aura effect). Finally, $\xi_{krt}$ is the mean of the random part of the consumer's unobserved preference for product *k* under region *r* at time *t*, observed by both manufacturers and consumers but unobserved by the econometrician, and $\epsilon_{ikrt}$ is an individual specific random error term that follows an IID type 1 extreme value distribution.

We model heterogeneity in consumer preferences by allowing i) the price sensitivity $\alpha_i$ to vary across consumers as $\alpha_i : N(\bar{\alpha}, \sigma_p^2)$, where $\bar{\alpha}$ is the mean price sensitivity in the population and $\sigma_p^2$ captures variation in price sensitivity, and ii) consumer valuation of size, technology and *TechnologyFrontier* to vary as $\beta_{2i} : N(\overline{\beta_2}, \sigma_{size}^2), \beta_{3i} : N(\overline{\beta_3}, \sigma_{technology}^2), \beta_{4i} : N(\overline{\beta_4}, \sigma_{closefront}^2)$, where $\overline{\beta_2, \beta_3}, \overline{\beta_4}$ are the mean consumer valuations for size, technology and *TechnologyFrontier* respectively and $\sigma_{size,}^2 \sigma_{technology}^2, \sigma_{closefront}^2$ capture the variation in valuation. To sum, the demand side parameters to be estimated are $(\bar{\alpha}, \overline{\beta_2}, \overline{\beta_3}, \overline{\beta_4}, \boldsymbol{\beta}, \sigma_p^2, \sigma_{size}^2, \sigma_{technology}^2, \sigma_{closefront}^2)$ where $\boldsymbol{\beta} = \{\beta_{0j}, \beta_5, \beta_6\}$ is the vector of coefficients without heterogeneity.

*Estimation Of Demand*: We use the BLP (1995) procedure to obtain the demand parameters specified above. Briefly, we first solve for the mean utility numerically using a contraction mapping. This yields a linear equation relating mean utility to the product preference dummies, prices, and other exogenous variables. As pointed out in the literature, the prices set by firms are likely to depend on unobserved product attributes ($\xi_{krt}$ in equation 1), which means that price is effectively an endogenous variable, and we need to instrument for it to obtain consistent estimates. The standard BLP (1995) procedure involves an instrumental variables (IV) regression, with the residuals from the regression used as the residuals in a GMM estimation.

*Price Instruments*[12]: Recall that the term $\xi_{krt}$ in equation 1 represents unobserved demand shocks. It is highly likely that these time-varying shocks are correlated with the chosen prices, thus creating a potential endogeneity bias. We use two alternative sets of instrumental variables for the price of a product to control for this endogeneity.

First, following Hausman (1997) and Nevo (2001), we use prices of the product in other regions as instruments. The assumption we make here is that after controlling for brand-specific means and demographics, region-specific shocks are independent across regions (but are allowed to be correlated within regions). Prices of product *k* in two regions will be correlated due to the common marginal cost, but due to the independence assumption will be uncorrelated with market-specific demand shocks. Specifically, for the price of a given product *k* in region *r* at time *t*, we use the average price across other regions, for that product for that quarter. For example, the instrument for the price of a

[12] We tried an alternate specification that endogenized both the price and the technology frontier variable. We used the outsourcing strategies of firms in other technologies as an instrument for Technology Frontier. Our results remain qualitatively unchanged (see online appendix).

Sony 32'' LCD in Quarter 1 of 2005 in North America would be the average of the prices of the same TV in Q1 2005 across Japan and Europe.

The weaknesses of such Hausman-style instruments have been the subject of much discussion in the literature (Nevo 2001). In our context, the main worry would be the presence of common shocks that affect all the regions simultaneously; this would increase the unobserved valuation of all TVs in all regions, violating the independence assumption. While determining the plausibility of these instruments is an empirical issue (that we address shortly) it helps to give an intuitive rationale for why we feel these instruments are appropriate in our case. First, the regions show very different demand patterns, with different preferences for both technologies and brands across regions (e.g., the market shares of brands vary, as does the relative preponderance of LCD vs. PDP). Indeed, we model demand explicitly taking these differences into account. Second, it is reasonable to believe that well-established brands are less susceptible to systematic demand shocks, and those are the only kinds of brands we have in our sample.

The second set of instruments we use is cost shifters that are uncorrelated with the demand shock. We use the cost of TV screens, software interface component, labor and distribution costs to come up with a cost estimate. The rationale for cost shifters as demand side instruments is that changes in cost affect supply and are therefore correlated to price, but are uncorrelated to the demand for the product. For example, an increase in the cost of TV screens is bound to affect the supply (number of TVs produced) and the price for TVs, but it is unlikely to affect the demand for TVs (other than through price).

As before, empirically establishing the credibility of instruments requires us to demonstrate their validity and test for their weakness. Following Nevo (2001), we test different subsets of these instruments for validity, using the *J*-test for over identifying restrictions. We find that even though the test is rejected for the complete set (a common occurrence as specified in Nevo (2001)), it is not rejected for different subsets of instruments; even stronger evidence is the fact that the demand coefficients estimated from the complete set of instruments are very similar to those estimated from the various subsets, leading us to conclude that our original set of instruments is valid. To check if our instruments are weak, we look at the first stage results in Table E1 in the online appendix. The $R^2$ for this regression is 0.92, suggesting a good fit, and the *F*-test rejects the weak instruments hypothesis ($p < 0.01$). Finally, the *F* statistic at different values of relative bias exceeds the thresholds set by Stock and Yogo (2005), further buttressing the finding that our instruments are not weak.

***Robustness Checks***

Our framework consists of a number of models, each of which comes with its own assumptions, whether in the creation of measures or in the minutiae of estimation. While we have tried to justify our assumptions in the model description, it is nevertheless important to check how robust our models are to the relaxing of some of these assumptions. We list here the variety of robustness checks we have performed, relegating details to the online appendix. All of the checks below yield substantively similar conclusions to those reported in the main body of the paper.

*Demand*

- Different definitions of 'product': In particular, we try out different size combinations and a more comprehensive set of brands (e.g., actual size definitions with sizes ranging from 12 to 65 inches)
- Different definitions of technology frontier (in particular, we examined the industry's technological progress on alternate dimensions like resolution and combinations of resolution and size)
- Different sets of instruments (akin to the *J*-test, we redid our estimates with various subsets of instruments)
- Alternative specifications incorporating various interactions and alternate functional forms (e.g., we tried interactions of *TechnologyFrontier* with technology and size, interactions of size and technology with region, and logarithmic specifications of size)

*Outsourcing & TechnologyFrontier*

- Specification with various interactions (e.g., we tried interactions of outsourcing and technology)
- Different definitions for outsourcing
- Different sets of instruments (akin to the *J*-test, we redid our estimates with various subsets of instruments)

*Marginal Cost*

- Various interactions and alternate functional forms (e.g., we tried interactions of outsourcing and technology, outsourcing and size, a linear model, and a random effects model).
- Alternate pricing game specification – Stackelberg leader-follower game instead of the Bertrand pricing game.

## RESULTS

### *Fixed Costs*

Our results show that the fixed cost of insourcing relative to outsourcing a product line for a year is \$455 Million for an LCD plant and \$277 Million for a PDP plant (Table 7). These numbers pass the face validity test on two counts. First, LCD plants on the whole are viewed as far more expensive than PDP plants - an average LCD plant costs anywhere between \$1 billion to \$3 billion while an average PDP plant costs up to \$700 million (see the *New York Times* 2004; *Business Week* 2005; *Engadget* 2005; Hart 2008). Second, while it is difficult to accurately compare our fixed cost estimates with actual plant level investments (plants produce more than one product and are used for multiple years), institutional evidence seems to suggest that plants generally last about five years, and frequently produce around three or more product lines (Hart 2008). Given this, the annual cost per product would fall well within the range of numbers that we have estimated above. It is important to note that we arrived at point estimates as opposed to a set estimate that is typical in an inequalities approach. In our case, this is because the identified set collapses to a singleton every time. Briefly, this happens because the estimated lower bound is greater than the estimated upper bound (Pakes et al. 2015 points out that this occurs when the number of inequalities is large).

