

Data-Driven Analysis of Hero-Product Dependence, Operational Risk, and Sustainable Brand Growth in Maternal and Infant E-Commerce

MO, Lei ^{1*}

¹ Nanjing Xihu Clothing Co., Ltd., CN

* MO, Lei is the corresponding author, E-mail: 1306485658@qq.com

Abstract: The rapid growth of platform-based retail and social commerce has enabled maternal and infant e-commerce businesses to achieve market visibility through hero-product strategies. However, reliance on a limited number of high-performing products may increase product concentration and expose businesses to sales volatility, returns, cancellations, and other operational risks. This study develops a conceptual framework linking hero-product dependence, digital operational innovation, risk governance, and sustainable brand building, and provides an exploratory empirical analysis using public transaction data. We extracted a maternal- and infant-related subsample of 23,622 transaction lines and 94 product codes from the UCI Online Retail II dataset and aggregated it into 25 monthly observations. We measured hero-product dependence as the monthly revenue share of the highest-selling product, while product concentration, return and cancellation value rate, and rolling sales volatility were measured using the Herfindahl–Hirschman Index and transaction-based indicators. We used descriptive statistics, Spearman correlation analysis, and quadratic regressions with HC3 robust standard errors. The results show that hero-product revenue share is strongly associated with overall product concentration and negatively associated with monthly purchase sales. However, within the observed hero-product share range of 6.7% to 18.6%, we find no statistically significant nonlinear relationship with return and cancellation risk or sales volatility. These findings suggest that hero-product success does not automatically generate operational risk; such risk may become more pronounced when product concentration is extreme and is not supported by portfolio development and effective risk governance.

Keywords: Maternal and Infant E-commerce, Hero-product Strategy, Brand Building, Operational Innovation, Risk Governance, Digital Transformation, Brand Sustainability.

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1 INTRODUCTION

The rapid expansion of platform-based retail, social commerce, and data-driven marketing has created new growth opportunities for maternal and infant e-commerce brands, particularly those seeking to achieve rapid market penetration through a hero-product strategy. By concentrating promotional resources, platform traffic, influencer exposure, and pricing incentives on a limited number of highly marketable products, emerging brands can quickly increase sales, attract consumer attention, and establish an initial market presence. However, short-term product success does not necessarily lead to sustainable brand development. Excessive dependence on a single hero product may expose firms to demand volatility, product portfolio concentration, inventory imbalance, high return rates, platform dependence, quality-related complaints, and reputational risks, while the decline of product popularity can rapidly weaken sales and consumer engagement. This issue is

particularly important in the maternal and infant sector, where purchasing decisions are strongly influenced by product safety, quality assurance, trust, service reliability, and customer experience. Existing studies provide several relevant but largely separate perspectives on this problem.

Research on cross-border e-commerce and supply chain integration shows that the coordination of information, logistics, and financial flows can improve operational efficiency, responsiveness, and risk mitigation, while research in the maternal and infant product sector demonstrates that the integration of employees, accounting systems, inventory tools, online marketplaces, and delivery processes can support order synchronisation, inventory control, record keeping, and daily operational efficiency. The same case evidence also suggests that digitalisation enables firms to consolidate operational data, automate manual processes, strengthen inventory management, and convert transaction data into managerial insights. At the same time, studies on brand sustainability argue that long-term brand

development requires more than current awareness or loyalty and should instead reflect a brand's continuing relevance, growth potential, value creation, and ability to maintain consumer preference over time.

Operational innovation research further indicates that superior performance depends not merely on the adoption of individual technologies but on the coordinated redesign of organisational processes, supply chain relationships, traceability systems, and decision-making mechanisms. Nevertheless, these research streams have not been sufficiently integrated. Supply chain studies generally focus on technology adoption, process coordination, logistics efficiency, and operational performance, whereas branding studies concentrate on brand equity, consumer preference, loyalty, and sustainability. Consequently, limited attention has been paid to how hero-product-driven growth can be transformed into sustainable brand building, or to how operational innovation and risk governance jointly influence this transition. To address this gap, the present study examines the relationship among hero-product dependence, digital operational innovation, risk governance, and long-term brand performance in the maternal and infant e-commerce sector. Using brand- and product-level operational data, the study evaluates changes in sales, online attention, customer reviews, brand-search activity, inventory turnover, return rates, product concentration, and sales volatility before and after the emergence of a hero product. It further investigates whether the relationship between hero-product dependence and brand sustainability is nonlinear, with moderate dependence supporting market expansion while excessive dependence increases structural and operational risks.

