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The impact of mergers and acquisitions on brand equity: A structural analysis ☆

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ABSTRACT

An overlooked strategic benefit of mergers and acquisitions (M&As) is their impact on brand equity. M&As may affect consumer brand preferences, which in turn will affect a firm's profit. We develop a structural model with a difference-in-differences specification to measure how M&As affect a firm's profit through three mechanisms: brand equity, cost synergies, and product portfolios. We analyze Lenovo's acquisition of IBM's PC division in China's PC market and find that the increase in brand equity contributed the most to increasing Lenovo's profit, followed by cost synergies. To explore the generalizability of our modeling approach, we apply it to Geely's acquisition of Volvo and also find that the gains in brand equity contributed the most to Geely's profit increase.

1. Introduction

Mergers and acquisitions (M&As) occur frequently and play an important role in the world economy. In the first three quarters of 2018, global M&As worth $3.3 trillion set a record for the previous three decades, and M&A transaction volumes accounted for more than 4% of global GDP between 1995 and 2018.[1] Given the ubiquity and importance of M&A activities, researchers in various disciplines have investigated them from diverse perspectives, including their drivers, implications for market power, impact on product strategies, cost synergies, consumer welfare, and post-merger performance.

At the industry level, M&As can take place due to resource deficiencies, technological innovation, deregulation, and capital liquidity (Harford, 2005; Mitchell and Mulherin, 1996; Shleifer and Vishny, 2003). At the firm level, M&As can be motivated by resource dependence, cost synergies, market entry, tax considerations, and firm-manager interactions (Fama, 1980; Larsson and Finkelstein, 1999). M&As can enhance or reduce total economic welfare, depending on the balance between heightened market power, cost reduction, and market structure (Agrawal et al., 1992; Borenstein, 1990; Jeziorski, 2014; King et al., 2004; Peters, 2006; Stigler, 1950).

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[1] We compute this number based on M&A volume data from Dealogic and gross worldwide product data from IMF and the Economic Research Service of the United States Department of Agriculture.

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In addition to market power and cost synergies, another strategic benefit may result from M&As: the brand equity effect. M&As can substantially increase consumers' preferences, which in turn will affect firm profit. For instance, a firm can charge a higher price to increase its profit margins or maintain the price to increase demand. However, prior research has overlooked consumers' reactions to M&As and their changing preferences for the acquirer and acquiree.

This paper sets out to investigate the role of consumer preferences in M&A outcomes by quantifying their impact on post-acquisition profits and comparing their profit impact relative to gains in cost efficiency and the product portfolio. Following Goldfarb et al. (2009), we define the profit impact of change in consumer preferences as the brand equity effect.

M&As can affect consumer brand preferences in several ways. First, M&As are usually followed by the consolidation of brands and product lines, which may lead to positive or negative spillover effects in consumers' perceptions of the brands of the acquiring and acquired firms (Aaker and Keller, 1990; Wernerfelt, 1988). Second, the acquiring firm can apply the acquired firm's technologies to its original products to improve product quality. Third, if a less well-known brand acquires a better-known brand, it may signal its technological capability and management capacity—as well as the quality of its products—to the market. Fourth, cross-border M&As may even tap into national pride on the part of the acquiring firm's consumers (Chu, 2013). These possible consequences of M&As can increase consumers' willingness to pay and their demand for certain products, which will affect the acquiring firm's profits. These potential brand equity effects may influence a firm's profit as significantly as the possible cost synergies and broader product portfolio effects.

We use a conceptual framework (Fig. 1) to depict how the changes in brand equity, cost synergies, and the product portfolio individually and jointly affect firm profit.[2] First, with gains in brand perceptions, a firm can charge a higher price to increase its profit margins or maintain the price to increase demand. Second, with cost synergies, firms will enjoy a larger markup if they maintain the price; they can also lower prices to increase market share. And third, with a widened product portfolio, a firm can use product line pricing to soften internal competition.

Lenovo's acquisition of IBM's personal computer (PC) division in 2004 serves as a suitable context to measure the brand equity effect and compare the associated profit impact with other channels. The acquisition could potentially have yielded three gains: improvement in brand preference, cost synergies, and product portfolio gain. First, as an internationally renowned US brand and the firm that standardized the PC industry, IBM was perceived by Chinese consumers as a premium brand (Chu, 2013). By the agreement, Lenovo could co-brand with IBM by embedding its logo on Think Series products along with the IBM logo for 5 years, which could have significantly enhanced the intrinsic preferences of consumers for Lenovo. Second, the acquisition increased Lenovo's market share, both inside and outside China. Due to economies of scale in procurement, marketing, distribution, and production, the deal might have generated cost synergies; Lenovo also expected to save up to $200 million from the economies of scale in its supply chain (Bloomberg Businessweek, 2005). Third, the addition of IBM's Think Series to Lenovo's portfolio put the former rivals under common ownership. Lenovo could set prices jointly for its original brands and the Think Series to soften competition and, in turn, create product portfolio gain.

On the other hand, it is possible that the three gains might not have materialized. Co-branding with IBM might not work for Lenovo, because consumers might doubt its ability to incorporate advanced technologies from the Think Series in its lower-end PCs. Lenovo spent little on R&D and focused on low-cost production (Spooner and Kanellos, 2004), whereas premium quality and advanced technologies require considerable investment in R&D and production. Moreover, Lenovo might not achieve substantial cost synergies. After the acquisition, Lenovo had two business groups: the Lenovo Business Group (LBG), which managed the original Lenovo portfolio, and the Think Business Group (TBG), which managed the acquired IBM Think Series. The two groups procured their PC components separately until mid-2006 (Zellen, 2005). In addition, there might not be much product portfolio gain, given that the original Lenovo PCs and the Think Series targeted different consumer segments.

We address the following questions in our empirical analysis: (1) Do the three gains exist in Lenovo's acquisition of IBM's PC division? (2) Compared with the profit impact of potential cost synergies and product portfolio gains, does the change in brand preference have a larger or smaller impact on the acquiring firm's profit?

Our demand estimates show that consumers valued the Lenovo brand significantly more after the acquisition.[3] The change arose primarily from co-branding with the Think Series brand, rather than the IBM brand, which implies that the Think Series brand was independent of its mother brand, IBM. This explains why Lenovo dropped the IBM logo from Think Series computers earlier than scheduled. We also find no dilution of Think Series' brand equity in the data period. Our cost estimates

[2] We acknowledge that our research only captures part of the benefits of the acquisition. Lenovo benefited in three respects from the acquisition: the brand, the technology, and global channels, as noted by its founder, Liu Chuanzhi (Hamm, 2008). Our paper focuses on the brand benefits. We only have data from the Chinese market, which prevents us from examining the benefits from global channels. As for the benefits of technology, Lenovo adopted technologies from the Think Series to design the IdeaPad at the end of 2008–4 years after the acquisition and the end of our data period.

[3] We agree that consumers might be forward-looking when purchasing PCs, although we do not think such behavior would qualitatively change our main results regarding the impact of acquistion for the following reasons: (1) We use quarterly data for model estimation. As long as a great majority of consumers did not delay their purchases for more than one quarter, short-term forward-looking behavior would not materially influence the estimated change in brand preference. (2) We use a DiD specification to identify the effect of acquisition on brand equity. As long as the acquisition did not change consumers' forward-looking behavior in the post-acquisition period differently for Lenovo than for other vendors, our results would continue to hold. Meanwhile, it is worth noting that the acquisition should be exogenous for consumers, because it was uncertain even for Lenovo. IBM approached Lenovo for a sale at the end of 2003, and even so, the merger proposal met with strong objection from lawmakers and regulators in the United States. On the other hand, if forward-looking behavior is indeed salient in this industry, we may underestimate the profit impact of the change in brand preference. As shown by Hendel and Nevo (2006), lack of control for forward-looking behavior can lead to an overestimation of own-price elasticities. As a result, we may underestimate the margin of each vendor, which means that our estimate of the acquisition's impact on profit is conservative.

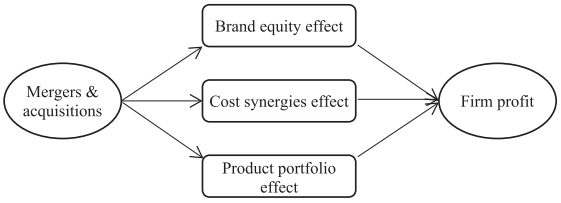

Fig. 1. Conceptual framework of M&As and firm profit.

indicate that the acquisition generated 5% in cost synergies for Lenovo. A comparison of the substitution pattern before and after the acquisition suggests that the acquisition enhanced Lenovo's market position and rendered it more competitive than all other PC makers in China's PC market. Although our framework only explicitly considers the adjustment in pricing strategies under the new market structure, we also checked potential confounding factors, such as changes in product lines and channel strategies, and found them unlikely to explain our findings (see Section 3.4 for details).

Our counterfactual experiments show that the acquisition boded well for Lenovo, generating an additional profit of $1.87 billion from 2005Q2 to 2008Q4 that more than offset the acquisition costs of $1.75 billion. Brand equity gains were the most important profit enhancer, leading to a 15% increase in profit, and cost synergies were responsible for enhancing profit by 11%. The product portfolio effect was positive but negligible, because with prices twice those of Lenovo, the Think Series focused on the business segment—whereas Lenovo targeted price-conscious consumers—and the cross-elasticity table shows low substitution between the two.

Our analysis demonstrates the importance of consumer preferences in M&As, which the merged firm can actively leverage to capitalize on. Our analysis also sheds light on the motives and potential gains for cross-border M&As. More and more firms in emerging markets are engaging in cross-border M&As to expand into developed markets and break their links with their country of origin (Zhang, 2015). For example, BenQ (Taiwan) acquired the mobile devices division of Siemens (Germany) in 2005; Tata Motor (India) acquired Jaguar Land Rover (UK) in 2008; Geely (China) acquired Volvo (Sweden) in 2010; Haier (China) bought GE's appliance business (US) in 2016; Hon Hai (Taiwan) bought Sharp (Japan) in 2016; and the Midea Group (China) acquired Toshiba's line of home appliances (Japan) in 2016.

To demonstrate the generalizability of our proposed approach, we apply the modeling framework to analyze Geely's acquisition of Volvo in China's automobile market. We find that the acquisition led to a substantial increase in firm profit, which arose primarily from the enhanced brand preference; the effect of cost synergies was negligible because of the more sophisticated production process of automobiles and the nature of the agreement between Geely and Volvo.

Our contributions are as follows. Substantively, this paper applies the proposed framework to China's PC and automobile industries. Results across two disparate industries show that enhanced brand equity by mergers has the largest profit-boosting effect among the three mechanisms. The boost in profit is comparable to the acquisition cost of IBM's PC division. This is a novel finding to the literature, and the analysis of the two different industries suggests generalizability. This has significant managerial implications, because it offers firms involved in M&As a new approach for analyzing the potential benefits of an M&A. It also demonstrates the potential importance of changes in brand preference in an M&A. Firms can purposely leverage the brand equity of the acquired firm and its brand(s) to maximize the M&A's profit impact. Theoretically, this article provides a useful perspective for evaluating the performance of an M&A by evaluating brand equity change based on consumer choice. Our study introduces an important but missing piece in the evaluation of M&As and strengthens the marketing literature on M&As by investigating an important factor: brand equity. Brand equity may be more influential than cost synergies, the focus of previous IO research on M&As. There is not much work in the marketing literature on evaluating the *ex-ante* impact of a merger on consumer brand valuations. Though we perform *ex-post* analysis of M&As, since managers presumably have some knowledge of the potential cost synergies of an M&A, as long as they can gauge, via surveys or conjoint analysis or based on managerial insights, the potential change in consumer's brand preference should an M&A occur, they can apply the proposed modeling approach to assess the viability of an M&A *ex-ante*.