***Technology Frontier***

Recall that one of our main areas of interest was in identifying how outsourcing affects a firm's ability to be on the frontier. Table 8 reports the results of this IV regression. The coefficient on the outsourcing measure is significant and negative (-23.70, p<.10), suggesting that firms that produce in-house are more likely to be on the frontier than firms that outsource production of core components. However, there is a fair amount of unobserved heterogeneity around this estimate (sd(outsourcing)=24.93, p<.01), suggesting that the marginal impact of outsourcing could be very different across firms. For instance, a firm that is two standard deviations to the right of the mean is 70% more likely to be on the frontier than a firm at the mean.

***Marginal Costs***

Table 9 gives results for the random coefficient cost regression. The main points to note are the following. First, the cost estimates seem to satisfy face validity considerations - size has a significant positive impact on costs, and LCDs seem to be costlier to produce than equivalent plasma TVs. Second, there is a significant efficiency effect on average; outsourcing reduces costs significantly (-698.53, p<.01). However, there is little heterogeneity across firms on this dimension. Further, we find no evidence for spillover effects on marginal costs across products within the firm – both $PercentOutsourced$ and $PercentOutsourced^2$ are non-significant. (p>.10 and p>.10 respectively).

***Consumer Demand***

Table 10 reports the consumer demand results for three different specifications – a simple logit specification, which involves an OLS regression with the difference between log(share) of each of the inside goods and the outside good (i.e., $\ln(s_j/s_0)$) as the dependent variable, with no instruments for price and no control for unobserved heterogeneity; a logit estimation with instruments for price but no control for unobserved heterogeneity (denoted logit+IV); and a random coefficients logit model with instruments for price and controls for unobserved heterogeneity (denoted RC logit+IV). The discussion that follows focuses on the most general specification, the random coefficients logit.

An important part of the demand estimation is to check for the aura effect. We find that *TechnologyFrontier* has a positive and significant effect on demand, as hypothesized (0.04, p<.01). In other words, there is a positive aura effect, and the firm's position on the technology frontier can be thought of as acting as a signal of technological ability. Size affects demand negatively, and customers seem to prefer LCD over plasma[13]. Finally, the price coefficient is significant (-0.07, $p<0.01$), with significant unobserved heterogeneity (S.D. price = 0.03, significant at 1%), indicating different price sensitivity across customers.

## UN DERSTANDING THE CONSEQUENCES OF OUTSOURCING

It important to appreciate that in our framework, profits are the only driver of firms' decisions; firms outsource if profits from outsourcing are higher than profits from insourcing. What drives these profits is an interplay of the *efficiency, aura* and *strategic* effects. To understand better how these effects manifest themselves and to get a sense of the magnitudes of various outcomes, we conduct a series of counterfactual thought experiments. Our counterfactual simulations can be used in three ways by managers. First, our framework can be used to assess the consequences of different sourcing strategies on profits, revenue, prices, margins and competitor response. For instance, Sony, which currently outsources, can use our framework to assess the consequences of integrating production on its overall margins and profits, as well as on competitor response. Second, the framework can be used to assess the magnitude of the various effects. For instance, the strategic effect, which measures the impact of competition on the potential benefits and costs of outsourcing and is determined by the relative position of products in attribute space, can only be assessed using counterfactual simulations which allow for different positioning and pricing by competitors. Third, our framework can be used to assess the impact of mergers, joint ventures and collaborations on firm profitability. This counterfactual, unlike the previous thought experiments, allows for competitors to react endogenously and change their outsourcing structure based on competitors' reaction. It is important to note that two limitations of our thought experiments. First, the outsourcing structure of all firms is fixed, which means that we cannot make strong claims about the policy invariance of our estimates. Also, recommendations on whether firms should, in general, outsource or not are difficult to illustrate in our framework, because the consequences of outsourcing depend on who is outsourcing, their current sourcing strategies, and the environment they are likely to face.

### *Base Case*

Our base case is the equilibrium that currently exists in the market. Using the estimated demand and cost coefficients we re-estimate the new equilibrium retail prices, margins, market shares, and the firm's new position on the technology frontier. From this we compute profits for each firm, separately for LCD and plasma markets. For ease of presentation, we only discuss results for the LCD market. Results for plasma TVs are available from the authors upon request.

Before moving to a discussion of the thought experiments, it is useful to recap the three effects we had discussed earlier. Consider a move from in-house production to outsourcing. First, there is a positive *efficiency* effect, namely a reduction in the cost of production. Second, there is the

[13] An argument can be made that consumers in different regions perceive attributes like size, technology, etc. differently. We ran a model which accounted for regional variation in preferences for size, technology, etc. and found no significant regional interaction effects.

intermediate consequence of a reduction in the firm's position on the technology frontier; this in turn leads to a lowering of the firm's attractiveness to consumers, manifested in a negative *aura* effect. Third, there is the *strategic* effect, i.e., if a firm decides to move higher on the technology frontier, it may suffer enhanced competition from rivals who are already at that position on the technology frontier, leading to lower prices. The sign of this effect is more ambiguous, since it depends on the relative configuration of products in attribute space. Note finally that there is also the matter of fixed costs, which are considerably greater when producing in-house. However, because the impact of fixed costs on profits is relatively straightforward, while the three effects are more subtle, we choose to focus on the effects in the thought experiments.

***Thought Experiment # 1: When to outsource?***

In this section, we provide readers with an illustration of how firms can use our framework to assess the consequences of outsourcing based on their position on the technology frontier. To do so, we first move all firms to an insourcing strategy to obtain a common baseline and then examined the consequences of outsourcing on firms' profits, competitor response, revenues etc.. We compute equilibrium outcomes when i) all firms outsource their production (scenario 1a), and ii) all firms insource (vertically integrate, scenario 1b) and then use it to identify the impact of outsourcing.

<u>Scenario 1a: All firms outsource production</u>: Equilibrium outcomes are displayed in Table 12. We would expect a positive efficiency effect and a negative aura effect. The strategic effect is idiosyncratic to individual firms – in the aggregate, however, one would expect the strategic effect to become more intense because firms have now come 'closer' to each other on the *TechnologyFrontier* attribute, while remaining unchanged on other attributes (except price)[14]. One can see this by constructing a dispersion measure of the *TechnologyFrontier*. The coefficient of variation for the *TechnologyFrontier* goes from 0.19 in the base case (mean of 43 and standard deviation of 8) to 0.13 (mean of 41 and standard deviation of 5.6). This suggests that i) on average firms are now further away from the frontier than before, and ii) firms are clustered more closely around each other, leading to stronger downward price pressures.

Turning to individual firms, there were two firms that were not outsourcing in the base case – Samsung and Sharp. Looking at their profits, we see that both firms lose from outsourcing. The story behind these profit changes is interesting. Note that both firms experience an *increase* in margins, even though their prices have declined. At the very least, this suggests that the positive efficiency effect outweighs the decline in aura. Now, the only way for a firm to lose profits even with a margin increase is for it to sell a smaller quantity. This is indeed what happens. Samsung and Sharp (as well as Philips and LGE) sell less than they were selling before. In other words, consumers switch away

[14] One could argue that this is not a complete picture, because firms could alter their positions along other attributes to perhaps lower the intensity of competition. Accounting for such changes would require us to endogenize all product attributes, a task that is well beyond the scope of this research (and one that has hitherto not been accomplished in the literature).

from products made by Samsung and Sharp (as well as Philips and LGE) because the price decrease is insufficient to overcome the loss in attractiveness of the products caused by their drop in position on the *TechnologyFrontier* (Samsung drops on the frontier by13.04% while Sharp drops by 16.67%) . Anecdotally, this accords with what one would expect – both Sharp and Samsung have positioned themselves as cutting-edge brands, so a fall for them has a larger proportionate impact on consumer perceptions.