2 RELATED WORK

Existing studies on e-commerce operations have primarily examined how digital technologies improve supply chain integration, process efficiency, and risk responsiveness. Du [1] develops a digitally enabled cross-border e-commerce supply chain management mechanism that combines data-driven decision optimisation, digital supplier management, intelligent inventory control, smart logistics, technological applications, and emergency response. The study demonstrates that digital coordination can improve inventory circulation, reduce product returns, and shorten supply chain response time. From a broader integrative perspective, Wang et al. [2] conceptualise cross-border e-commerce firms as supply chain integrators that coordinate information, logistics, and financial flows. Their findings indicate that the effective interaction of these three flows strengthens supply chain service capabilities, relationship quality, customer satisfaction, and risk mitigation. In the maternal and infant product sector, Zainuddin et al. [3] further illustrate how digital tools connect employees, accounting systems, inventory platforms, online marketplaces, and delivery processes. Their case study shows that integrating accounting software, order-synchronisation tools, and e-commerce

platforms can support inventory control, record-keeping, operational efficiency, and data-driven decision-making. Taken together, these studies suggest that operational innovation in e-commerce should not be understood as the isolated adoption of a particular technology but as the coordinated redesign of data, inventory, logistics, platform, and customer-service processes. However, the existing literature mainly evaluates technology acceptance and supply chain efficiency, without sufficiently explaining how such operational capabilities help consumer brands convert the temporary traffic generated by a hero product into a diversified product portfolio and sustainable brand growth.

Research on brand sustainability and operational innovation provides a complementary foundation for understanding this transition. Schultz and Block [4] argue that conventional measures such as brand awareness and brand loyalty mainly reflect past or current consumer responses and offer limited insight into a brand's future development. They therefore introduce brand sustainability as a forward-looking construct associated with consumer preference, growth potential, and the brand's ability to remain relevant over time. Grubor and Milovanov [5] similarly position sustainability as an important component of brand strategy and brand equity, emphasising that sustainable brand development requires firms to translate their values and long-term commitments into credible and accessible consumer propositions. From an operational perspective, Shou et al. [6] demonstrate that superior performance does not result from technological adoption alone; rather, operational innovation is achieved when technological traceability is appropriately matched with supply chain coordination.

These findings imply that the success of a hero product does not automatically lead to sustainable brand building. In maternal and infant e-commerce, converting short-term product popularity into long-term brand equity likely depends on the firm's ability to coordinate product portfolio development, consumer data, inventory planning, logistics, customer service, and risk monitoring. Nevertheless, the supply chain literature generally concentrates on efficiency, coordination, and operational risk, whereas the branding literature focuses on consumer preference, brand equity, and sustainability. Few studies have connected these two streams to examine hero-product dependence as both a source of rapid growth and a potential source of structural risk. The present study addresses this gap by investigating the relationship among hero-product dependence, operational innovation, risk governance, and brand sustainability, while further examining whether hero-product dependence has a nonlinear effect on long-term brand performance and whether operational innovation and risk governance moderate this relationship.

3 DATA AND METHODS

3.1 RESEARCH DESIGN

This study adopts a research design combining conceptual framework development with a small-scale empirical experiment using public transaction data. The conceptual framework links hero-product dependence, digital operational innovation, operational risk governance, and long-term brand performance. The empirical experiment does not replace the proposed brand-level panel analysis. Instead, it demonstrates how hero-product dependence can be operationalized and provides preliminary evidence regarding its relationships with product concentration, return and cancellation risk, and sales volatility.

The unit of analysis is the month. Because the public dataset does not contain internal measures of digital capability, inventory turnover, or risk-governance quality, the experiment examines only the baseline relationships in the conceptual framework:

H1: A higher level of hero-product dependence is associated with a higher return and cancellation value rate.

H2: Hero-product dependence has a nonlinear relationship with sales volatility.

The moderating effects of digital operational innovation and risk governance should subsequently be tested with brand surveys, platform-operation records, or internal enterprise data.