2. Literature review

This article is related to M&A studies in multiple disciplines, such as industrial organization (IO), strategy, management, and marketing. The IO research mainly looks at how M&As influence total economic welfare and a firm's motives via production, cost synergies, and market power. Stigler (1950) has shown that if there are no cost synergies and the merged firms produce less than the combined pre-M&A production, the acquirer and acquiree may theoretically benefit less than outsiders from increased post-M&A prices. Deneckere and Davidson (1985) and Perry and Porter (1985) reach different conclusions on the larger firm's incentive to merge in a price-setting game under the assumption of constant returns to scale. Nevo (2000a) uses the Berry, Levinsohn, and Pakes (1995) approach to simulate the competitive effects of M&As. Peters (2006) shows that standard merger simulation methods that ignore changes in firm conduct and cost reductions after the M&A do not accurately predict the M&A's performance. Jeziorski (2014) proposes a method to identify cost efficiencies from the production-cost curve in M&As. This paper supplements the IO literature by empirically measuring the brand impact of M&As and comparing it with cost reductions.

The strategy and management literatures study M&A performance mainly at the individual firm level, and investigate issues such as resource dependence, organizational learning, executive departures, cultural conflicts, synergies from operations and management, and short-/long-term evaluations based on changes in the stock market (Haleblian & Finkelstein, 1999; Hayward, 2002; Morosini, Shane, & Singh, 1998; Weber, Shenkar, & Raveh, 1996).

A review by Yu (2013) found that M&A research is underdeveloped in marketing. Previous research examines various topics, such as brand value and strategic fit between firms, the impact of redeploying marketing resources on costs and revenue after M&As, managers' evaluations of the brands involved, and strategic fitness and stock market returns (Bahadir, Bharadwaj, & Srivastava, 2008; Capron & Hulland 1999; Mahajan, Vithala, & Srivastava, 1994; Swaminathan, Murshed, & Holland, 2008). However, few marketing studies consider the role of consumers in M&As. Golder, Mitra, and Moorman (2018) study the role of quality considerations in M&As and how they influence consumers in different types of M&As. Jaju, Joiner, and Reddy (2006) study how different corporate brand redeployment strategies influence consumers' brand evaluations. We focus on the strategic impact of M&As on brand equity, which until now has not been explored in the literature. We go a step further by measuring the effect of changes in consumer brand preferences induced by acquisition on a firm's post-M&A performance and comparing it with the effects of cost synergies and the broadened product portfolio.

3. Data and preliminary analysis

3.1. Data summary

Our data were provided by the International Data Corporation, a leading marketing research firm, with quarterly retail prices and units of all PC models sold in China from 2001 to 2008. Retail prices are the end-user (street) prices paid for a typical configuration for each PC model; units sold refer to the number of PCs sold to end-users. The acquisition of IBM's PC division was announced at the end of 2004, approved by the Committee on Foreign Investment in the United States in March 2005, and completed at the end of May 2005. The data encompass roughly 4 years before and 4 years after the acquisition, which enables us to assess the impact of the acquisition on Lenovo.

Each observation in the dataset consists of the following information: PC vendor (e.g., Dell, HP, Lenovo); PC brand (e.g., Pavilion, Inspiron, Portege); form factor (desktop, laptop, or ultraportable); type of distribution channel (dealers, retailers, direct inbound by telephone/fax, direct outbound by salesforce, internet); central processing unit or CPU maker (Intel, AMD, and other brands); CPU speed; number of cores (single, dual, or quad); retail price; and units sold. Table 1 provides a summary of the data. Average PC prices decreased from $1,325 in 2001 to $747 in 2008, and annual PC sales grew from 9.59 million units to 39.57 million units during the same period.

The top nine PC vendors—Lenovo, Founder, HP, Dell, Tongfang, Acer, Asus, IBM, and Sony—together with user-assembled or "white box" PCs had a market share of 81.7% in 2001 and 92.5% in 2008. We label the remaining PC vendors "other vendors." China's PC market became increasingly concentrated during the 8 years we study, with the top nine PC vendors' market share increasing from 53% to 71%.

Before the acquisition, IBM's sales mainly came from the Think Series, which had about 4% market share. After the acquisition, Lenovo kept only the Think Series; IBM continued to sell its IntelliStations line, which had a negligible market share (0.01%), and discontinued all other products in China. Lenovo's market share dropped from 27% in 2004 to 24% in 2005 and then increased to 25% in 2008.

3.2. Changes in brand preference: model-free evidence

We plot the evolution of quantity shares and prices for major vendors in Figs. 2 and 3, respectively. Foreign brands such as HP and Dell gained market share, and most Chinese vendors lost market share, especially after 2005. However, the trajectory for Lenovo was different: Its market shares dwindled until 2004, then reversed and grew. A closer examination reveals that both LBG and TBG witnessed market share gain in the post-acquisition period. The timing of the reversal suggests that the acquisition may be a key contributor. Lenovo's price trend was also different from the downward trend of the other vendors, because its mean price decreased prior to the acquisition but *increased* in the post-acquisition period. A closer look at Lenovo reveals that both LBG and TBG witnessed a price rise in the post-acquisition period.

These two figures together suggest a potential branding effect: Consumers liked Lenovo more in the post-acquisition period, and consequently the market shares of both Lenovo's original brands and the Think Series increased with their prices.[4]

3.3. Changes in brand preference: a reduced-form analysis

Brand preference is not directly observed, and thus is difficult to measure. One aspect of structural/reduced-form estimation of brand equity is that the estimated intercept may capture factors beyond brand preference. However, changes in brand preference due to M&As can be identified using a difference-in-differences (DiD) method. If Lenovo's sales were not different from those of its competitors before the acquisition, after controlling for other demand shifters (parallel pre-trends), but

[4] A DiD regression on price also shows a significant increase for Lenovo post-acquisition.

Table 1
Summary statistics.

	CPU Speed (GHz)		No of Cores		Price (US$)		Sales by Units (million)
	Mean	SD	Mean	SD	Mean	SD	
2001	1.20	0.74	1	0	1,324.81	619.84	9.59
2002	1.73	0.68	1	0	1,216.76	497.05	11.03
2003	1.98	0.67	1	0	1,092.37	417.34	12.96
2004	2.06	0.74	1	0	1,004.31	376.05	15.55
2005	2.17	0.68	1.05	0.22	845.49	360.78	23.61
2006	2.21	0.64	1.34	0.48	800.71	296.31	28.83
2007	2.20	0.64	1.65	0.51	803.02	281.95	36.20
2008	2.16	0.49	1.90	0.66	746.50	217.26	39.57

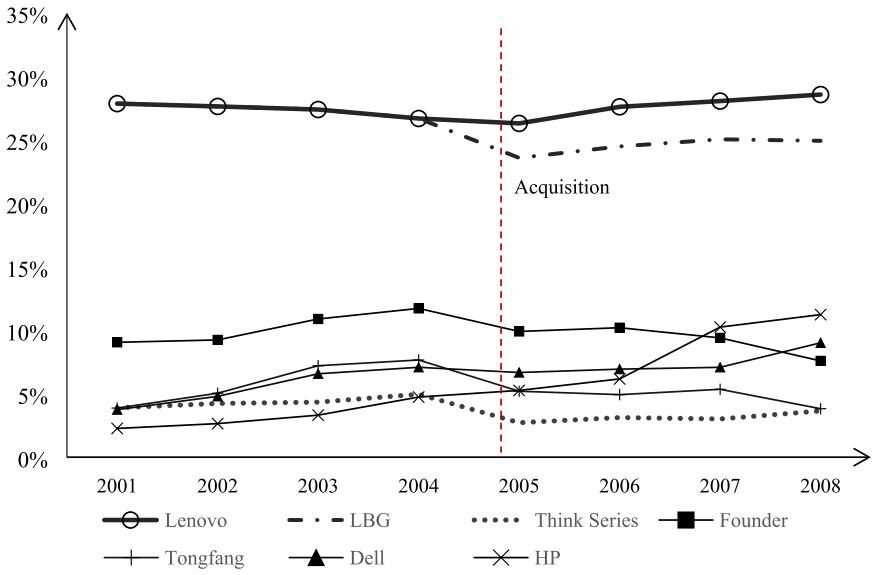

Fig. 2. Market share evolution of major vendors.

went up significantly more than those of its competitors after the acquisition—and if we can rule out other possible reasons for the sales increase—then we can infer that brand preference may have been improved by the acquisition. Following this reasoning, we first check whether Lenovo's sales went up after the acquisition, then test for parallel pre-trends and rule out other possible explanations.

To detect a different sales pattern for Lenovo after the acquisition, we regress sales of PC model j in quarter t, q_{jt}, on demand shifters as follows:

$$\ln(q_{jt}) = X_{jt}\eta_1 + \eta_2 p_{jt} + \eta_3 I_L * I_{post} + \eta_t I_t + e_{jt} \quad (1a)$$

where X_{jt} is the vector of dummies for PC vendors, PC brands, CPU makers, distribution channels, form factors, and other product attributes, including CPU speed and its square term and the number of cores and its square term; and p_{jt} is retail price. I_L is an indicator for Lenovo, and I_{post} is an indicator for the post-acquisition period (2005Q2–2008Q4); thus η_3 stands for Lenovo's additional demand change after the acquisition, and is the parameter of main interest. I_t denotes quarter dummies, and η_t represents quarter fixed effects.[5]

Results are reported in Table 2, Panel 1. The coefficient of $I_L{}^*I_{post}$ is significantly positive, indicating that demand for Lenovo increased more than for others after the acquisition. Because price might be endogenous in this ordinary least squares (OLS) regression, we use cost shifters—1- and 2-quarter lagged PPI for products related to PC production (semiconductors, processors, memory, storage, and other peripherals)—as instruments and run a two-stage least squares (2SLS) (Table 2, Panel 2). The coefficient of $I_L{}^*I_{post}$ remains statistically significant. To check whether the brand effect is evident for Lenovo products other than the Think Series, we create a dummy for Lenovo's other products and interact it with the post-acquisition dummy

[5] We omit the main effect of I_{post} in the model because it is absorbed by quarter fixed effects. Without quarter fixed effects, I_{post} will represent overall demand change for all PC vendors in the post-acquisition period.

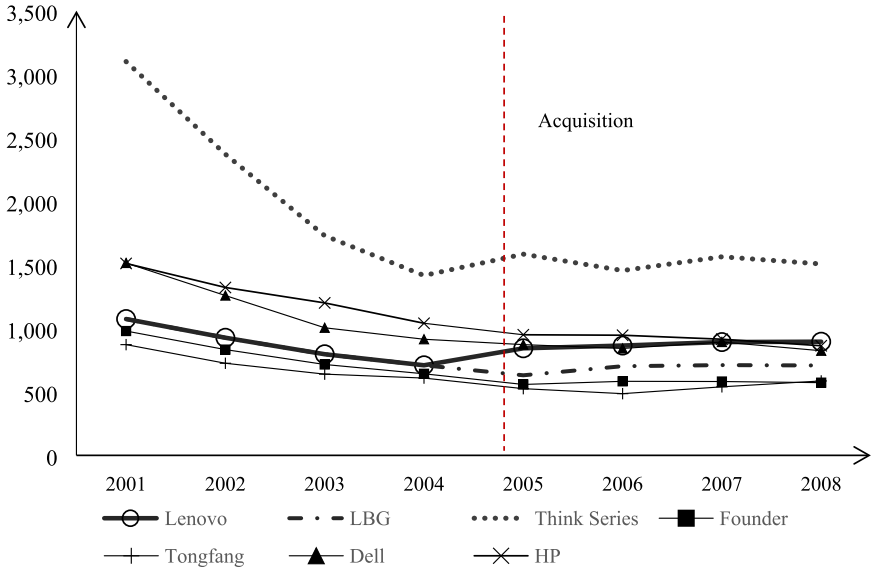

Fig. 3. Mean price evolution of major vendors.

Table 2
Regression of ln(Demand) on product attributes.