Turning to firms that were already outsourcing, the picture is mixed. Thus, Sony, Toshiba, Panasonic and TTE gain (7%, 6%, 6% and 7%) while LGE loses (7%). Clearly, there is no efficiency effect for any of these firms, since they were fully outsourced to start with. Similarly, there is no change in aura, since their position on the *TechnologyFrontier* is as before. Any change in final prices, therefore, is entirely due to changes in the competitive landscape, or the strategic effect. One can infer that Sony, Panasonic, Toshiba and TTE now face less competitive pressure than earlier, while LGE faces more, due entirely to the movement of other firms along the technology frontier dimension.

<u>Scenario 1b: All firms insource (vertically integrate) production</u>: Equilibrium outcomes are displayed in Table 13. We would expect a negative efficiency effect and a positive aura effect through a higher position on the *TechnologyFrontier*. As before, while the strategic effect is harder to discern for an individual firm, in the aggregate one would expect it to become more intense. The logic is similar to the previous experiment - firms are now 'closer' to each other on the *TechnologyFrontier* dimension, while remaining unchanged on other attributes (except price). The dispersion measure of the *TechnologyFrontier* bears this out - the coefficient of variation goes from 0.16 (mean of 0.86 and standard deviation of 0.14) in the base case to 0.09 (mean of 54 and standard deviation of 5).

Turning to individual firms, first note that Sony, Panasonic, Phillips, Toshiba, TTE and LGE were completely outsourced earlier, so their production structure is changed maximally. While cost goes up for each of them, they also move higher on the *TechnologyFrontier*, by differing amounts, with Sony moving the least (26%) and Panasonic the most (37.5%). Prices increase for all firms. Margins, however, decline for every firm, suggesting that the negative efficiency effect is dominant. Turning to profits, we see that Sony, Panasonic, Toshiba and TTE increase their quantity sold by enough to outweigh the loss in margin, leading to an increase in profits. Phillips and LGE however see a decrease in profits, suggesting that their relatively minor aura gain is not overwhelmed by the adverse efficiency effect.

Sharp and Samsung are the polar opposites of the firms above, in that they were already producing in-house earlier. There is no efficiency effect, since their production strategy is unchanged. There is also no change in their position on the technology frontier, and hence in their aura effect. However, they do experience a strategic effect. This is best illustrated for Sharp in particular, which was already high on the *TechnologyFrontier*. As pointed out earlier, there are more firms higher on the frontier now, which suggests enhanced competition for Sharp. The enhanced strategic effect leads to an 11% decline in its own price and an 11% profit decline.

***Putting things together: When to outsource?***

We use the counterfactual results from scenarios 1a and 1b to understand the impact of outsourcing decisions on revenues, profits and competitor reactions based on firms' positions on the *TechnologyFrontier*. Table 14 shows the results from this analysis. First, outsourcing leads to an increase in quantities sold, a decrease in prices and an increase in margins for all firms independent of their position on the technology frontier. However, only firms that are the technology leader are able to compensate for the drop in prices with sufficient revenue to make positive profits. Firms that are neither at the forefront of technology nor at the bottom fare the worst from moving to outsourcing; they are now little differentiated from the competition, leading to increased pricing pressure, lower margins, and lower profits. Table 15 explains the above in terms of the three effects modeled in our paper, namely, *strategic*, *aura* and *efficiency* effects. The shift to outsourcing leads to an 18% decrease in costs (the efficiency effect) for all our firms as they all move from insourcing to outsourcing. However, the impact of the other two effects is different for different firms. Firms on the technology frontier see an increase in demand of 1.13% due to the *strategic* effect and a decrease of 0.85% in demand due to the *aura* effect. On the other hand, firms that are neither at the forefront nor at the bottom see a drop in demand from the aura effect that is bigger than the increase from the strategic effect.

***Thought Experiment #2: The Competitive Impact of Sony's Joint Venture Decision***

One of the advantages of using a structural modeling approach is its ability to provide inputs to managerial decision-making in complex scenarios. Of particular interest to us is the outsourcing decision – if one firm decides to outsource, how do other firms react? Our model lets us model their possible reaction on the outsourcing dimension, as well as on prices, while accommodating the strategic, aura and efficiency effects. We illustrate one such application by examining the decision of Sony to jointly produce LCDs with Samsung right around the end of our data period. S-LCD corporation, the joint venture between Sony and Samsung, was formed in April 2004 and started production around October 2005. As of 2012, Sony had sold all its shares in S-LCD to Samsung, suggesting perhaps that the venture was not successful. Our example shows how managers at Sony and Samsung could have used our model to understand the impact of their sourcing strategy.

To conduct this experiment, we need to identify the optimal outsourcing strategies and prices that would be selected in this new scenario. Since our optimization does not specify an outsourcing selection strategy, we have to enumerate all possible outsourcing combinations to arrive at the optimal assortment decision. This is computationally intensive and complex to solve numerically, e.g., the optimal outsourcing choice for each firm in a market with 25 products involves enumerating $2^{25}$-1 combinations. Each combination in turn involves solving the optimal outsourcing strategy for each firm, and the market prices and demand conditional on this set of optimal outsourcing strategies. Briefly the procedure to identify the optimal outsourcing strategy for all firms conditional on Sony and Samsung forming a joint venture can be outlined as follows:

**1.** Start with an outsourcing strategy for all firms. In our estimation, we assume that Sony and Samsung are insourcing all their products and restrict our attention to competitors' outsourcing strategies in the LCD market[15].

   a. Simulate demand and cost shocks for the outsourcing combination
   b. Predict demand and cost residuals for the chosen outsourcing strategies
   c. Compute optimal retail prices using estimated marginal cost and demand parameters
   d. Compute the profit function given costs and the optimal prices

**2.** Change the outsourcing strategy for one firm, go back to Step 1 and continue till all the possible outsourcing combinations for all firms are exhausted.

**3.** The optimal outsourcing strategy is the one that generates the highest profits for all the firms.

Table 16 shows the equilibrium results from this thought experiment. First, all firms except Sony and Samsung change their sourcing strategy to outsourcing. In general, all firms except Sony and Samsung see an increase in profits. Firms that outsourced earlier (Panasonic, LGE) see an increase in profits mainly through an increase in demand driven by lower prices, while Sharp that insourced earlier gains from the efficiency effect and is able to increase prices without sacrificing demand. Finally, overall demand for LCDs increases, suggesting market expansion as all firms move closer to the technology frontier.

Looking deeper, Sony moves closer to the frontier and is able to raise prices while Samsung decreases prices. This happens because the strategic effect dominates; all the other firms are "closer" on the *TechnologyFrontier* dimension and are also able to produce cheaper, thanks to outsourcing. Sharp is the biggest beneficiary of this change as it is able to raise prices, increase margins and also increase demand. Summing up, the verdict is clear – given what we knew then, the joint venture did not make sense on profitability considerations, which was perhaps the reason it was eventually dissolved a few years later.