3.2 DATA SOURCE AND SAMPLE

The experiment uses the Online Retail II dataset from the UCI Machine Learning Repository (Chen, 2012; DOI: 10.24432/C5CG6D). Released under a CC BY 4.0 license, the dataset contains 1,067,371 real transaction records from a UK-based non-store retailer between 1 December 2009 and 9 December 2011. Its variables include invoice number, product code, product description, quantity, invoice date, unit price, customer identifier, and country. According to the dataset documentation, invoice numbers beginning with the letter C represent cancelled transactions.

To align the experiment with the maternal and infant e-commerce context, relevant products were identified using the following terms in the English product descriptions: BABY, BABIES, CHILD, CHILDS, CHILDREN, CHILDRENS, KID, KIDS, NURSERY, INFANT, PRAM, BIB, BIBS, MATERNITY, PACIFIER, and DUMMY. The term BOTTLE was deliberately excluded as a stand-alone keyword because it would incorrectly capture hot-water bottles and decorative bottles. The resulting analytical sample contains 23,622 transaction lines, 94 product codes, and 25 calendar months.

The source company primarily sold giftware rather than specializing in maternal and infant products. The extracted subsample should therefore be treated as a reproducible

methodological demonstration rather than an industry-representative sample. Its results do not support strong causal claims about the maternal and infant e-commerce sector as a whole.

3.3 DATA PROCESSING

The two annual worksheets in the original workbook were first combined. Invoice dates were converted to a consistent datetime format. Records were excluded when the product description was blank, the invoice date was invalid, quantity or unit price was missing, or unit price was not positive.

A transaction line was classified as a cancellation or return when its invoice number began with C or its quantity was negative. Positive-quantity, non-cancelled records were used to calculate purchase sales, while the absolute monetary value of cancelled or negative-quantity records was used to calculate return and cancellation value.

For each transaction line j , the transaction value was calculated as the product of the recorded quantity and unit price:

$$TransactionValue_j = Quantity_j \times UnitPrice_j$$

where $Quantity_j$ denotes the number of units recorded in transaction line j , and $UnitPrice_j$ represents the corresponding price per unit. For valid purchase transactions, only records with positive quantities and invoice numbers not beginning with the letter C were included.

Monthly sales for product i in month t were then calculated by aggregating the values of all valid purchase transactions associated with that product and month:

$$Sales_{it} = \sum_{j \in \mathcal{P}_{it}} Quantity_j \times UnitPrice_j$$

where $\mathcal{P}_{it}$ denotes the set of valid purchase transaction lines associated with product i during month t . Total monthly purchase sales were calculated by summing the sales of all active products in the maternal and infant-related subsample:

$$PurchaseSales_t = \sum_{i=1}^{N_t} Sales_{it}$$

where N_t represents the number of products with positive purchase sales in month t . These monthly product-level sales values provide the basis for measuring hero-product dependence and overall product concentration.

3.4 VARIABLE MEASUREMENT

3.4.1 Hero-product dependence

Hero-product dependence was measured using the

monthly revenue share of the highest-selling product. The revenue share of product i in month t was first calculated as:

$$Share_{it} = \frac{Sales_{it}}{PurchaseSales_t} = \frac{Sales_{it}}{\sum_{i=1}^{N_t} Sales_{it}}$$

The Hero Share variable was subsequently defined as the maximum product revenue share observed in each month:

$$HeroShare_t = \max_{1 \leq i \leq N_t} (Share_{it})$$

Equivalently,

$$HeroShare_t = \max_{1 \leq i \leq N_t} \left(\frac{Sales_{it}}{\sum_{i=1}^{N_t} Sales_{it}} \right)$$

A higher value of $HeroShare_t$ indicates that a larger proportion of monthly purchase sales is generated by a single leading product. The variable therefore captures the degree to which the retailer's monthly revenue structure depends on its highest-performing product. However, it does not measure whether the same product remains dominant across consecutive months.

3.4.2 Product concentration

Overall product concentration was measured using the Herfindahl–Hirschman Index. Unlike Hero Share, which focuses only on the highest-selling product, the HHI incorporates the revenue shares of all active products in a given month:

$$HHI_t = \sum_{i=1}^{N_t} Share_{it}^2$$

Substituting the definition of the product revenue share gives:

$$HHI_t = \sum_{i=1}^{N_t} \left(\frac{Sales_{it}}{\sum_{k=1}^{N_t} Sales_{kt}} \right)^2$$

where N_t is the number of active products in month t . A higher HHI_t value indicates that monthly sales are concentrated among a relatively small number of products, whereas a lower value reflects a more diversified product portfolio. The joint use of Hero Share and HHI allows the analysis to distinguish between the dominance of the single highest-selling product and the broader concentration of sales across the entire product portfolio.