	(1) OLS		(2) 2SLS		(3) Impact on Lenovo's original brands	
	Beta	SE	Beta	SE	Beta	SE
Lenovo*post-M&A	0.65	0.22	0.66	0.17		
LBG*post-M&A					0.65	0.22
Price (in $1000)	−0.86	0.16	−3.43	0.88	−0.86	0.16
CPU speed	1.68	0.19	2.33	0.31	1.68	0.19
CPU speed^2	−0.44	0.05	−0.47	0.06	−0.44	0.05
No. of cores	0.35	0.17	1.45	0.41	0.35	0.13
No. of cores^2	−0.15	0.03	−0.19	0.04	−0.15	0.03
PC vendor fixed effects	Yes		Yes		Yes	
PC sub-brand fixed effects	Yes		Yes		Yes	
Form factor fixed effects	Yes		Yes		Yes	
Channel fixed effects	Yes		Yes		Yes	
CPU vendor fixed effects	Yes		Yes		Yes	
Quarter fixed effects	Yes		Yes		Yes	
N	30,976		30,976		30,976	
R^2	0.28				0.28	

* Standard errors clustered at vendor-quarter level.

to see whether the effect remains (Table 2, Panel 3). The estimated brand effect remains unchanged, which suggests that the acquisition increased the overall preference for Lenovo.

As a first step to verify that the control group is comparable to Lenovo, Table 3 shows that the observed product attributes are similar for Lenovo and other vendors. We then test for parallel pre-trends as follows:

$$\ln(q_{jt}) = X_{jt}\eta_1 + \eta_2 p_{jt} + \eta_{Lt} I_L * I_t + \eta_t I_t + e_{jt} \quad (1b)$$

We plot the 31 coefficients of Lenovo and quarter interactions in Fig. 4. Two observations follow: (1) Brand preference for Lenovo followed the same trend as other vendors before the acquisition; and (2) there was a brand-preference lift for Lenovo immediately after the acquisition and no discernible trend after that. Moreover, the flat and stable brand preference in the post-acquisition period also rejects an alternative explanation: that the effect was driven by a news effect, since Lenovo was more visible for a short period after the acquisition.

In summary, the above analyses provide evidence on the existence of a brand equity effect in China's PC market induced by Lenovo's acquisition.

Table 3
A comparison of Lenovo and other vendors.

	Lenovo (N = 3824)		The rest (N = 27,152)	
	Mean	SD	Mean	SD
Price (US 1000$)	0.99	0.56	1.04	0.68
CPU Speed	2.16	0.67	2.04	0.69
# of cores	1.43	0.57	1.39	0.57
Dealer (0–1)	0.38	0.49	0.41	0.49
Retail (0–1)	0.39	0.49	0.38	0.49
Intel (0–1)	0.87	0.34	0.85	0.36
AMD (0–1)	0.13	0.34	0.13	0.33

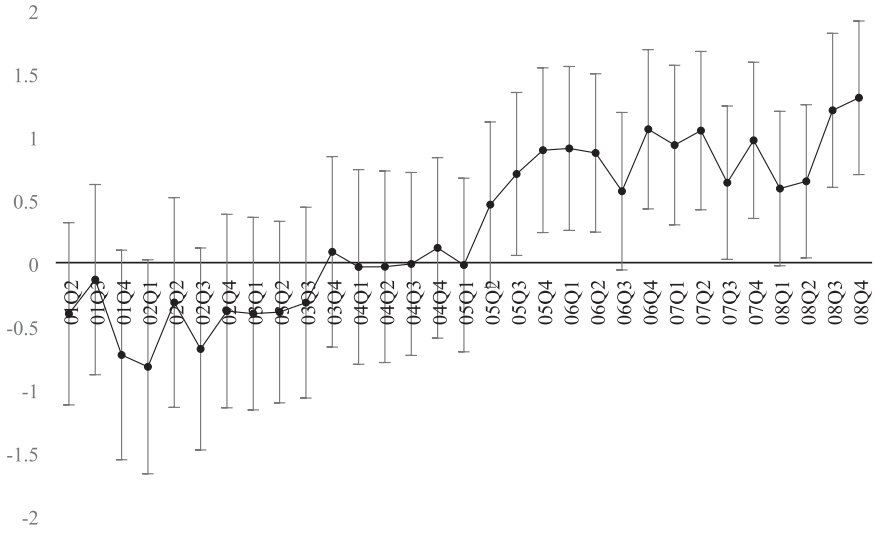

Fig. 4. Temporal change in Lenovo's brand preference.

3.4. Potential confounding factors

Together, the model-free evidence and regression analysis suggest that the acquisition may have increased consumer preference for Lenovo. However, it is important to discuss potential confounding factors before we dive into the full structural analysis.

Change of Distribution Channels. Yuanqing Yang, Chairman of Lenovo, announced the acquisition at a press conference and stated that Lenovo's distribution channels would not be affected by the acquisition.[6] Fig. 5 shows the distribution of sales by channel for Lenovo, other Chinese vendors, Dell, and other overseas vendors. The change in Lenovo's distribution channels was no different from that of other vendors, with the exception of Dell.[7] We further examined sales changes within indirect channels (dealers and retailers) and found that Lenovo and other PC vendors had a similar pattern: More sales came from retailers than dealers over time. Their similar changes in distribution channels will be differenced out via our DiD approach. Thus, the estimated coefficient is the net impact of the acquisition on Lenovo's demand.

Changes in product lines. Firms involved in M&As may use instruments other than price to exploit changes in consumer preferences (Fan, 2013). As M&As often involve product line consolidation, we verified whether Lenovo changed its product lines around the time of acquisition (2004Q4). During the study period, six of Lenovo's product lines were dropped before the acquisition: three in 2001 and another three in the second quarter of 2003. After the acquisition, four product lines were introduced: one in 2006Q2, a year and a half after the acquisition, and three in 2008, long after the acquisition. Thus, it appears that Lenovo did not consolidate its product lines because of the acquisition.

Advertising spending. In an interview in 2014 regarding acquisition of the Think Series, Lenovo's Chief Marketing Officer, David Roman, stated that "the company spends roughly in line with the industry average of 1.5 percent of sales" on advertising.[8] It seems Lenovo did not change its advertising strategy because of the acquisition. We argue that advertising spending may be a source of price endogeneity, but is less likely to influence the estimate of the brand effect.

[6] http://tech.sina.com.cn/it/2004–12-08/1223472551.shtml, accessed March 29, 2020.
[7] Dell was known as "the direct model of selling" and had a channel strategy different from other PC vendors.
[8] https://www.strategy-business.com/article/00274?gko=abf3ez, accessed March 29, 2020.

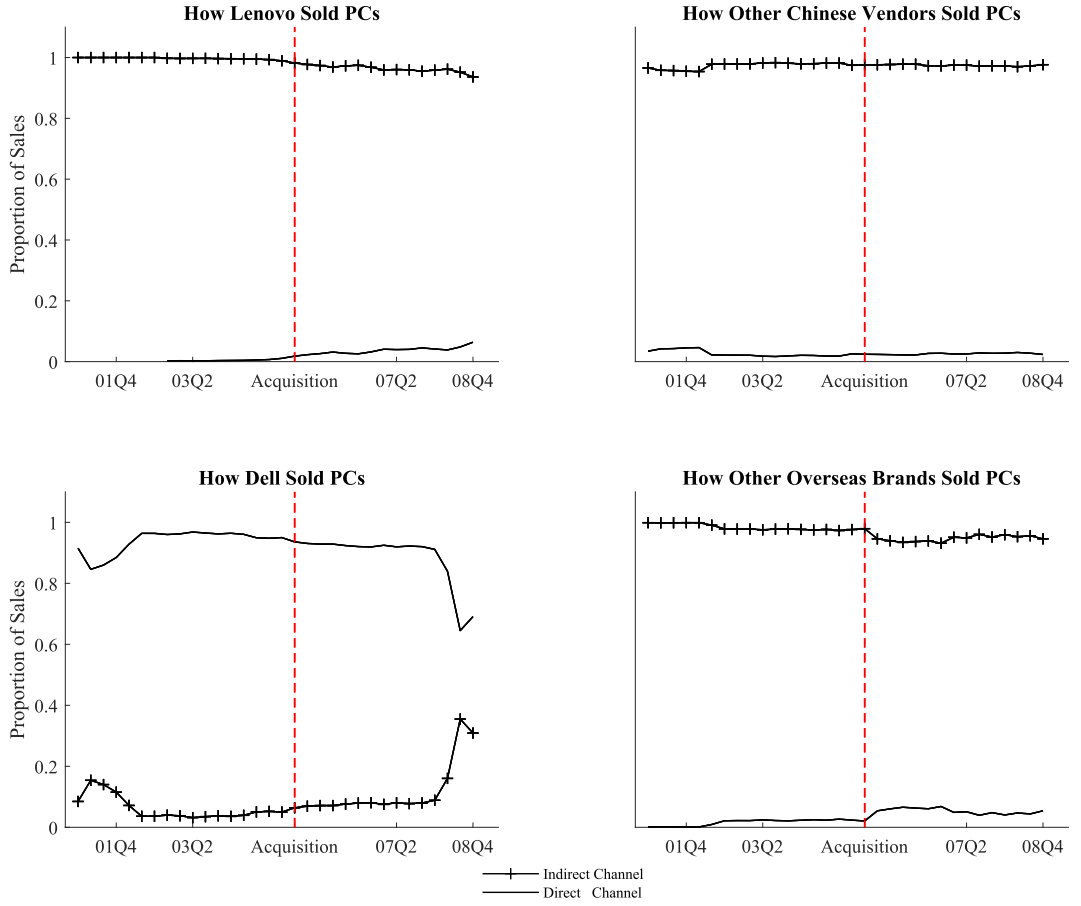

Fig. 5. Distribution of sales by channels.

Economic growth. China's GDP growth is highly correlated with the linear time trend, with a Pearson correlation coefficient of 0.95. Quarter dummies can control for the effect of economic growth. Therefore, it is safe to conclude that economic growth does not drive our estimated impact of the acquisition on Lenovo's demand. Further, we examine the incremental impact on Lenovo, whereas economic growth should affect overall market demand for PCs.

4. Model formulation

To measure the impact of M&As on firm profit through different mechanisms, we must determine what would happen to firm profit if an M&A did not have any effect on consumer preferences, marginal costs, or the firm's pricing. Based on comparison of the potential effects, we can then assess the importance of the brand equity effect and its managerial relevance. Our main research objective cannot be achieved through DiD regression, which necessitates counterfactual experiments and structural modeling. Further, compared with reduced-form analysis, a structural model can incorporate competitive responses and mitigate the difficulty of choosing a good control group for Lenovo.

In our structural model setup, we derive the demand model from consumer utility maximization behavior. This allows us to capture how M&As affect the intrinsic preferences of consumers. To assess the influence of changes in brand preferences on firm prices and profits, we also need the firm's pricing equations on the supply side to back out marginal costs. We derive the pricing equation from the profit-maximizing behavior of PC vendors (i.e., manufacturers). As we will explain below, vertical integration is the typical channel arrangement in China's PC market, so PC vendors set retail prices based on their product portfolios and marginal costs. From the pricing equation, we can back out wholesale marginal costs and estimate potential cost synergies by comparing the cost trajectories of firms involved in an M&A with those that are not, before and after an M&A. If the marginal costs at the product level of the focal firm fall faster than those of other firms *and* faster than during the pre-acquisition period, we conclude that there are cost synergies. By comparing the acquiring firm's actual post-merger profit with that in the counterfactual scenario—in which the acquired brands were not under its ownership after the acquisition—we can examine the effect of changes in product portfolio on the acquirer's profits.