What explains the merger decision of Sony and Samsung, if our model suggests that they would make negative profits from the merger? Our model treats the merger decision as exogenous and looks at the impact of this merger on the equilibrium reactions of competitors as they pertain to outsourcing and pricing, and consequently demand in the counterfactual scenario. In that sense, the merger decision is exogenous to the model. To reiterate, our model focuses purely on the technology and demand aspects of a firm's decision to outsource. These are captured through the notion of the

[15] To be accurate, Sony despite having a joint venture with Samsung did not insource all of its products. As of 2012, Sony[15] outsourced roughly 60% of its TV production, while Panasonic and Sharp outsourced roughly one third of its production. Our model (because of a lack of data) cannot capture differences when firm decide to partly insource and outsource data.

technology frontier, as well as the aura, efficiency, and strategic effects. However, a large literature, particularly in strategy, has suggested a variety of determinants of mergers, of which technology aspects are but one (Hussey 1999; Jensen 2005; Harford et al. 2012; Moeller, Schlingemann, and Stulz 2005; Dong et al. 2006). As far as failures of mergers are concerned, the major factors are misaligned incentives and managerial hubris, both of which often lead to mergers destroying value (Roll 1986; Schmidt and Fowler 1990). It is quite possible that these factors could have been at play in the merger we have discussed. In fact, the uncertainty in predictions on merger analysis has led to calls from the FTC advocating further studies on post-merger analysis (Farell et al. 2009, Feinstein 2014).

## CONCLUSION

Core component outsourcing is a pervasive phenomenon in technology markets. Yet, surprisingly little empirical research exists on the performance implications of such outsourcing. As Jiang et al. (2008, p. 1281) note, "in an age in which management carefully weighs the costs and benefits of every discretionary investment dollar, finding evidence of the results of outsourcing is critical." Further, the limited work that does exist offers inconclusive and seemingly contradictory evidence. In part, the apparent contradiction is because different studies focus on different dimensions of performance: for example, some examine performance on cost reduction, whereas others examine performance on the technological front. Moreover - and of particular relevance to marketing - the important role of consumer and competitor response to outsourcing decisions is never explicitly considered.

In this paper, we develop a framework that reconciles the tradeoffs between the various performance dimensions of outsourcing, such as cost reductions and technological performance, while factoring in consumer and competitor response. By combining unique data on outsourcing decisions (and their various performance consequences) with a rich econometric model, we show in the context of the flat panel TV industry that a firm's position on the technological frontier creates an aura effect which leads to positive spillovers on a firm's entire product range. Thus, being on the technological frontier brings tangible benefits by increasing consumers' willingness to pay for other products in the firm's product line. Separately, we find that i) outsourcing decreases a firm's ability to be on the technological frontier, but at the same time ii) decreases production costs significantly. This suggests a trade-off that the firm has to resolve when making its outsourcing decisions.

This paper contributes to the literature on outsourcing in three ways. First, we are among the few papers to quantify the impact of outsourcing on firm profitability and consumer choice. More importantly, we are the only paper that explicitly considers the impact of outsourcing on consumer decision making. We model the link between outsourcing and profitability explicitly, by endogenizing the outsourcing decision, and making it depend on firm profitability. Second, we explicitly model the role of competition. To the best of our knowledge, we are the first paper to specifically incorporate competitor response and its impact on outsourcing strategies. Finally, we are among the first to examine the phenomenon of outsourcing by building up from the micro foundations of utility maximizing consumers and profit maximizing firms. The resultant econometric model lets us conduct a number of thought experiments that are useful in answering managerially relevant questions.

Our paper is an attempt at tackling some of the many dimensions of the phenomenon of outsourcing. Our attempt clearly suffers from many limitations, which in turn can hopefully further research on the topic. One, we have not modeled the retailer's role in the distribution of TVs; we unfortunately have no data on retail sales, which precludes such an exploration. Two, we have not modeled consumer dynamics, which could be important given the rapid pace of technology and price change in this industry. Similarly, our model does not allow for learning by doing. This requires a fairly long data series, something we do not have. Three, our model conditions outsourcing decisions on an exogenously determined product line. While there are good reasons for it in our context (e.g., the difficulty of making decisions on a hypothetical set of products that *could be chosen*), it is fair to say that product line choice is definitely an endogenous decision for a firm, and should be modeled in future research. Four, we make the assumption that outsourcing decisions are made first, leading to a realization of the technology frontier. It is, in almost any real-world situation, impossible to unambiguously observe the sequence in which the outsourcing and technology frontier decisions are made. A possible direction for future research could therefore be to build a broader conceptual framework wherein firms decide the sequence, based on firm-specific factors and their strategic objectives. One could then examine the consequences of heterogeneity in the sequence with which firms make these decisions, i.e., outsourcing followed by technology frontier or the other way round. This is very likely impossible using field data, but could perhaps be done using economic games in a laboratory. Finally, there could be other reasons for core component outsourcing, such as geographic proximity, country of origin effects, and regulatory incentive. Modeling these other possible reasons requires a dataset that is rich enough and a structural model that is tractable enough to accommodate all these features.

**Table 1: Variable Description and Descriptive Statistics**

| Variable | Description | Mean | Std Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| Price | $/unit | 3321.42 | 2764.36 | 326.75 | 12558.08 |
| LCD | Dummy<br>1 if LCD<br>0 if Plasma | 55.15 | 74.75 | .001 | 410.62 |
| Size | Inches | 38.40 | 14.53 | 15 | 62 |
| Technology Frontier | Ratio:<br>Max Size in Quarter | 52” | 24.5 | 32 | 80 |
| Outsourcing | Dummy<br>1 if Core Component Outsourced<br>0 otherwise | .47 | .46 | 0 | 1 |
| Sony | Dummy | 22.02 | 33.40 | .03 | 135 |
| Samsung | Dummy | 29.89 | 50.47 | .01 | 218.73 |
| Panasonic | Dummy | 28.11 | 30.28 | .48 | 133 |
| Sharp | Dummy | 83.34 | 82.89 | 1 | 283.60 |
| Philips | Dummy | 56.24 | 78.36 | .06 | 272 |
| Toshiba | Dummy | 18.13 | 20.64 | .25 | 69.14 |
| TTE | Dummy | 10.09 | 15.32 | .00 | 46.38 |
| LGE | Dummy | 23.51 | 33.24 | .04 | 132.56 |
| North America | Dummy | 32.32 | 59.08 | .00 | 410.62 |
| Europe | Dummy | 42.89 | 65.38 | .01 | 378.29 |
| Japan | Dummy | 34.73 | 54.38 | .01 | 283.60 |
| Q4-04 | Dummy | 33.87 | 56.07 | .01 | 283.60 |
| Q1-05 | Dummy | 29.17 | 49.34 | .01 | 241.78 |
| Q2-05 | Dummy | 35.81 | 58.85 | .03 | 334.37 |
| Q3-05 | Dummy | 48.90 | 74.12 | .001 | 410.62 |

*Note*: For brand and quarter dummies, the numbers represent the number of units sold (in 000’s) with Dummy =1

**Table 2: Number of Products by Market and Time**

| Country | Q4-04 | Q1-05 | Q2-05 | Q3-05 |
|---|---|---|---|---|
| North America | 36 | 34 | 36 | 39 |
| Europe | 37 | 35 | 36 | 38 |
| Japan | 23 | 24 | 22 | 23 |

**Table 3: Variation in Market Shares across Technology and Time**

| Technology | Q4-04 | Q1-05 | Q2-05 | Q3-05 |
|---|---|---|---|---|
| Plasma | 0.20 | 0.19 | 0.18 | 0.19 |
| LCD | 0.80 | 0.81 | 0.82 | 0.81 |

*Note:* For this table and the rest of this document, Period 1 refers to Q4 -2005, Period 2 to Q1- 2005, Period 3 to Q2- 2005, and Period 4 to Q3- 2005.

**Table 4: Variation in Number of Products across Brand, Technology and Time**

| Brand | Q4-04 | Q1-05 | Q2-05 | Q3-05 |
|---|---|---|---|---|
| Sony | 15 | 15 | 13 | 14 |
| Samsung | 11 | 9 | 11 | 12 |
| Panasonic | 15 | 15 | 16 | 16 |
| Sharp | 9 | 9 | 9 | 10 |
| Phillips | 10 | 10 | 10 | 11 |
| Toshiba | 8 | 7 | 7 | 9 |
| TTE | 4 | 2 | 2 | 3 |
| LGE | 10 | 10 | 10 | 9 |
| Others | 14 | 16 | 15 | 17 |

**Table 5: Variation in Core Component Outsourcing Across Time**

| | Q4-04 | Q1-05 | Q2-05 | Q3-05 |
|---|---|---|---|---|
| % Core Component Outsourcing | 49% | 47% | 45% | 48% |

*Note:* The percentage is over all products across all brands. There is no change in the outsourcing strategy for any product during our data period. The small differences in percentages shown above are due to the introduction and exits of products (e.g., an extra outsourced product would boost the percentage of outsourced overall in the data).