3.5 RETURN AND CANCELLATION VALUE RATE

Transactions were classified as returns or cancellations when the invoice number began with the letter C or when the recorded quantity was negative. Because these transactions generated negative monetary values, their absolute values were used to measure the total monthly value of returned or cancelled transactions:

$$ReturnValue_t = \sum_{j \in \mathcal{R}_t} |Quantity_j \times UnitPrice_j|$$

where $\mathcal{R}_t$ denotes the set of transaction lines classified as returns or cancellations in month t .

The monthly return and cancellation value rate was then calculated as:

$$ReturnRate_t = \frac{ReturnValue_t}{PurchaseSales_t}$$

or, in expanded form:

$$ReturnRate_t = \frac{\sum_{j \in \mathcal{R}_t} |Quantity_j \times UnitPrice_j|}{\sum_{i=1}^{N_t} Sales_{it}}$$

This variable represents the monetary value of returned or cancelled transactions relative to valid monthly purchase sales. A higher value indicates greater exposure to transaction reversals and potential after-sales operational risk. Nevertheless, because the public dataset does not provide explicit return-reason codes, the variable should be interpreted as a combined measure of returns, cancellations, and other negative-quantity transaction adjustments rather than as a pure product-return rate.

4 4. SMALL-SCALE PUBLIC-DATA EXPERIMENT

4.1 DESCRIPTIVE RESULTS

TABLE 1. DESCRIPTIVE STATISTICS

Variable	N	Mean	SD	Minimum	Median	Maximum
Monthly purchase sales (GBP)	25	14,501.03	5,704.62	6,352.25	13,811.11	30,745.41
Active products	25	51.72	8.95	32.00	50.00	62.00
Hero-product revenue share	25	0.114	0.032	0.067	0.109	0.186
HHI	25	0.052	0.018	0.033	0.045	0.090
Return/cancellation value rate	25	0.016	0.010	0.004	0.016	0.043
Three-month rolling sales CV	23	0.196	0.141	0.028	0.181	0.581

Note: GBP denotes British pounds; HHI denotes the Herfindahl–Hirschman Index; CV denotes the coefficient of variation. The

three-month rolling sales CV has 23 observations because the first two months are used to construct the initial rolling window.

Table 1 shows that the highest-selling product contributed an average of approximately 11.4% of monthly purchase sales, with a maximum of 18.6%. The mean return and cancellation value rate was approximately 1.6%. The sample therefore contains identifiable leading products but does not exhibit extreme dependence on a single product.

4.2 REGRESSION RESULTS

The regression results do not provide statistical evidence that increasing hero-product dependence necessarily increases return risk or sales volatility within the observed sample. The Spearman analysis shows that Hero Share is strongly and positively correlated with HHI ($\rho=0.908$), indicating that Hero Share captures meaningful variation in product concentration. Hero Share is negatively associated with monthly purchase sales ($\rho=-0.510$), suggesting that higher-sales months tend to be supported by a broader product portfolio. Its correlations with the return and cancellation value rate ($\rho=0.098$) and rolling sales volatility ($\rho=-0.225$) are weak and statistically insignificant.

These findings do not invalidate the conceptual framework. First, observed Hero Share ranges only from 6.7% to 18.6%, meaning that the sample does not cover extreme single-product dependence. Second, the use of a single retailer limits variation in operational systems and governance practices. Third, the public dataset lacks inventory, page traffic, customer reviews, complaints, or measures of digital operational innovation.

The full study should therefore be extended to multiple maternal and infant brands and should include brand fixed effects, platform fixed effects, and interaction terms between hero-product dependence, digital operational innovation, and risk governance.