4.1. Demand model

The indirect utility consumer i derives from buying PC model j in quarter t is

$$u_{ijt} = X_{jt}\alpha_i + \beta_i p_{jt} + \lambda_i I_L * I_{post} + \lambda_t I_t + \alpha_{TS,pre} I_{TS} * (1 - I_{post}) + \alpha_{TS,post} I_{TS} * I_{post} + \xi_{jt} + \varepsilon_{ijt} \quad (2)$$

where all variables except I_{TS} are defined the same as in Equation (1a). I_{TS} is an indicator for the Think Series, and we allow consumer preferences for the Think Series to differ before and after the acquisition to verify whether there was brand equity dilution. We further allow for unobserved consumer heterogeneity in preference and price sensitivity. α_i stands for consumer i's preferences for product attributes; β_i represents the disutility of price; λ_i is consumer i's preference change for Lenovo in the post-acquisition period; ξ_{jt} refers to unobserved product characteristics or product-specific demand shocks; and ε_{ijt} is the idiosyncratic consumer utility component. Consumers exhibit heterogeneous intrinsic preferences for product attributes, price sensitivity, and change in brand preference for Lenovo, as follows:

$$\begin{cases} \alpha_i = \bar{\alpha} + \alpha_i', \ \textit{where } \alpha_i' \sim N(0, \sigma_\alpha^2) \\ \beta_i = \bar{\beta} + \beta_i', \ \textit{where } \beta_i' \sim N(0, \sigma_\beta^2) \\ \lambda_i = \bar{\lambda} + \lambda_i', \ \textit{where } \lambda_i' \sim N(0, \sigma_\lambda^2) \end{cases} \quad (3)$$

We allow consumers the option of not purchasing any PCs to accommodate market expansion or contraction. The utility of the outside good is $\mu_{iot} = \varepsilon_{iot}$, where the mean utility is normalized to zero for identification purposes. Denoting δ_{jt} as the mean utility common to all consumers and μ_{ijt} as consumer-specific utility,

$$\begin{aligned} \delta_{jt} &\equiv X_{jt}\bar{\alpha} + \bar{\beta} p_{jt} + \bar{\lambda} I_L * I_{post} + \lambda_t I_t + \alpha_{TS,pre} I_{TS} * (1 - I_{post}) + \alpha_{TS,post} I_{TS} * I_{post} + \xi_{jt} \\ \mu_{ijt} &\equiv X_{jt}\alpha_i' + \beta_i' p_{jt} + \lambda_i' I_L * I_{post} \end{aligned} \quad (4)$$

Assuming ε_{ijt} follows an i.i.d. Type-I extreme value distribution, we have the random coefficients (RC) logit probability of consumer i choosing alternative j at time t:

$$P_{ijt} = \frac{\exp(\delta_{jt} + \mu_{ijt})}{1 + \sum_{k=1}^{K} \exp(\delta_{kt} + \mu_{ikt})} \quad (5)$$

Integrating over the distribution of consumer heterogeneity, we obtain the market share for alternative j at time t as

$$\widehat{S}_{jt} = \int \frac{\exp(\delta_{jt} + \mu_{ijt})}{1 + \sum_{k=1}^{K} \exp(\delta_{kt} + \mu_{ikt})} \varphi(\mu_{ijt}) d\mu_{ijt} \quad (6)$$

The RC model relaxes the independence of irrelevant alternatives property inherent in the standard logit model and helps generate flexible substitution patterns, which are crucial for quantifying the total impact of an M&A on a firm's profit and assigning the impact to different mechanisms.

4.2. Pricing model

The pricing model requires that we "know" the games being played among manufacturers and between manufacturers and retailers. We conducted extensive interviews with the sales managers of six large PC vendors, retail managers in chain stores, independent PC retailers, and industry experts, and searched industry news reports extensively. We conclude that sales of PCs in China operate more like vertically integrated channels. For example, the Chief Operating Officer of HP Asia-Pacific told us that PC vendors tightly control shelf prices across channels and do not allow retailers to adjust retail prices freely. Vendors will also try to ensure that small retailers are not carrying competitors' products. Gome and Suning, the top two electronics retail chains in China, have used revenue-sharing contracts for two decades, by which PC manufacturers set retail prices and retailers get a share of the manufacturer's revenue.

Based on this information, we assume that PC vendors are playing a Bertrand-Nash pricing game among themselves, and PC vendors and retailers are vertically integrated. Nevertheless, we test a manufacturer-led vertical Stackelberg pricing game as a robustness check.

Each vendor in the PC market offers multiple models of PCs. Vertical integration and profit maximization mean that each PC vendor sets *retail* prices jointly for its products to maximize its channel profits. Vendor v's channel profit is

$$\prod_{vt} = \sum_{j \in v} (p_{jt} - mc_{jt}^w) M_t S_{jt}(P_t) - FC_{vt}^w \quad (7)$$

where p_{jt} is the retail price, mc_{jt}^w is the manufacturer or wholesale marginal cost, M_t is the time-varying market size, S_{jt} is the vector of market share, P_t is the vector of retail price, and FC_{vt}^w is the vector of manufacturer's fixed cost. Fixed costs do not

affect the vendor's pricing behavior, because they drop out of the first-order conditions (FOCs) of profit maximization. The FOC for vendor v is

$$S_{jt} + \sum_{k \in v}(p_{kt} - mc_{kt}^{w})\frac{\partial S_{kt}}{\partial p_{jt}} = 0 \tag{8}$$

Arranging the FOCs of all vendors in matrix form, we have

$$S(P_t) + (\Omega_t^w \cdot \Delta_t)(P_t - MC_t^w) = 0 \tag{9}$$

where $S(P_t)$ and MC_t^w are, respectively, the vectors of market share and wholesale marginal cost across all vendors. Ω_t^w is the vendor's product ownership matrix, whose ω_{jk}^{th} cell takes the value of 1 if row product j and column product k belong to the same vendor, and 0 otherwise. Δ_t is the matrix of the first-order derivatives of market share S_t with respect to retail price P_t whose $(k, j)^{th}$ cell is $\partial S_{kt}/\partial p_{jt}$, and "•" indicates element-wise product or dot product. Thus,

$$P_t = MC_t^w - (\Omega_t^w \cdot \Delta_t)^{-1} S(P_t) \tag{10}$$

The marginal costs can be backed out as

$$MC_t^w = P_t + (\Omega_t^w \cdot \Delta_t)^{-1} S(P_t) \tag{11}$$

With the demand estimates, we can compute $\partial S_{kt}/\partial p_{jt}$, i.e., the Δ_t matrix, and back out the marginal costs. Once we obtain the wholesale marginal costs, we can project them onto cost shifters and estimate the potential cost synergies. We then take the demand estimates and marginal costs as given, and run various counterfactual experiments.

5. Estimation

5.1. Demand and cost parameter estimation

Price is likely endogenous due to unobserved product attributes. One such attribute is manufacturer advertising, which would affect demand: When manufacturers advertise, they are likely to factor the cost of advertising into their pricing. We use instrumental variables to address this. Similar to literature on the PC market (Chu et al., 2007; Chu, 2013), we use the following data as instruments: producer price index (PPI) and observed product characteristics of the focal PC model. Specifically, the IVs are cost shifters, including 1- and 2-quarter lagged PPI for products related to PC production, such as semiconductors, processors, memory, storage, and other peripherals. PPI is a weighted index of the average changes in price at the wholesale or producer level, so PPI should affect PC prices but be uncorrelated with unobservables in the PC market. The first-stage R-squared is 0.51, and the Cragg-Donald F-statistic is 22.21, which indicates they are strong instruments.

As PCs are purchased by both individuals and institutions, we define the potential market size as the weighted sum of households and office-based employees in China. The potential market size increased from 537 million in 2001Q1 to 676 million in 2008Q4. We also test the sensitivities of the estimates to other definitions of market size, such as the number of government and business employees alone and the number of households alone, and our estimates are robust to the market size definition.

We use a two-step approach (Nevo, 2001) to estimate the system of Equations (6) and (11). We first estimate the demand parameters (Equation (6)) using the generalized method of moments, and then use the demand parameter estimates to back out marginal costs (Equation (11)). We next project marginal costs onto various cost shifters (Chu, 2013; Sudhir, 2001) in the following manner, and use generalized least squares to account for estimation precision in marginal costs:

$$\ln(mc_{jt}^{w}) = X_{jt}\gamma_1 + \gamma_2 I_L * I_{post} + \gamma_t I_t + e_{jt} \tag{12}$$

We would like to note that Equation (12) is an equivalent test of cost synergies under an implicit assumption of economies of scale. The rationale is as follows: If there are cost synergies within the acquirer and acquiree, we expect that the marginal cost at the product level, in addition to the vendor level, will also drop more than that of competitors (details in Appendix A).[9]

5.2. Counterfactual experiments

The goals of our counterfactual experiments are to measure the profit impact of the three potential gains: brand equity gain captured by λ_i in Equation (2),[10] cost synergies captured by γ_2 in Equation (12), and product portfolio gains captured by the addition of the Think Series to Lenovo's pricing equation in the post-acquisition period. To achieve these goals, we need to make comparisons based on the profits of different counterfactuals with part or all of the following three actions:

[9] We are grateful to the AE for this comment.

[10] We are mindful that even if we have checked the assumptions for the DiD, run robustness checks, and ruled out some confounds in the reduced-form analysis, it is still possible that other concurrent factors might have contributed to brand equity. Therefore, brand equity here has a broader interpretation.

A. Remove brand equity gain by setting λ_i to zero in the demand model;
B. Eliminate cost synergies by setting γ_2 to zero in the marginal cost regression; and
C. Get rid of product portfolio gain by excluding the Think Series from Lenovo's pricing equation, specifically by changing Lenovo's product ownership matrix from left to right in Equation (13):

$$\Omega^{With\ Gain}_{Lenovo,TS} = \begin{pmatrix} 1_{Lenovo} & 1 \\ 1 & 1_{TS} \end{pmatrix} \text{ and } \Omega^{No\ Gain}_{Lenovo,TS} = \begin{pmatrix} 1_{Lenovo} & 0 \\ 0 & 1_{TS} \end{pmatrix} \quad (13)$$

where 1_{Lenovo} and 1_{TS} are matrices of 1's.

Table 4 presents the seven counterfactual experiments, i.e., a 2*2*2 design. We use the counterfactual profit with none of the three gains, i.e., Π_1 of experiment 1 in Table 4, as the *base* for comparison. To measure the profit impact of brand equity gain, one needs to calculate the difference between Π_1 of experiment 1 and Π_2 of experiment 2, because the only difference between the two experiments is brand preference change. Similarly, we can calculate the profit impact for the other two effects and their interactions.

We compute the counterfactual profit based on the equilibrium prices and shares in each "experiment" by simultaneously solving the system of demand and pricing equations (Equations (6) and (10)), conditional on the demand estimates, marginal costs, and marginal cost parameter estimates.

It is important to note that when we compare profits across different scenarios, we do not account for potential changes in fixed costs, which might differ across scenarios. M&As might also lead to synergies in fixed costs when production or sales staff are combined. On the other hand, M&As may increase fixed costs if the merged firm increases spending. However, firms have information on these fixed costs and can easily include them when calculating their profit.

6. Results

In this section, we first report the demand parameter estimates, derived substitution patterns, implied marginal costs, and firm margins. We then examine the robustness of the model and conclude by analyzing the results of our counterfactual experiments.

6.1. Demand estimates

Table 5 presents demand estimates from the OLS, 2SLS, and RC logit models. For reasons of space, we do not report coefficient estimates for the PC sub-brands. In the OLS estimates, the implied median price elasticity is −0.71, which is small and likely to suggest the existence of price endogeneity. In the 2SLS estimates, the price coefficient becomes more negative. The implied median price elasticity is −2.82—a more reasonable estimate—which indicates that our instruments are effective in addressing price endogeneity.

The RC logit model accounts for unobserved consumer heterogeneity and price endogeneity, which makes the price coefficient more negative. The implied median price elasticity is −5.99, and the implied profit margin is 17%. Consumers exhibit considerable heterogeneity in their intrinsic preferences for PC vendors, CPU speed, number of cores, and form factor. Consistent with our expectations, consumers prefer Intel processors to Advanced Micro Devices (AMD) processors: For the same configuration, they were willing to pay about $100 (=0.71/7.30*1,000) more to substitute an Intel CPU for an AMD. They also prefer PCs with higher CPU speed and more cores, and prefer laptops to desktops.

We now discuss the effect of Lenovo's acquisition. The mean coefficient of the interaction term between Lenovo and the post-acquisition indicator $I_L{}^*I_{post}$, our key parameter of interest, is 0.24 and significant at the 1% level. This suggests that the acquisition increased Lenovo's brand equity and helped Lenovo differentiate itself from other PC vendors. Everything else

Table 4
Counterfactual experiments.