**Table 6: Simultaneous Estimation Results (3SLS)**

| Variables | Quantities | Price | Technology-Frontier | CorecomponentOutsourcing |
|---|---|---|---|---|
| | Coefficient (S.E) | Coefficient (S.E) | Coefficient (S.E) | Coefficient (S.E) |
| Price | -0.05** (5.3e-3) | | | |
| LCD | 3.57** (0.56) | -4.85** (1.21) | -21.52** (1.11) | -0.15** (0.03) |
| lnSize | -0.53* (0.23) | 7.46** (1.64) | | -3.5e-3** (1e-3) |
| TechnologyFrontier | 0.17** (0.03) | | - | |
| CoreComponentOutsourcing | | -4.85** (1.21) | -38.22** (2.07) | |
| RawCosts | | 4.5e-3 (4.11e-3) | | |
| Z(instruments) | | 0.70** (0.03) | | |
| Z(outsourcing) | | | | 0.71** (0.07) |
| Brand Dummies (Included) | Included | Included | Included | Included |
| Region Dummies (Included) | Included | Included | Included | Included |
| Quarter Dummies (Included) | Included | Included | Included | Included |
| Constant | -12.59** (1.76) | -21.09** (5.81) | 95.94** (2.84) | 0.70** (0.70) |
| N | 383 | 383 | 383 | 383 |
| R2 | 0.43 | 0.81 | 0.43 | 0.49 |

Note: **: significant at 1% level; *: significant at 5% level
Endogenous variables: q(s/s0) Price TechnologyFrontier CoreComponentOutsourcing

**Table 7: Fixed Cost Results**

| Parameters | Results | 95% CI |
|---|---|---|
| Constant | 455 | [282.6 627.23] |
| Technology (PDP) | - 178.1 | [-349.51 -6.6] |
| Related_Experience | -453.6 | [-569.7 -377.7] |
| N | 185 | |

**Table 8: Outsourcing and *TechnologyFrontier* (Random Coefficients)**

| Variable | Coefficient | Std. Error |
|---|---|---|
| Outsourcing | -23.70§ | 13.09 |
| LCD | -17.24** | 0.68 |
| Brand Dummies | Included | |
| Quarter Dummies | Included | |
| Constant | 76.44** | 2.68 |
| | | |
| **Random – Effects Parameters** | | |
| Grouped by Brand | | |
| Sd(Outsourcing) | 24.93** | 2.38 |
| Log Likelihood | -1191.52 | |
| N | 57 | |
| LR test vs. linear regression: chi2 = 172.76 Prob > chi2 = 0.00 | | |

*Note*: §: significant at 10% level *: significant at 5% level; **: significant at 1% level

**Table 9: Cost Estimates (Random Coefficients)**

| Variable | Coefficient | Std. Error |
|---|---|---|
| Outsourcing (product) | -698.53** | 182.91 |
| PercentOutsourcing | -1563.49 | 1607 |
| PercentOutsourcing^2 | 627.32 | 1516 |
| LCD | 1190.35** | 238.30 |
| Size | 129.48** | 5.53 |
| Brand Dummies | Included | |
| Region Dummies | Included | |
| Time Dummies | Included | |
| Constant | -3818.48** | 430.60 |
| **Random – Effects Parameters** | | |
| Grouped by Brand | | |
| Sd(Outsourcing) | 1e-3 | 0.16 |
| Log Likelihood | -3222.75 | |
| N | 383 | |
| LR test vs. linear regression: chi2 = 0 Prob > chi2 = 1 | | |

Note: *: significant at 5% level; **: significant at 1% level

**Table 10: Demand Estimates**

| Variables | OLS | | Logit +IV | | RC Logit+IV[†] | |
|---|---|---|---|---|---|---|
| | Coefficient | Std. Error | Coefficient | Std. Error | Coefficient | Std. Error |
| Price[§] | -0.03** | 4.7e-3 | -0.04** | 5.6e-3 | -0.07** | 5.8e-3 |
| LCD | 1.01** | 0.23 | 1.17** | 0.24 | 1.59** | 0.32 |
| Size | -0.04** | 0.01 | -0.02* | 0.01 | 0.00* | 9.3e-3 |
| Technology Frontier | 0.05** | 8.7e-3 | 0.05** | 8.8e-3 | 0.04** | 9.0e-3 |
| Brand Dummies | Included | | Included | | Included | |
| Region Dummies | Included | | Included | | Included | |
| Time Dummies | Included | | Included | | Included | |
| Constant | -4.51 | .64 | -5.08 | .66 | -3.61 | .91 |
| **Unobserved Heterogeneity** | | | | | | |
| Price | | | | | 0.03** | 1.7e-3 |
| TechnologyFrontier | | | | | 0.03** | 0.01 |
| LCD | | | | | 1.38** | 0.35 |
| Size | | | | | 0.00 | 0.02 |
| Constant | | | | | -11.22** | 0.20 |
| N | 383 | | | | | |

*Note*: **: significant at 1% level, † RC Logit+ IV represents a random coefficients logit model with instruments for price and controls for unobserved heterogeneity. § Price variable scaled by a factor of 100.

**Table 11: Base Case Equilibrium (LCD)**

| Brand | Outsourcing | Technology Frontier | Wholesale Price ($) | Margins (p-c)/p | Quantity Sold (thousands) | Profits ($ millions) |
|---|---|---|---|---|---|---|
| Sony | 1 | 46 | 1888.51 | 0.46 | 1434.38 | 2601.52 |
| **Samsung** | 0.40 | 46 | 1810.46 | 0.42 | 2160.75 | 3400.07 |
| Panasonic | 1 | 32 | 1542.54 | 0.61 | 1705.31 | 3106.57 |
| **Sharp** | 0.10 | 60 | 3214.31 | 0.13 | 2230.03 | 2989.30 |
| Philips | 1 | 42 | 2970.33 | 0.11 | 2363.04 | 4031.84 |
| Toshiba | 1 | 42 | 1883.81 | 0.33 | 563.29 | 799.98 |
| TTE | 1 | 36 | 997.71 | 0.95 | 208.02 | 369.46 |
| **LGE** | 1 | 42 | 1771.93 | 0.29 | 1377.25 | 1711.77 |

**Table 12: All Firms Outsource (LCD)**

| Brand | Outsourcing | Technology Frontier | Wholesale Price ($) | Margins (p-c)/p | Quantity Sold (thousands) | Profits ($ millions) |
|---|---|---|---|---|---|---|
| Sony | 1 | 46 | 1861.33 | 0.46 | 1563.72 | 2780.21 |
| **Samsung** | 1 | 40 | 1600.31 | 0.60 | 1894.66 | 3284.83 |
| Panasonic | 1 | 32 | 1516.91 | 0.61 | 1851.56 | 3304.69 |
| **Sharp** | 1 | 50 | 2890.75 | 0.24 | 1803.16 | 2697.77 |
| Philips | 1 | 42 | 2763.18 | 0.18 | 2026.18 | 3630.96 |
| Toshiba | 1 | 42 | 1859.52 | 0.33 | 613.12 | 849.96 |
| TTE | 1 | 36 | 977.03 | 0.96 | 225.85 | 396.74 |
| **LGE** | 1 | 42 | 1439.52 | 0.57 | 1078.25 | 1599.33 |

*Note*: Firms in bold are those that produced in-house in the base case.