4.3 GRAPHICAL ANALYSIS AND TREND EXAMINATION

Figure 1 presents the monthly evolution of hero-product dependence and the return and cancellation value rate over the observation period. Hero-product dependence is represented by the revenue share of the highest-selling product in each month, while operational risk is represented by the monetary value of cancelled or negative-quantity transactions relative to monthly purchase sales. The figure shows that Hero Share varies noticeably across months, indicating that the identity and relative importance of the leading product were not constant over time. In several months, the highest-selling product accounted for a comparatively large proportion of total sales, whereas in other months revenue was distributed more evenly across the available product portfolio. The return and cancellation value rate also fluctuated over the sample period, but its peaks did

not consistently coincide with months of high hero-product dependence. For example, some increases in the return and cancellation rate occurred when Hero Share remained at a moderate level, while several months with relatively high Hero Share did not exhibit unusually high transaction-reversal values. This visual pattern provides no clear evidence of a stable contemporaneous relationship between reliance on the leading product and operational risk.

The absence of consistent co-movement should not be interpreted as evidence that product concentration is irrelevant to operational risk. Rather, it indicates that return and cancellation outcomes are likely influenced by multiple factors that are not observed in the public dataset, including product quality, promotional intensity, order-processing errors, seasonal demand, customer expectations, delivery performance, and after-sales policies. Hero Share captures the concentration of monthly revenue in the highest-selling product, but it does not identify whether that product experienced quality problems, supply shortages, aggressive discounting, or unusually high return behaviour. Furthermore, the two series are plotted using different vertical scales. Figure 1 should therefore be interpreted as a descriptive comparison of temporal patterns rather than as direct evidence of numerical equivalence or causal association.



FIGURE 1. MONTHLY HERO-PRODUCT DEPENDENCE AND OPERATIONAL RISK.

Note: The blue line represents the monthly revenue share of the highest-selling product in the maternal and infant-related subsample. The red line represents the absolute value of cancelled or returned transactions as a proportion of monthly purchase sales. Source: UCI Online Retail II; authors' calculations.

Figure 2 provides a complementary graphical examination of the possible nonlinear relationships between hero-product dependence and the two operational outcomes. Panel (a) plots Hero Share against the return and cancellation value rate, while Panel (b) plots Hero Share against the three-month rolling coefficient of variation of net sales. The fitted quadratic curve in Panel (a) displays a shallow inverted-U pattern, with the return and cancellation value rate increasing slightly at intermediate Hero Share levels before declining at the upper end of the observed range. However, the monthly

observations are widely dispersed around the fitted curve, and the estimated quadratic term is not statistically significant. The graphical pattern therefore does not provide sufficient evidence that moderate hero-product dependence systematically increases return and cancellation risk.

Panel (b) also shows a weak nonlinear pattern. Sales volatility appears relatively stable at low and moderate Hero Share levels and then declines toward the upper end of the observed range. Nevertheless, this apparent decline is influenced by a small number of monthly observations and should not be interpreted as evidence that greater dependence on a hero product reduces sales volatility. The observed Hero Share values range only from 6.7% to 18.6%, meaning that the dataset contains no cases of extreme single-product dependence. Consequently, the fitted curve reflects variation within a relatively moderate concentration range and cannot reveal what might occur when one product accounts for a substantially larger share of total revenue.

The curves shown in Figure 2 are unadjusted descriptive polynomial fits. They do not incorporate the logarithm of monthly sales included as a control variable in the regression models. Their purpose is therefore to visualise the distribution of the observations and the approximate shape of the associations rather than to replace the formal regression estimates. Consistent with the regression results, the figures suggest that the relationships between Hero Share, return and cancellation risk, and sales volatility are weak within the available sample. The analysis does not establish either a statistically reliable U-shaped or inverted-U-shaped relationship. The relevant regression coefficients were statistically insignificant, and the limited number of monthly observations further reduces the precision of the estimated curves.

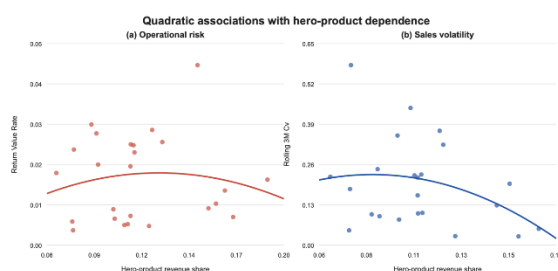


FIGURE 2. QUADRATIC RELATIONSHIPS BETWEEN HERO-PRODUCT DEPENDENCE AND OPERATIONAL OUTCOMES.