Experiment (Profit)	Actions			Main effect			Two-way interactions			Three-way interaction
				BE	CS	PP	BE*CS	BE*PP	CS*PP	BE*CS*PP
0 (Π_0)	Actual			√	√	√	√	√	√	√
1 (Π_1)	A	B	C	×	×	×	×	×	×	×
2 (Π_3)		B	C	√	×	×	×	×	×	×
3 (Π_3)	A		C	×	√	×	×	×	×	×
4 (Π_4)	A	B		×	×	√	×	×	×	×
5 (Π_5)			C	√	√	×	√	×	×	×
6 (Π_6)		B		√	×	√	×	√	×	×
7 (Π_7)	A			×	√	√	×	×	√	×

*BE: brand equity effect; CS: cost synergies; PP: product portfolio effect.
*Actions taken: A. Set λ_i = 0; B. Set γ_2 = 0; C. No change in product ownership (Lenovo had the same ownership matrix as before acquisition).
*√ indicates the effect is present, and x indicates the effect is absent.

Table 5
Demand parameter estimates.

	OLS		2SLS		Random Coefficient Logit			
					Means		Standard Deviations	
	Beta	SE	Beta	SE	Beta	SE	Beta	SE
Price (in $1,000)	−0.86	0.02	−3.43	0.41	−7.30	0.36	2.48	0.37
Post-acquisition*Lenovo (λ_2)	0.65	0.16	0.66	0.18	0.24	0.02	0.75	0.10
Intel	0.83	0.09	−0.04	0.17	1.24	0.03		
AMD	0.45	0.10	−0.56	0.20	0.53	0.10		
Lenovo	−15.95	0.21	−14.17	0.39	−15.09	0.85	2.06	0.01
Founder	−17.21	0.17	−15.18	0.38	−16.69	2.37	0.85	0.01
HP	−15.57	0.19	−13.02	0.75	−14.40	1.56	0.71	0.12
Dell	−16.08	0.21	−15.47	0.48	−15.92	1.44	1.73	0.16
Tongfang	−16.90	0.18	−15.15	0.35	−15.58	0.47	0.39	0.01
Acer	−16.41	0.25	−16.03	0.47	−19.91	1.52	2.54	1.16
Asus	−16.78	0.19	−15.77	0.52	−15.27	2.14	1.01	0.26
IBM	−15.91	0.22	−12.85	0.84	−14.76	4.75	0.00	0.06
Sony	−15.90	0.19	−14.00	0.65	−14.49	1.87	1.27	0.63
Other vendors	−17.60	0.16	−15.51	0.38	−20.18	1.01	2.56	0.15
White Box	−15.38	0.17	−13.67	0.33	−15.22	0.50	0.27	0.91
CPU speed	1.68	0.11	2.33	0.17	1.96	0.05	0.43	0.03
Square of CPU speed	−0.44	0.02	−0.47	0.03	−0.44	0.01		
Number of cores	0.35	0.09	1.45	0.20	0.81	0.01	0.29	0.02
Square of number of cores	−0.15	0.02	−0.19	0.03	−0.20	0.00		
Desktop	0.84	0.05	−0.87	0.28	−0.68	0.04		
Laptop	0.49	0.04	−0.04	0.09	0.19	0.00		
Dealer	1.62	0.04	1.68	0.04	1.50	0.06	3.40	0.02
Retailer	1.38	0.04	1.33	0.04	1.27	0.03	0.83	0.00
Think Series (pre-acquisition)	0.81	0.16	−0.68	0.30	0.05	0.01		
Think Series (post-acquisition)	0.01	0.10	1.14	0.21	0.76	0.02		
PC sub-brand fixed effects	Yes		Yes		Yes			
Quarter fixed effects	Yes		Yes		Yes			

being the same, the acquisition allowed Lenovo to increase its PC price by $32 (=0.24/7.30*1,000) without affecting consumer utility or purchases; i.e., consumer valuation of Lenovo PCs increased by $32.

When IBM decided to sell its PC division to Lenovo, a lesser-known Chinese PC vendor, there was concern that the acquisition might dilute the Think Series' brand equity (Zellen, 2005). However, we did not find brand equity dilution of the Think Series brand in China's PC market. Instead, the average intrinsic preference for the Think Series post-acquisition was nearly the same as for the pre-acquisition period, −14.44 versus −14.32. Converted to monetary value, which can be interpreted as consumer's willingness to pay or valuation of the product, the difference was only $13 out of an average price of $1,400. Therefore, we conclude that the Think Series' brand equity was not diluted in China in the post-acquisition period.

Table 6 presents the derived substitution pattern.[11] The diagonal elements are own-price elasticities, and the off-diagonal elements are cross-price elasticities. Each column represents the market share changes of the brands in the rows in response to a 1% change in the price of the brand in the column. The first and second numbers in the first column indicate that when Lenovo decreased prices by 1%, its share increased by 6%, and Founder's share fell by 0.5%. To identify strong and weak brands, we compute each vendor's clout and vulnerability (Chintagunta et al., 1991), as shown in the last two rows of Table 6. Clout measures a brand's impact on other brands, calculated as the sum of the cross-elasticities it exerts on other brands when its price changes (cross-elasticities in each column). Vulnerability measures other brands' impact on a brand, calculated as the sum of the cross-elasticities it receives from other brands (cross-elasticities in each row). Of the branded PCs, Lenovo had the largest clout, and Sony and Acer had the smallest; Sony was the least vulnerable, and Founder was the most.

To identify how the acquisition influenced market competition, we calculate the substitution pattern separately for the pre- and post-acquisition periods and compute each vendor's clout and vulnerability for the two periods. Fig. 6 contrasts the clout-vulnerability map pre- and post-acquisition. After the acquisition, PC vendors, in general, became more vulnerable to their competitors' price changes. The contrast indicates that the market became more competitive. The most pronounced change was the increased distance between Lenovo and its competitors on the horizontal (clout) axis. After the acquisition, Lenovo was further from its main competitors. The increased distance in clout suggests that the acquisition increased Lenovo's ability to gain market share from competitors.

[11] The contrast in the magnitude of own- and cross-price elasticities is driven by the small magnitude of market shares, as noted by Nevo (2000b). The own- and cross- price elasticities without consumer heterogeneity will be $\beta p_{jt}(1\text{-}s_{jt})$ and $-\beta p_{kt}s_{kt}$, respectively. In order to have enough room for the market to expand and contract in counterfactual experiments, the market size used for the PC industry was much larger than the sales volume of any single product or even any vendor, and hence both s_{kt} and s_{jt} are close to zero.

Table 6
Derived substitution patterns.

	Lenovo	Founder	HP	Dell	Tongfang	Acer	Asus	IBM	Sony	Others	White Box
Lenovo	−5.67	0.16	0.10	0.03	0.05	0.00	0.01	0.01	0.00	0.04	0.25
Founder	0.50	−4.90	0.13	0.04	0.05	0.01	0.03	0.01	0.00	0.05	0.35
HP	0.25	0.10	−7.98	0.03	0.04	0.00	0.01	0.01	0.01	0.03	0.20
Dell	0.10	0.04	0.03	−7.29	0.01	0.00	0.01	0.01	0.01	0.04	0.07
Tongfang	0.34	0.11	0.10	0.03	−4.81	0.01	0.01	0.01	0.00	0.03	0.35
Acer	0.07	0.04	0.03	0.02	0.02	−6.10	0.01	0.00	0.00	0.02	0.13
Asus	0.13	0.05	0.04	0.03	0.01	0.00	−7.97	0.01	0.01	0.03	0.07
IBM	0.12	0.06	0.03	0.02	0.03	0.00	0.00	−12.00	0.00	0.03	0.10
Sony	0.04	0.01	0.03	0.02	0.00	0.00	0.01	0.00	−10.55	0.08	0.01
Others	0.13	0.06	0.04	0.04	0.01	0.01	0.01	0.01	0.02	−6.19	0.08
White Box	0.23	0.10	0.07	0.03	0.05	0.01	0.01	0.01	0.00	0.03	−4.73
CI: upper bound*	−5.57	−4.82	−7.80	−7.16	−4.71	−5.95	−7.81	−11.51	−10.30	−6.12	−4.62
CI: lower bound	−5.77	−4.97	−8.15	−7.41	−4.91	−6.24	−8.13	−12.50	−10.79	−6.26	−4.85
Clout	1.91	0.72	0.60	0.28	0.27	0.05	0.11	0.08	0.06	0.39	1.61
Vulnerability	0.65	1.16	0.68	0.33	0.97	0.34	0.37	0.39	0.21	0.41	0.54

*Lower and upper bounds for the 95% confidence interval of own-price elasticities

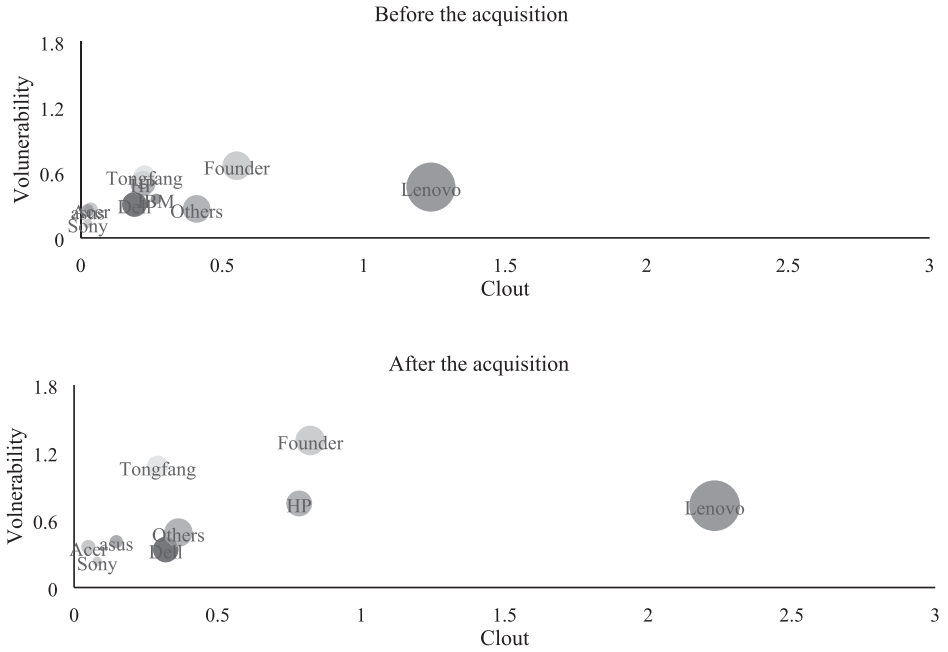

Fig. 6. Clout and vulnerability before and after lenovo's acquisition.

6.2. Implied marginal costs and vendor margins

Table 7 reports the coefficients of the marginal cost regression. We plot the estimated quarter fixed effects in Fig. 7, which shows that the marginal costs of PCs declined over time. The cost of a PC is directly proportional to the speed of its CPU and number of cores. For the same configuration, desktops cost about 40% less than laptops, which cost about 16% less than ultra-portables. PCs with Intel inside cost 6% more than those powered by AMD.

Table 7
Marginal cost regression results and cost synergies.

	Beta	SE
Post-acquisition*Lenovo	−0.054	0.027
CPU Speed	0.117	0.004
No of cores	0.260	0.006
Intel	0.057	0.015
AMD	−0.003	0.017
Lenovo	−0.457	0.030
Founder	−0.347	0.024
HP	0.169	0.027
Dell	−0.398	0.032
Tongfang	−0.442	0.025
Acer	−0.373	0.039
Asus	−0.193	0.028
IBM	0.264	0.032
Sony	0.024	0.027
Other vendors	−0.425	0.021
White Box	−0.640	0.023
Desktop	−0.690	0.008
Laptop	−0.185	0.007
PC sub-brand fixed effects	Yes	
Channel fixed effects	Yes	
Quarter fixed effects	Yes	
N	30,976	
R^2	0.714	

*Cost synergies = 1- post-M&A MC/pre-M&A MC = 1-exp(-0.054)/exp(0) = 5.30%.