**Table 13: All Firms Move to In-house Production (LCD)**

| Brand | Outsourcing | Technology Frontier | Wholesale Price ($) | Margins (p-c)/p | Quantity Sold (thousands) | Profits ($ millions) |
|---|---|---|---|---|---|---|
| **Sony** | 0 | 58 | 2225.54 | 0.25 | 1815.38 | 2851.74 |
| Samsung | 0 | 54 | 1965.54 | 0.34 | 2269.71 | 3431.31 |
| **Panasonic** | 0 | 44 | 1882.07 | 0.33 | 2091.48 | 3317.13 |
| Sharp | 0 | 60 | 3268.41 | 0.12 | 2022.75 | 2663.59 |
| Philips | 0 | 54 | 3147.51 | 0.07 | 2387.09 | 3736.64 |
| **Toshiba** | 0 | 54 | 2233.96 | 0.14 | 694.04 | 836.34 |
| **TTE** | 0 | 48 | 1326.46 | 0.48 | 269.36 | 408.80 |
| LGE | 0 | 54 | 1799.53 | 0.30 | 1274.52 | 1610.12 |

*Note*: Firms in bold are those that were outsourced in the base case.

**Table 14: When should firms outsource?**

| Curr-ent Frontier | Change in | | | | | |
|---|---|---|---|---|---|---|
| | Technology Frontier | Wholesale Price ($) | Margins (p-c)/p | Quantity Sold (thousands) | Profits ($ millions) | Technology Frontier (competition) |
| 1.0 | -17% | -378 | 12% | -219.6 | 34 | -24% |
| 0.8 | -24% | -365 | 24% | -313.4 | -109 | -21% |
| 0.7 | -27% | -369 | 26% | -161.8 | -35 | -20% |
| 0.5 | -20% | -365 | 28% | -239.9 | -12 | -23% |

**Table 15: When should firms outsource?**

| Current Frontier | Effects | | |
|---|---|---|---|
| | Strategic Effect | Aura Effect | Efficiency Effect |
| 1.0 | 1.13% | -0.85% | 18.33% |
| 0.8 | 1.09% | -1.19% | 18.33% |
| 0.7 | 1.10% | -1.34% | 18.33% |
| 0.5 | 1.09% | -1.00% | 18.33% |

**Table 16: Sony and Samsung (Joint Venture (LCD)** )

| Brand | Outsourcing | Technology Frontier | Wholesale Price ($) | Margins (p-c)/p | Quantity Sold (thousands) | Profits ($ millions) |
|---|---|---|---|---|---|---|
| Sony | 0 | 58 | 1940.65 | 0.44 | 1313.11 | 2333.04 |
| Samsung | 0 | 58 | 1700.04 | 0.50 | 1550.01 | 3251.63 |
| Panasonic | 1 | 32 | 1597.15 | 0.41 | 2123.13 | 3678.66 |
| Sharp | 1 | 50 | 3413.00 | 0.14 | 2537.25 | 3084.12 |
| Philips | 1 | 42 | 3005.76 | 0.11 | 2793.41 | 3829.27 |
| Toshiba | 1 | 42 | 2313.50 | 0.21 | 723.38 | 1012.76 |
| TTE | 1 | 36 | 1340.72 | 0.67 | 332.02 | 610.38 |
| LGE | 1 | 38 | 1199.22 | 0.34 | 1252.44 | 1388.49 |