Note: Panel (a) presents the quadratic fit between Hero Share and the return and cancellation value rate. Panel (b) presents the quadratic fit between Hero Share and the three-month rolling coefficient of variation of net sales. Dots represent monthly observations, and solid curves represent quadratic polynomial fits. Source: UCI Online Retail II; authors' calculations.

4.4 SUMMARY AND INTERPRETATION OF THE EMPIRICAL FINDINGS

Using 23,622 maternal and infant-related transaction lines extracted from the UCI Online Retail II dataset, this study constructs monthly measures of hero-product revenue share, overall product concentration, return and cancellation risk, and rolling sales volatility. The sample covers 94 product codes and 25 calendar months. The highest-selling product contributed an average of approximately 11.4% of monthly purchase sales, with observed values ranging from 6.7% to 18.6%. These results indicate that identifiable leading products existed in the sample, although the retailer did not exhibit extreme dependence on a single product.

The strongest empirical relationship is observed between Hero Share and the Herfindahl–Hirschman Index, with a Spearman correlation of 0.908, confirming that Hero Share captures meaningful variation in monthly product concentration. Hero Share is also negatively associated with monthly purchase sales ($\rho = -0.510$), suggesting that higher-sales months tended to be supported by a broader product portfolio rather than by stronger reliance on the leading product. However, the relationships between Hero Share and the return and cancellation value rate ($\rho = 0.098$), as well as rolling sales volatility ($\rho = -0.225$), are weak and statistically insignificant.

The quadratic regression results similarly provide no statistically significant evidence that hero-product dependence increases return and cancellation risk or sales volatility within the observed range. These findings suggest that the presence of a hero product does not automatically create operational risk. Instead, structural risk may become more pronounced when product concentration reaches extreme or persistent levels and is accompanied by limited portfolio development, weak inventory planning, or insufficient after-sales risk governance. Because the analysis is based on a single retailer and only 25 monthly observations, the findings should be interpreted as exploratory rather than causal.

5 DISCUSSION AND CONCLUSION

The empirical results provide a qualified interpretation of hero-product strategies in maternal and infant e-commerce. The strong positive correlation between Hero Share and the Herfindahl–Hirschman Index confirms that the revenue contribution of the highest-selling product is a meaningful indicator of product concentration. However, hero-product success should not be treated as equivalent to structural dependence. In the present sample, the leading product contributed an average of 11.4% of monthly purchase sales, with values ranging from 6.7% to 18.6%, indicating identifiable leading products but not extreme single-product concentration. Hero Share was also negatively associated with monthly purchase sales, suggesting that stronger sales months tended to be supported by a broader product portfolio.

rather than by greater reliance on one product. This finding is consistent with the argument that sustainable brand building depends on converting the attention generated by a hero product into demand for related products and a more diversified revenue structure.

The results do not provide statistically significant evidence that Hero Share has either a linear or quadratic relationship with the return and cancellation value rate or rolling sales volatility. This does not imply that product concentration is unrelated to operational risk; rather, it suggests that a hero product does not automatically produce adverse operational outcomes within a moderate concentration range. Structural risk is more likely to emerge when dependence becomes extreme or persistent and is accompanied by insufficient portfolio development, inaccurate demand forecasting, inventory imbalance, weak logistics coordination, or inadequate after-sales management. Digital operational innovation and risk governance are therefore important for monitoring product concentration, coordinating marketplace orders with inventory capacity, identifying abnormal return patterns, and extending hero-product traffic to complementary products. These mechanisms form part of the conceptual framework, although their moderating effects cannot be directly tested with the available public dataset.

Overall, this study offers a reproducible approach to measuring hero-product dependence and examining its relationship with product concentration and operational outcomes. The main conclusion is that the strategic challenge is not whether maternal and infant e-commerce businesses should develop hero products, but whether they can transform short-term product popularity into a diversified portfolio, stable operations, and sustainable brand equity. The findings remain exploratory because the sample is derived from one UK-based non-store retailer, includes only 25 monthly observations, and lacks direct measures of inventory, customer reviews, digital operational capability, and internal risk governance. Future research should therefore employ multi-brand and multi-platform panel data to distinguish temporary hero-product success from persistent dependence and to test more directly how operational innovation and risk governance influence long-term brand performance.

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AUTHOR CONTRIBUTIONS

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ABOUT THE AUTHORS

MO, Lei

Nanjing Xihu Clothing Co., Ltd., CN,
1306485658@qq.com.

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