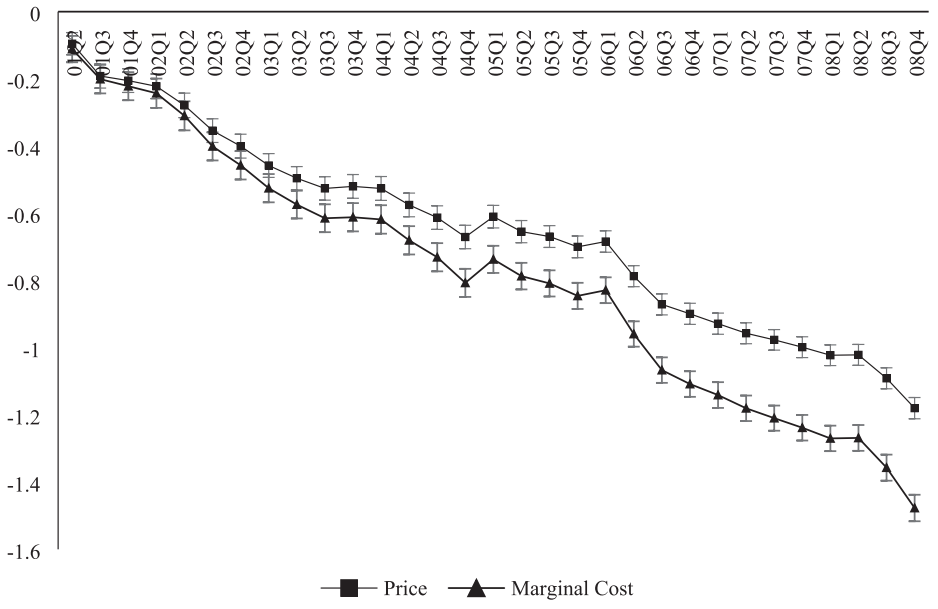

Fig. 7. Estimated quarter fixed effects from cost and price regressions.

Of the PC vendors, white box PCs had the lowest marginal cost, and IBM had the highest. However, the acquisition helped reduce Lenovo's marginal costs significantly. The coefficient was –0.05, significant at the 5% level, implying a cost reduction of 5% and confirming the existence of cost synergies for Lenovo.

Table 8 presents the implied vendor margins. Although PC prices decreased over time (Table 1), vendor margins increased in the same period. This is because marginal costs declined at a faster pace than retail prices, especially in the post-acquisition period, as shown in Fig. 7. Average vendor margins increased from 14% in 2001 to 23% in 2008, although there was substantial variation in vendor margins. A similar phenomenon was observed for the video game console market (Liu, 2010).

6.3. Counterfactual experiments: profit impact of the acquisition on vendors

(1) Impact on Total Profit

Table 9 reports the total profit for Lenovo and its two business units, LBG and TBG, under different counterfactual experiments for the whole post-acquisition period. Our first experiment is to evaluate the total profit impact of the acquisition, in which we assume there were no change in brand preference for Lenovo and no cost synergies, and Lenovo set prices independently for LBG and TBG. LBG's and TBG's profits would be, respectively, $1.54 billion and $0.33 billion less than their actual profits. The acquisition helped LBG and TBG gain $1.87 billion in total profits in *the post-acquisition period in China alone*. The dual gain implies that mutual enhancement between the Think Series and LBG was an important revenue source for Lenovo. Lenovo's total gain from the acquisition in China's PC market is the increased profit for LBG plus *all of the profit from TBG*; $1.54+$0.83 = $2.37 billion for the whole post-acquisition period. Compared with the $1.75 billion acquisition cost, the acquisition paid for itself in China's PC market alone in 4 years.

Table 8
Implied PC vendor's margin.

	Lenovo	Founder	HP	Dell	Tongfang	Acer	Asus	IBM	Sony*	Others	White box	Mean
2001	14%	15%	10%	10%	16%	12%	6%	8%	.	13%	16%	14%
2002	16%	17%	13%	12%	19%	13%	8%	9%	5%	15%	21%	17%
2003	19%	21%	13%	15%	23%	17%	9%	10%	7%	16%	28%	19%
2004	23%	23%	16%	16%	24%	19%	9%	11%	7%	17%	28%	21%
2005	25%	28%	18%	19%	28%	19%	12%	12%	9%	18%	35%	25%
2006	26%	29%	18%	20%	31%	18%	14%	5%	9%	20%	37%	26%
2007	25%	28%	18%	18%	28%	19%	15%	5%	8%	20%	34%	24%
2008	23%	27%	18%	19%	26%	20%	17%	5%	10%	19%	32%	23%
Mean	23%	25%	17%	18%	26%	18%	15%	10%	9%	18%	31%	22%

*Sony entered China's market in 2002.

Table 9
Profit (US$ billion) of LBG and TBG under different scenarios.

		Actual	Scenario1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
			No Gain	BE*	CS*	PP*	BE + CS	BE + PP	CS + PP
Vertical Integration	LBG	5.59	4.06	4.92	4.61	4.07	5.57	4.93	4.62
	TBG	0.83	0.50	0.61	0.69	0.50	0.84	0.61	0.69
	Total	6.42	4.56	5.53	5.30	4.56	6.41	5.54	5.31
	Changes over Scenario 1	1.87		0.97	0.74	0.01	0.13	0.00	0.00
Stackelberg Leader-follower (exclusive)	LBG	5.73	4.36	5.25	4.77	4.38	5.71	5.26	4.79
	TBG	0.86	0.52	0.62	0.72	0.51	0.87	0.62	0.72
	Total	6.60	4.88	5.87	5.49	4.89	6.58	5.88	5.51
	Changes over Scenario 1	1.72		0.99	0.62	0.01	0.09	0.00	0.00

*BE: brand equity; CS: cost synergies; PP: product portfolio.

(2) Brand Equity Gains, Cost Synergies, and Product Portfolio Gains: Main Effects

To disentangle the main effects of the gains in brand equity, cost synergies, and product portfolio and assess their relative contributions, we run three additional counterfactual experiments (Scenarios 2–4) by alternately closing off two of the three mechanisms (see Table 5 for details). Comparing Experiment 2 with Experiment 1, we find that brand equity alone would lift Lenovo's profit from $4.06 billion to $4.92 billion—a net gain of $0.97 billion—which is 15% of Lenovo's actual profit. The gain is larger than the total profit ($0.83 billion) from TBG in China, which testifies to the importance of improvement in consumer brand preference for Lenovo.

Similarly, comparing Experiment 3 with Experiment 1, we find that cost synergies lifted Lenovo's profit by $0.74 billion, which was 12% of Lenovo's actual profit. Comparing Experiment 4 with Experiment 1, we find that the product portfolio effect is positive but small and economically insignificant. This might be due to the absence of competition between Lenovo and IBM because of their very different price levels and brand positioning. First, Lenovo and IBM targeted different consumer segments and did not compete much with each other. Price differences between IBM and Lenovo were large: The average price was $1,400 for the Think Series and $700 for Lenovo. In addition, we searched news reports on the brand positions of Lenovo and IBM, and found that the Think Series was popular with businesses due to its durability and stability, whereas Lenovo served price-conscious consumers.[12]

The above counterfactual experiments suggest that if there were no brand equity gains, the total gains from cost synergies and product portfolios would be only $0.75 billion—not enough to recoup the $1.75 billion acquisition costs. The stock market reacted negatively immediately after the announcement of Lenovo's buyout. If we were to use the immediate stock market response to evaluate Lenovo's acquisition, or to ignore the brand equity effects, we would put the acquisition into the "failure" category.[13] However, if we put brand equity gains into the picture, we would reach a radically different conclusion. The market slowly corrected its assessment: Lenovo's stock price returned to the pre-announcement level in one quarter and subsequently outperformed the market index.

In sum, in this acquisition, gains in brand equity were the biggest contributor to the increase in Lenovo's profit, followed by cost synergies; changes in the product portfolio played a minimal role. Though the 5% cost synergies were significant, their profit impact was still smaller than the brand effect. This shows the importance of consumers and their preferences in assessing the outcome of M&As.

(3) Interaction Effects

The total of the three main effects of gains in brand equity, cost synergies, and changes in product portfolio (the sum of the profit increases from Experiments 2, 3, and 4) is $1.72 billion, which is less than the $1.87 billion increase in total profit. This means there are positive interactions between the three mechanisms. To reveal interaction effects, we keep two of the three mechanisms and close off the third to obtain two main effects and one interaction effect. By subtracting the two main effects from the previous counterfactual experiments, we can obtain the interaction effect.

Experiment 5 gives us the counterfactual profit of $6.41 billion when we keep the main effects of the gains in brand equity and cost synergies and their interaction effect, for a net profit gain of $1.85 billion over Experiment 1. Subtracting the main effects of the gains in brand equity ($0.97 billion) and cost synergies ($0.74 billion), we obtain the brand equity*cost synergies interaction effect of $0.13 billion, or 2.0% of actual profit.

[12] https://en.wikipedia.org/wiki/ThinkPad, accessed March 29, 2020.
[13] We could not use accounting measures here, because Lenovo did business in PCs, mobile phones, real estate, capital investment, etc.

Similarly, Experiment 6 keeps the main effects of the gains in brand equity and changes in the product portfolio and their interaction effect. Experiment 7 keeps the main effects of cost synergies and the changes in the product portfolio and their interaction effect. We find negligible interaction effects from these two experiments.

6.4. Robustness checks

We conduct a series of robustness checks on the definition of potential market size and instrumental variables for price, similar to Chu and Chintagunta (2009) and Chu and Manchanda (2016). We also conduct a vertical Stackelberg game in the PC industry to validate our findings.

A vertical Stackelberg game: Based on our interviews with PC vendors and retailers, we used a vertically integrated model in the main text. To further validate our results, we estimated a manufacturer-led Stackelberg leader–follower game between PC vendors and channel members, in which PC vendors set wholesale prices in indirect channels (dealers, retailers) and retail prices in direct channels to jointly maximize profits. Dealers and retailers take wholesale prices as given, and set retail prices to maximize product line profits (Goldfarb et al. 2009). Due to the absence of retailer identity in the data, we assume all dealers/retailers are exclusive and only carry one vendor's product lines, as in Chu et al. (2007); Chu and Chintagunta (2009); and Chu (2013). For reasons of space, we relegate the derived pricing equations to Appendix B. Vertical integration is a special case of these price equations, in which the retailer's reaction function is unity. We find a qualitatively similar profit impact of brand equity change induced by the merger from counterfactual experiments (Table 9, lower panel).

7. Generalizability of the modeling approach and managerial implications

7.1. Generalizability

To explore the potential generalizability of our modeling framework beyond the PC industry, we collect data from China's automobile industry and examine Geely's acquisition of Volvo. For reasons of space, we relegate the details to Appendix C. With a similar structural model, we find that the acquisition improved Geely's brand preference and accounted for 20% of its profit increase.

However, the acquisition did not lead to cost synergies, due to the complicated production process and the special acquisition arrangements between Geely and Volvo. The production of automobiles is much more complicated than that of PCs. By the acquisition agreement, Volvo produced automobiles outside China, while Geely produced all cars inside China during our data period.

Analysis of the two acquisitions provides empirical support for the importance of factoring brand equity into M&A analysis and the general applicability of our modeling framework. Therefore, we believe that our modeling approach can be applied to other industries for a more comprehensive assessment of M&As.

7.2. Managerial implications

First, inclusion of the brand equity effect may change how researchers and managers assess the outcome of M&As. Our study provides an important but missing piece in the evaluation of M&As. According to our findings, if the brand equity effect were not factored in, Lenovo's acquisition of IBM's PC division would be taken as a failure; so would be Geely's acquisition of Volvo. Therefore, we believe that our research demonstrates the value of a new perspective to assess M&As more comprehensively.

Second, our results should inspire managers to manage the acquired brands more carefully. M&As can boost consumers' brand preferences, but it may take roughly 6 years for consumers to change their perceptions of brand quality (Mitra and Golder, 2006). The potentially swift change in brand preference suggests that M&As can be used as a brand-lifting tool.