**Figure 1a: Sales of LCD TVs across regions by brands**

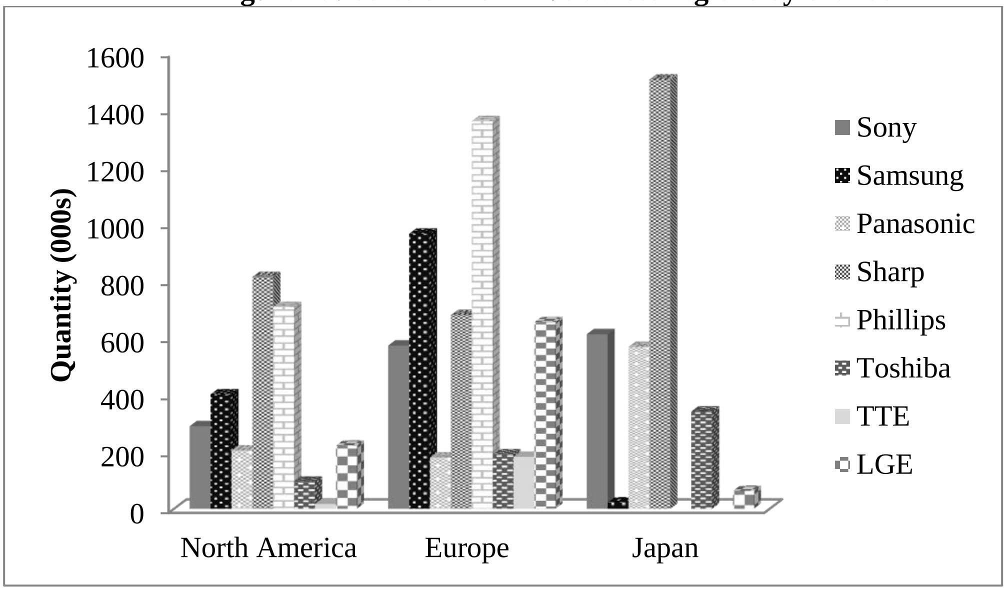



**Figure 1b: Sales of Plasma TVs across regions by brands**

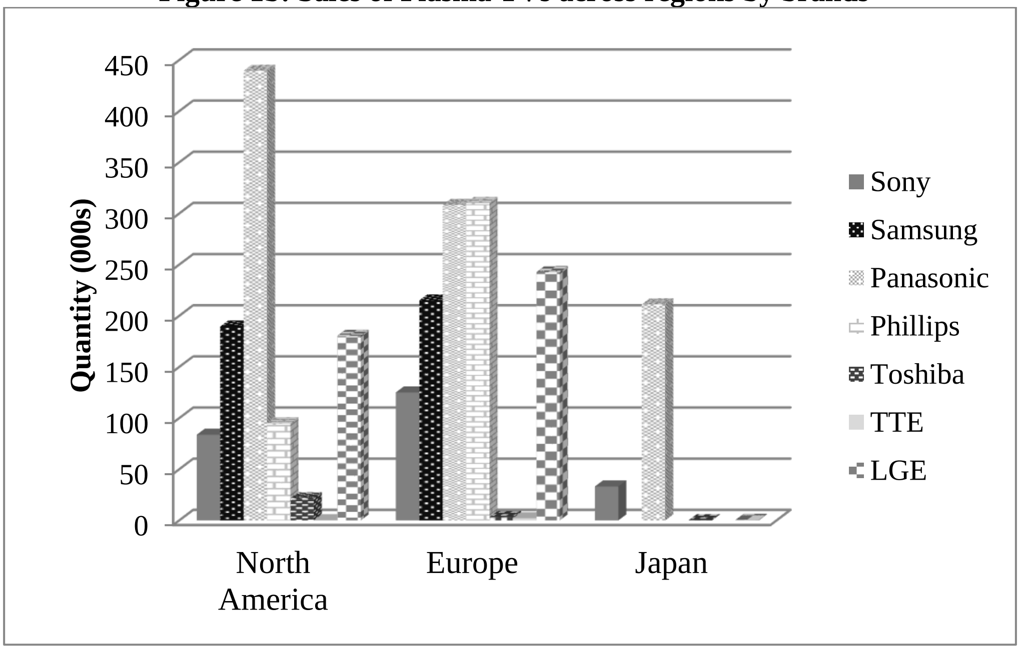


**Figure 2: Supply Chain Information** (Production Information for Q1-05, LCD Products)

| Brand | Size | Resolution | OEM | TFT LCD Supplier1 | DeInterlace Supplier | Timing |
|---|---|---|---|---|---|---|
| Samsung | 15" | XGA | Samsung | BOE Hydis,Samsung | Trident, Pixelworks, Genesis | |
| | 17" | 1280x1024 | Samsung | Samsung, | Trident, Genesis | |
| | 17" | 1280x768 | Samsung | Samsung, | Trident, Pixelworks | |
| | 20" | SVGA | Samsung | AUO, | Genesis | |
| | 20" | VGA | Samsung | CMO,Samsung | | |
| | 26" | 1280x768 | Samsung | AUO,Samsung | | |
| | 26" | 1366x768 | Samsung | Samsung, | | |
| | 32" | 1280x768 | Samsung | AUO,CMO | Trident | |
| | 37" | 1366x768 | Samsung | Sharp, | | |
| | 40" | 1366x768 | Samsung | Samsung, | Genesis | |
| | 46" | 1920x1080 | Samsung | Samsung, | Genesis | |
| Sharp | 13" | VGA | Sharp | Sharp, | Renesus | |
| | 15" | XGA | Sharp | Sharp, | Genesis, Renesus | |
| | 20" | XGA | Sharp | Sharp, | Pixelworks | |
| | 22" | 854x480 | Sharp | Sharp, | Genesis, Renesus | |
| | 26" | 1366x768 | Sharp | Sharp, | Genesis | |
| | 30" | 1280x768 | Sharp | Sharp, | Pixelworks | |
| | 32" | 1366x768 | Sharp | Sharp, | Sharp | |
| | 37" | 1366x768 | Sharp | Sharp, | Genesis | |
| | 45" | 1920x1080 | Sharp | Sharp, | | |
| | 65" | 1920x1080 | Sharp | Sharp, | | |
| Sony | 14" | VGA | Amtran | CMO, | Sony | |
| | 15" | VGA | Amtran | CMO, | Pixelworks | |
| | 17" | 1280x768 | Sony | CMO,Samsung | Trident | |
| | 19" | 1280x768 | Sony | Samsung, | Sony | |
| | 21" | XGA | Sony | Hitachi, | Sony | |
| | 23" | 1366x768 | Sony | Samsung, | Sony | |
| | 26" | 1280x768 | Sony | LPL,Samsung | Sony, Trident | |
| | 27" | 1280x720 | Sony | CMO, | Sony | |
| | 30" | 1280x768 | Sony | CMO, | Sony, Trident | |
| | 32" | 1366x768 | Sony | Samsung,Hitachi | Sony | |
| | 40" | 1366x768 | Sony | Samsung, | Sony | |
| | 42" | 1366x768 | Sony | Samsung, | Sony | |
| | 46" | 1920x768 | Sony | Samsung, | Sony | |

**Figure 3a: *TechnologyFrontier* by brands (LCD)**

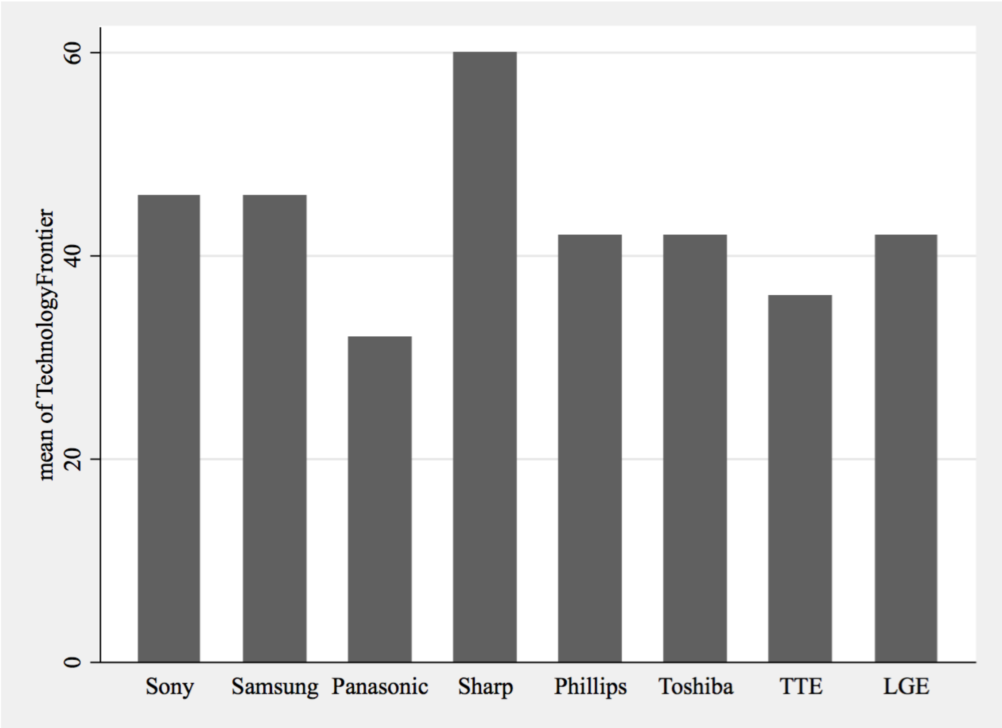
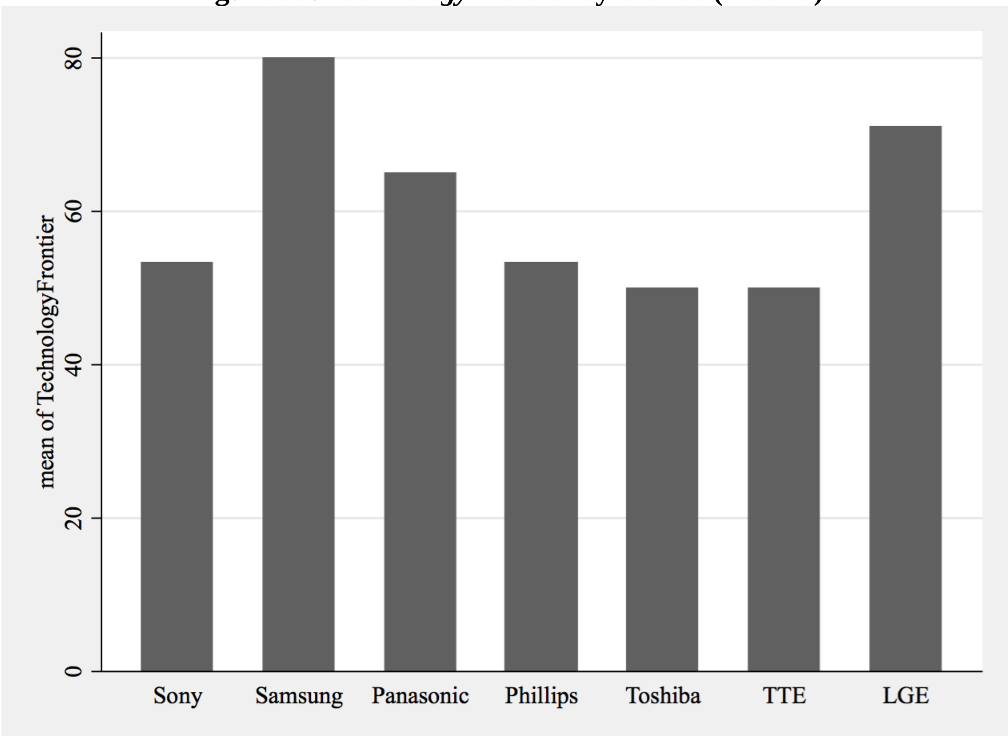



**Figure 3b: *TechnologyFrontier* by brands (Plasma)**




*Note*: Outsourcing is a scale from 0-1 with 1 representing complete outsourcing of all core components.