Third, our analysis sheds light on cross-border M&As. More and more brands from emerging markets acquire established brands in developed markets. Lenovo's post-acquisition strategy may provide a way to lift emerging brands while preserving the brand image of established ones, by adopting technologies from the established brands, but allowing them to operate independently.

8. Conclusion

In this paper, we introduce the role of brand preference change in assessing M&As' performance to the literature. We develop a framework to assess how M&As affect the intrinsic preferences of consumers for the firms involved in M&As, and how changes in intrinsic brand preferences affect firm profits through three mechanisms: brand equity, cost synergies, and changes in product portfolio. We use structural modeling and counterfactual experiments to quantify and decompose their profit impact, which allows us to assess the relative contribution of each mechanism.

Empirically, we examine the impact of Lenovo's acquisition of IBM's PC division and Geely's acquisition of Volvo in the Chinese market. Results demonstrate that Lenovo and Geely benefited more than their competitors from the acquisition: The acquisition significantly increased consumers' intrinsic preferences or valuations for Lenovo in the PC market, and also

helped Lenovo achieve significant cost synergies. In China's PC market alone, in 4 years, the increase in profit could fully offset Lenovo's acquisition cost. Geely's acquisition of Volvo also led to significant gains in Geely's brand equity. Gains in brand equity were the most important contributor to the increase in profit in both acquisitions, and were more influential than cost synergies. Managerially, our analysis highlights the importance of brand equity in M&As, and also sheds light on brand management post-acquisition.

One limitation of this paper is that it is essentially an ex-post analysis and cannot be directly used by managers to assess M&As ex-ante. However, it may lead to a meaningful future research direction that more methods should be developed to evaluate these effects, especially the prediction of brand preference change. With predicted brand preference change and presumed cost synergies based on firms' knowledge of cost structure, managers can assess M&As ex-ante more comprehensively and make more sound decisions.

Appendix A. Assumptions on cost synergies regression

We ackowledge that the cost regression in Equation (12) on p. 16 (also Equation (A.1) below) does not constitute a direct test of economies of scale. Instead, if the estimate for γ_2 is negative and significant, we take this as evidence of cost synergies because post-acquisition, there was a drop in the marginal costs of Lenovo's PC models. However, we remain agnostic about the source of cost synergies.

$$\ln(mc_{jt}^{w}) = X_{jt}\gamma_1 + \gamma_2 I_L * I_{post} + \gamma_t I_t + e_{jt} \tag{A.1}$$

Based on comments from the review team, we devised a more direct test of economies of scale by estimating the effect of vendor-level production scale Q_{vt}, i.e., the aggregate sales of all PC models at the vendor level. This approach is similar to Sudhir (2001), where the total output of an automaker is used in cost regression (Sudhir's Equation (10)) to examine cost synergies.

$$\ln(mc_{jt}^{w}) = X_{jt}\gamma_1 + \gamma_2 I_L * I_{post} + \gamma_t I_t + \gamma_3 Q_{vt} + \gamma_4 Q_{vt}^2 + e_{jt},\ j \in v \tag{A.2}$$

The rationale is as follows. If a firm produces/sells more units of different PC models, the marginal cost of each PC model could be lower due to economies of scale at the vendor level. Therefore, if cost synergies induced by the acquisition arise mainly from economies of scale at the vendor level, the estimate for γ_2 can become insignificant once we include vendor's sales quantity in the cost regression.

Given that sales/production in the past may or may not affect the current marginal cost, we use three ways to operationalize Q_{vt}:

(1) Zero-order process: Past sales/production do not influence the current marginal cost, i.e., Q_{vt} is the total sales of vendor v in period t.
(2) First-order process: Sales/production in period t-1 can influence the current marginal cost, i.e., Q_{vt} is the cumulative demand of vendor v in period t-1 and t.
(3) Infinite-order process: All historical sales/production can influence the current marginal cost, i.e., Q_{vt} is the cumulative demand of vendor v from period 1 to t;

The results are shown in Table A.1. As we conjectured, the coefficient of the Lenovo*post-acquisition interaction becomes insignificant for all three operationalizations of Q_{vt}. This demonstrates that cost synergies can arise from economies of scale at the vendor level, although it is difficult to further differentiate the sources of economies of scale.

One concern is that endogeneity issue may arise when adding Q_{vt} into the marginal cost regression. Because the error term may reflect unobserved variations in the production efficiency/inefficiency of vendor v, and thus correlate with the aggregate sales Q_{vt}. The marginal improvement in R^2 after including Q_{vt} and Q_{vt}^2 shows that the potential endogeneity issue might not be very strong. Nevertheless, to address this issue, we use the marginal costs of vendor v's competitors, $MC_{-v,t}$, as instruments for Q_{vt}. The rationale is as follows: (1) marginal costs of competitors will influence competitors' prices, which in turn influence the focal vendor v's output; (2) we assume that, after controlling for vendor and quarter fixed effects, the unobserved components of production efficienty (e.g., the experience of factory workers, the cost of logistics, and so on) are uncorrelated across vendors. The first-stage R^2 for Q_{vt} and Q_{vt}^2 is around 95% and 90% respectively in all three '2SLS' regressions. Our findings on the source of cost synergies remain qualitatively the same, as shown in the '2SLS' panels of Table A.1.

Appendix B. A vertical Manufacturer-led Stackelberg Leader-follower game

We assume Bertrand competition among PC vendors, a manufacturer-led Stackelberg leader–follower game between PC vendors and retailers, and Bertrand competition among retailers (Chu et al., 2007; Goldfarb et al., 2009; Sudhir, 2001). PC vendors set wholesale prices to maximize product line profits, based on competitors' price responses and retailers' reactions; retailers set retail prices to maximize profits, based on wholesale prices and other retailers' price responses.

Table A1
Marginal cost regression results and cost synergies.

	Model (A.1): No output	Model (A.2): Zero-order process		Model (A.2): First-order process		Model (A.2): Infinite process	
	Beta	GLS	2SLS	GLS	2SLS	GLS	2SLS
Post-acquisition*Lenovo	−0.05(0.03)	0.02(0.03)	0.03(0.04)	0.01(0.03)	0.00(0.04)	−0.03(0.03)	0.02(0.04)
CPU Speed	0.12(0.00)	0.12(0.00)	0.12(0.00)	0.12(0.00)	0.12(0.00)	0.12(0.00)	0.12(0.00)
No of cores	0.26(0.01)	0.26(0.01)	0.26(0.01)	0.26(0.01)	0.26(0.01)	0.26(0.01)	0.26(0.01)
Intel	0.06(0.02)	0.06(0.02)	0.06(0.02)	0.06(0.02)	0.06(0.02)	0.06(0.02)	0.06(0.02)
AMD	−0.00(0.02)	−0.00(0.02)	0.00(0.02)	−0.01(0.02)	0.00(0.02)	−0.01(0.02)	0.00(0.02)
$Q_{vt}/10^6$		−0.25(0.03)	−0.22(0.08)	−0.12(0.01)	−0.08(0.04)	−0.01(0.00)	−0.00(0.01)
$(Q_{vt})^2/10^{12}$		0.06(0.01)	0.08(0.02)	0.01(0.00)	0.02(0.01)	0.00(0.00)	0.00(0.00)
Quarter fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PC vendor fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PC sub-brands fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	30,976	30,976	30,976	30,976	30,976	30,976	30,976
R^2	0.71	0.72		0.72		0.71	

(1) Manufacturer's product line pricing

Under the Bertrand competition assumption, vendor v's profit is:

$$\prod_{vt} = \sum_{j \in v} (p_{jt}^{w} - mc_{jt}^{w}) M_t S_{jt}(P_t) - FC_t^{w} \tag{B.1}$$

where p_{jt}^{w}, mc_{jt}^{w} and S_{jt} are, respectively, product j's wholesale price, wholesale marginal cost, and market share at time t, and M_t is market size. P_t is the vector of retail prices, and FC_t^{w} is vendor fixed cost. The latter does not affect the firm's pricing behavior, because it drops out of the first-order conditions (FOCs) of profit maximization. The FOCs for vendor v are:

$$S_{jt}(P_t) + \sum_{k \in v} (p_{kt}^{w} - mc_{kt}^{w}) \frac{\partial S_{kt}}{\partial p_{jt}^{w}} = 0 \tag{B.2}$$

Arranging the FOCs of all vendors in matrix form, we have

$$S(P_t) + (\Omega_t^{w} \cdot \Delta_t^{w})(P_t^{w} - MC_t^{w}) = 0 \tag{B.3}$$

where $S(P_t)$ and MC_t^{w} are, respectively, the vectors of market share and wholesale marginal cost across all vendors. Ω_t^{w} is the vendor product ownership matrix, whose $(j, k)^{\text{th}}$ cell takes the value of 1 if row product j and column product k belong to the same vendor, and 0 otherwise. Δ_t^{w} is the matrix of the first-order derivatives of market share S_t with respect to wholesale price P_t^{w}, whose $(k, j)^{\text{th}}$ cell is $\partial S_{kt}/\partial p_{jt}^{w}$; "•" indicates dot product. Thus,

$$P_t^{w} = MC_t + [-(\Omega_t^{w} \cdot \Delta_t^{w})^{-1} S(P_t)] \tag{B.4}$$

Therefore, wholesale prices are the sum of a manufacturer's marginal costs and the wholesale margin. When manufacturers sell directly to consumers through direct channels, wholesale prices will be the same as retail prices.

(2) Retailer's product line pricing

Under the assumption of a Bertrand-Nash pricing game among retailers and a vertical Stackelberg game, each channel intermediary sets retail prices for all of its products to maximize profits. Denoting FC_t^{r} as retail fixed costs, the retail profit function is

$$\prod_{rt} = \sum_{j \in r} (p_{jt} - p_{jt}^{w}) M_t S_{jt}(P_t) - FC_t^{r} \tag{B.5}$$

FOCs for retailer r are

$$S_{jt} + \sum_{k \in r} (p_{kt} - p_{kt}^{w}) \frac{\partial S_{kt}}{\partial p_{jt}} = 0 \tag{B.6}$$

Arranging all retailers' FOCs in matrix form, we have

$$S(P_t) + (\Omega_t^{r} \cdot \Delta_t^{r})(P_t - P_t^{w}) = 0 \tag{B.7}$$

From the FOCs, we can have retail prices as

$$P_t = P_t^{w} + [-(\Omega_t^{r} \cdot \Delta_t^{r})^{-1} S(P_t)] \tag{B.8}$$

Δ_t^{r} is the matrix of the first-order derivatives of market share S_t with respect to retail price. Ω_t^{r} is the retailer's product ownership matrix, whose $\omega_{jk}{}^{\text{th}}$ cell takes the value of 1 if row product j and column product k are carried by the same retailer, and 0 otherwise. Due to the absence of retailer identity in the data, we assume that all dealers/retailers are exclusive and only carry one vendor's product lines, as in Chu et al. (2007) and Chu (2013). Substituting Equation (B.4) into Equation (B.8), we have

$$P_t = MC_t^{w} + [-(\Omega_t^{w} \cdot \Delta_t^{w})^{-1} S(P_t)] + [-(\Omega_t^{r} \cdot \Delta_t^{r})^{-1} S(P_t)] \tag{B.9}$$

Retail prices can be decomposed into the manufacturer's marginal cost, the wholesale margin, and the retail margin.

When wholesale prices change, they first affect retail prices, which then affect market share. Define Δ_t as the matrix of first derivatives of retail prices with respect to wholesale prices. This is the retailer's reaction function, whose $(\omega, \omega')^{\text{th}}$ element is defined as $\partial p_{\omega t}/\partial p_{\omega' t}^{w}$. By the chain rule, $\Delta_t^{w} = \Delta_t \Delta_t^{r}$. Similar to Chu and Chintagunta (2009) and Goldfarb et al. (2009), we derive Δ_t by fully differentiating the retailer's FOC (Equation (B.6)).