**Figure 4a: Core Component Outsourcing and Price**

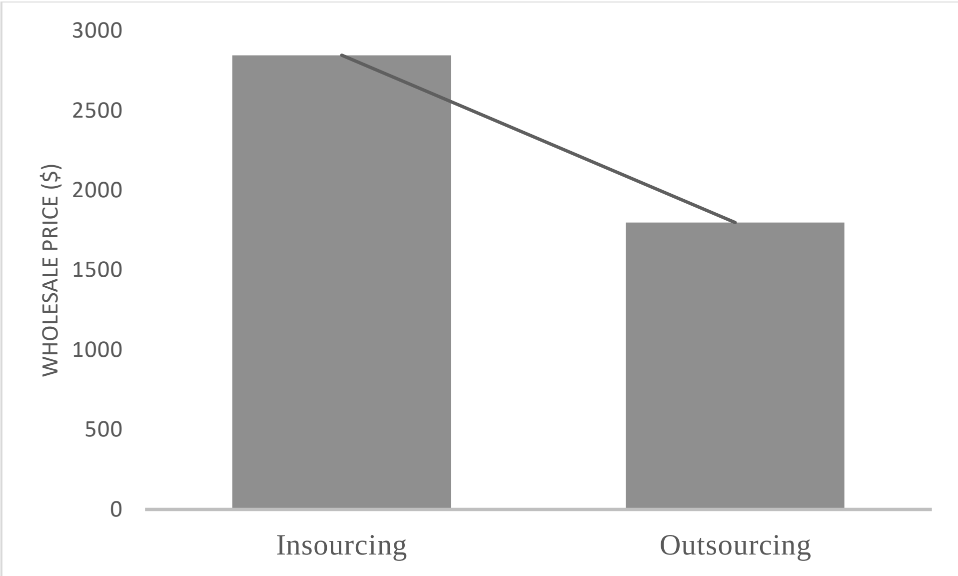



**Figure 4b: Core Component Outsourcing and Technology Frontier (max. size)**

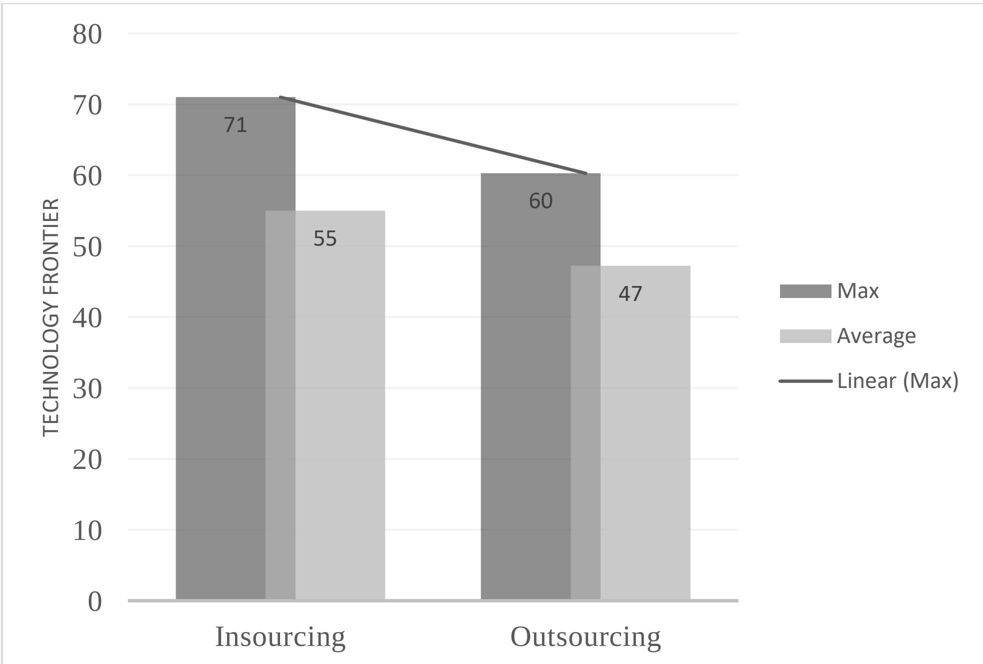
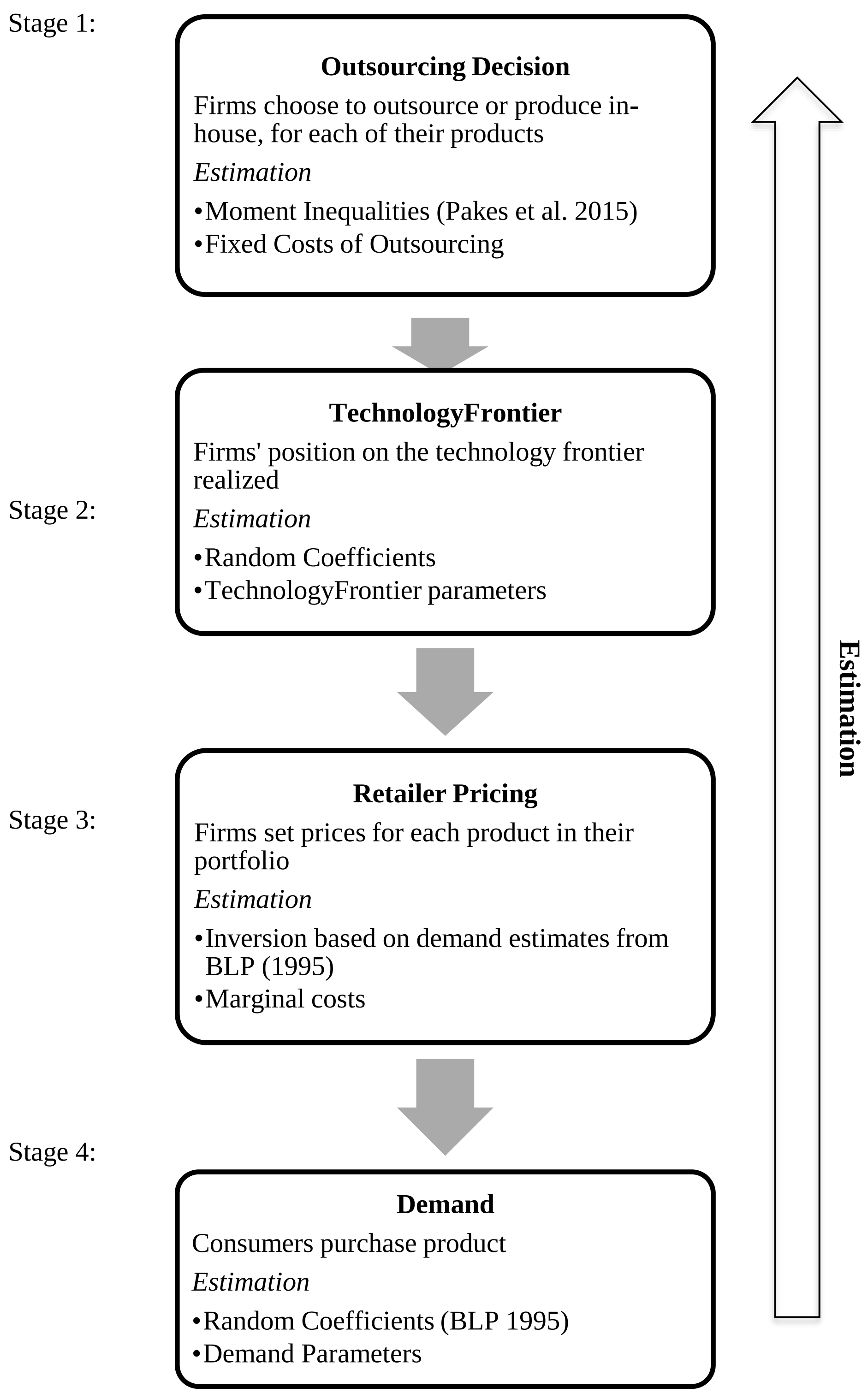


**Figure 5: Flowchart of Model and Estimation**



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