After estimating the demand parameters, we can compute the wholesale margin and the retail margin in Equation (B.9), and back out the wholesale marginal cost as

$$MC_t^{w} = P_t - [-(\Omega_t^{w} \cdot \Delta_t \Delta_t^{r})^{-1} S(P_t)] - [-(\Omega_t^{r} \cdot \Delta_t^{r})^{-1} S(P_t)] \tag{B.10}$$

We take a two-step approach to estimate the system of Equations (B.6) and (B.10). We first estimate the demand parameters in Equation (B.6) by the generalized method of moments, and then use demand parameter estimates to back out marginal costs (Equation (B.10)). We next project marginal costs onto various cost shifters and use the generalized least squares method to account for the estimation precision in wholesale marginal costs.

Appendix C. An application to China's automobile industry

Similar to Lenovo's acquisition, this is another case of a less famous brand from a developing country acquiring a world-renowned premium brand from a developed country: Volvo is a Swedish brand and once belonged to Ford (in 1999, Sweden's Volvo Group sold the Volvo Car Corporation to Ford Motor, where the division was placed within Ford's Premier Automotive Group). Geely promised to operate Volvo independently with separate plants, managing boards, and employees. The acquiring brand, Geely, wished to benefit from Volvo's more advanced technology, R&D, overseas sales network, management skills, etc.

(1) Background

Geely announced its acquisition of Volvo in March 2010 and closed the deal for $1.5 billion in August 2010. Geely's chairman, Li Shufu, expressed his interest in buying Volvo from Ford in 2007, 2008, and 2009, at a time when the US automobile industry was suffering the most from the financial crisis and when Ford had been losing money from the Volvo unit for a decade. Geely wanted what Volvo had: a heritage brand for safety, technology, R&D, and a global sales network. Geely had what Volvo needed: the cash and the opportunity to penetrate the world's largest automobile market. Geely promised independent operations for Volvo and would pay Volvo for the technology/intellectual property and build plants for Volvo in China (Conklin & Cadieux, 2010; Morcillo, 2010).

However, there were concerns about the acquisition (Morcillo, 2010). Geely might not have the management skills necessary to integrate and manage a premium brand: Volvo's revenues were six times larger than Geely's, with similar sales volumes. There might not be production or marketing-related synergies, and the production synergies could backfire if consumers learned that Geely produced parts for Volvo and, in turn, then cast doubt on Volvo's quality and safety features.

The acquisition took place in 2010. However, due to the long lead time in automotive production, Geely started assembling Volvo cars until 2013 after its new plant was approved in China. Thus, actual completion of the acquisition was in early 2013. Not until 2017 did the acquisition bring changes to Geely's product line, with Model LYNK&CO 01's use of Volvo's design language and architecture platform. Given this timeline, we would not expect to see any cost synergies or effects of a change in product portfolio.

(2) Data Summary

The data are provided by JATO Dynamic Ltd, a global supplier of automotive business intelligence with headquarters in London and offices in 45 countries. The data contain monthly sales volumes and manufacturers' suggested prices for each model sold in China from 2011 to 2014. The data encompass roughly 2 years before and 2 years after realization of the acquisition. We also supplement the data with car attributes collected from automotive websites such as *autohome.com.cn* and *chinacar.com.cn*.

Each observation in the dataset contains the following information: automaker (e.g., Geely, BYD, Chery, and Great Wall); model (e.g., Surui, Tiggo, Kingkong); product attributes, including body type (MPV, SUV, sedan, hatchback, etc.); size (length, width, height, wheelbase); engine specifications (horsepower, engine, cylinder, layout); transmission; fuel consumption; displacement; size of fuel tanks; and other multimedia features. Table C.1 presents the summary statistics.

Interviews with car manufacturers and car dealers reveal that China's automobile market consists of several sub-markets along price tiers, and cars of different price tiers do not compete much with each other. We therefore chose to focus on the sub-market, Chinese automakers, which consist of Geely, BYD, Chery, and Great Wall. These four automakers are comparable on price, other attributes, and market share (Table C.1). Furthermore, in our data period they were domestic automakers with no joint ventures with overseas brands. We exclude Volvo from the analysis because we believe that Volvo, priced at 400,000 yuan (US$65,000), would not compete for consumers who considered domestic cars with a mean price of 80,000 yuan (US$13,000).

(3) Demand Model

We use a similar specification to model consumer's utility from buying a car:

$$u_{ijt} = X_{jt}\alpha_i + \beta_i p_{jt} + \lambda_i I_{Geely} * I_{post} + \lambda_t I_t + \xi_{jt} + \varepsilon_{ijt} \quad \text{(C.1)}$$

where X_{jt} denotes a vector of product attributes, including dummies for automakers, engine, size, body type, transmission, fuel consumption, displacement, size of fuel tanks, and other multimedia features. I_{Geely} and I_{post} are indicators for Geely and post-acquisition period, respectively. λ_i denotes the change in the intrinsic preference for the acquiring firm induced by the

Table C1
Summary statistics of Geely and the rest (BYD, Chery, and Great Wall).

	Geely (N = 4541)		Others (N = 10,612)	
	Mean	SD	Mean	SD
Units sold per month	333.01	563.98	433.31	917.10
Price (in 100,000 yuan)	0.78	0.29	0.89	0.30
Hatchback (0–1)	0.28	0.45	0.25	0.43
SUV	0.10	0.31	0.27	0.45
Length (mm)	4,403.35	358.55	4,394.63	378.06
Width (mm)	1,744.24	64.75	1,736.13	86.68
Height (mm)	1,496.37	73.97	1,588.99	131.72
Wheelbase (mm)	2,577.68	131.76	2,594.21	153.73
Kilowatt	84.98	18.01	88.42	20.22
Fuel Consumption (litre/100KM)	7.51	1.02	7.68	1.54

acquisition. I_t is month dummy, ξ_{jt} is unobserved product characteristics or product-specific demand shocks, and ε_{ijt} is the idiosyncratic consumer utility.

Similarly, we denote δ_{jt} as the mean utility common to all consumers and μ_{ijt} as consumer-specific utility:

$$\begin{aligned} \delta_{jt} &\equiv x_{jt}\bar{\alpha} + \bar{\beta}p_{jt} + \bar{\lambda}I_{Geely} * I_{post} + \lambda_t I_t + \xi_{jt} \\ \mu_{ijt} &\equiv x_{jt}\alpha_i' + \beta_i' p_{jt} + \lambda_i' I_{Geely} * I_{post} \end{aligned} \tag{C.2}$$

Assuming ε_{ijt} follows an i.i.d. Type-I extreme value distribution, we obtain the market share for alternative j at time t as

$$\widehat{S}_{jt} = \int \frac{\exp(\delta_{jt} + \mu_{ijt})}{1 + \sum_{k=1}^{K}\exp(\delta_{kt} + \mu_{ikt})} \varphi(\mu_{ijt}) d\mu_{ijt} \tag{C.3}$$

(4) Supply Model

We use a vertical integration model with exclusive dealerships for China's automobile market. The Ministry of Commerce of China issued an administrative order to regulate the automobile market and protect consumers in 2005, which was in effect until July 2017.[14] The order effectively grants manufacturers overwhelming power over retailers in car sales, including exclusive dealerships and setting retail prices, service standards, upfront payments, etc.; it also requires that dealers publicly display car prices and related charges, which leaves dealers little space to maneuver. Our interviews with manufacturers and dealers confirm the vertical relationship and the close monitoring of dealer behavior by manufacturers.

The pricing model and the regression for estimating cost synergies are the same as in the PC market and are omitted for reasons of space.

(5) Results

The estimation strategy is the same as in the PC market. We collect PMI, PPI, and prices of raw materials such as steel as additional instruments. The instruments, together with product attributes, can explain 90% of price variation in the automobile market. We use the number of households as market size, and the results are robust to market size definition.

Table C.2 shows the demand estimates. The acquisition of Volvo improved consumer's preference for Geely vis-à-vis its close competitors. The coefficient of the interaction term $I_{Geely}{}^{*}I_{post}$ is 0.23, which is significant at the 1% level and equivalent to 1,337 yuan or $200—about 2% of Geely's average price—which suggests that the acquisition significantly boosted consumer's brand valuation for Geely.

The derived substitution pattern and mean margin of each automaker are shown in Table C.3. The estimated margin is 10%, close to the industry margin—8% and 9% in 2013 and 2014, respectively, from the annual report released by the National Bureau of Statistics of China. We find no significant cost synergies (Table C.4). This is expected, since Volvo operated its production independently, and Geely released its first car model using Volvo's design language and architecture platform only in November 2017.

In the absence of cost synergies and changes in the product portfolio, we only quantify the impact of enhanced brand equity on Geely's profit. We find that if Geely did not acquire Volvo, its profit for the entire post-acquisition period would be $274 million, or 19.6% less than the actual profit.

[14] http://www.mofcom.gov.cn/article/b/d/200502/20050200019191.shtml, accessed March 29, 2020.

Table C2
Demand parameter estimates: China's automobile market.

	OLS		2SLS		Random Coefficient Logit			
					Means		Standard Deviations	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Price (*in 100,000 yuan*)	−1.67	0.14	−3.19	2.82	−17.19	0.27	9.88	0.00
Post-acquisition*Geely dummy	0.40	0.11	0.43	0.12	0.23	0.01	1.59	0.00
Geely	−20.38	1.24	−24.07	6.95	−21.09	1.14	9.90	0.01
Byd	−21.17	1.23	−24.89	7.02	−26.03	2.24	6.00	0.02
Chery	−21.16	1.21	−24.74	6.74	−27.06	3.25	9.65	0.01
Great Wall	−21.56	1.22	−25.23	6.92	−43.27	1.07	7.29	0.01
Length/5000	11.45	0.87	10.20	3.30	1.11	0.01		
Width/2000	1.19	1.09	3.47	4.55	12.42	0.24		
Height/2000	−6.30	0.73	−5.16	1.73	3.81	0.06		
Wheelbase/3000	12.17	1.11	16.09	5.95	43.95	0.59		
Kilowatt	0.04	0.01	0.04	0.01	0.08	0.00		
Fuel Consumption	−0.49	0.03	−0.41	0.14	−1.59	0.03		
Model fixed effects	Yes		Yes		Yes			
Month fixed effects	Yes		Yes		Yes			
Other product attributes	Yes		Yes		Yes			

Table C3
Derived substitution patterns and implied margin.

	Geely	BYD	Chery	Great Wall	Margin
Geely	−8.08	0.00	0.00	0.00	13%
BYD	0.00	−11.23	0.00	0.00	9%
Chery	0.00	0.00	−10.17	0.00	10%
Great Wall	0.00	0.00	0.00	−11.32	9%

Table C4
Marginal cost regression results.

	Coefficient	Std errors
Post-acquisition*Geely dummy	−0.003	0.01
Geely	−5.53	0.08
Byd	−5.54	0.08
Chery	−5.41	0.08
Great Wall	−5.45	0.08
Length/5000	−0.90	0.06
Width/2000	2.01	0.06
Height/2000	0.92	0.04
Wheelbase/3000	2.41	0.07
Kilowatt	0.00	0.00
Fuel Consumption	0.03	0.00
Model fixed effects	Yes	
Month fixed effects	Yes	
Other product attributes	Yes	
N	15,153	
R^2	0.94	

(6) A Robustness Check

We limited the above analysis to four domestic automakers in China's automobile market with a total of 15% market share and an average price of 80,000 yuan, because our interviews with automakers and dealers reveal that China's auto market consists of several price tiers, and automobile brands in different price tiers do not compete for the same consumer segments. The "big six" China joint-venture automakers—SAIC, DFAC, FAW, CCAG, BAIC, and GAC—collectively command 81% market share. They have all formed joint ventures with overseas brands; 80% of their sales come from joint-venture brands with a mean price of 120,000 yuan, which is 50% higher than products from purely domestic automakers.

To check how exclusion of the big six automakers would affect our conclusion, we reran the analysis with all cars less than 200,000 yuan from the six automakers included. We find a similar brand equity effect in the demand estimation and a similar profit impact from a counterfactual experiment. The acquisition of Volvo helped improve consumer's preference for Geely over its competitors. The coefficient of the interaction term $I_{Geely}{}^{*}I_{post}$ is 0.21 (SE = 0.10), which is equivalent to $279 million, or 18.2% of Geely's actual profit.

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