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The relationships between productivity, operational risk, and firm performance

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Abstract: The aim of this study was to revisit the relationship between productivity and performance by using the panel data model on Taiwanese food listed firms during 2008–2020. The result found that there is a U-shaped relationship between productivity and performance. On the contrary, research and development (R&D) innovation and performance have an inverse U-shaped relationship, reminding that when the food listed firms have a specific R&D innovation base, they should invest more powerful resources, professional productivity, and innovate the food listed firms.

Keywords: asymmetric effects; food industry; R&D innovation; stock returns; U-shaped relationship

The food industry has been the target of investors in Taiwan's capital market in recent years, as they have been generally optimistic about share prices in this industry. Investors continue to believe that the food industry has high research and development (R&D) innovation capability. On the other side of the coin, food firms invest heavily in R&D to meet investors' expectations concerning stock price appreciation. However, whether R&D innovation investment brings about a marginal increasing or decreasing effect on the operations of food firms remains uncertain. It is thus an issue that many firms and investors cannot ignore.

Firm performance is a significant concern for all organizations and involves a multitude of antecedents. Bendickson et al. (2018) find that reducing operational risk and dependency through strategic actions under the resource dependency theory framework and enhancing work practices through high-performance work systems lead to higher levels of firm performance. Duncan (1972) argues that operational risk and complexity, and environment dynamics should not be considered constant features in any organization. Risk in the food industry is a phenomenon that investors rarely take into consideration. Yet, it is characterized by significant fluctuations in related stock prices, and thus the impacts of operational risk on this industry are of great concern. Many food firms are committed to R&D innovation of new firm technologies or combining other new application technologies to create technological thresholds for the future. When facing such high operational risk, it is necessary to observe whether R&D innovation or productivity is the main influencing factor for enhancing a firm's competitiveness.

Montani et al. (2019) argues that R&D innovation and productivity present an inverted U-shaped relationship, which means that when firms invest in R&D innovation

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and productivity, in addition to taking into account the substantial benefits of these two variables, they should also conceive of contribution to firm performance. Arkolakis et al. (2018) pointed out that R&D innovation is essential in creating corporate value. By observing OECD countries, including the US, Germany, Australia, and other countries, it is found that countries that focus on innovation can also gain productivity.

Acemoglu and Restrepo (2018) focus on the structural changes between US corporate innovation R&D and productivity. However, in recent years, operating risks have gained the attention of firms. The relevance of R&D innovation and productivity effort to firm performance should be considered to the effect of operational risk.

In addition, according to Arkolakis et al. (2018), R&D innovation and productivity are issues that firms should continue to pay attention to, not just short-term practices. Acemoglu and Restrepo (2018) stated that R&D innovation and productivity have significant relevance to the growth of firms, and it also implies that the development of firms must have an attitude of pursuing R&D innovation and productivity. Operational risk has been an important issue in recent years. The impact of an operational risk may allow firms to continue to maintain their competitiveness, which has a better effect on firms' investment in R&D, innovation, and productivity. However, operational risks are often neglected in the past literature. Therefore, this paper attempts to consider operational risk factors and re-empirically the relevance of R&D innovation and productivity to firm performance.

Acemoglu and Restrepo (2018) found that the threshold effect of operational risk should be considered when considering R&D innovation, productivity, and firm performance. This paper also found a non-linear relationship between R&D innovation and firm performance, and there is also a non-linear relationship between productivity and firm performance. These phenomena, in addition, prove partial consistency with the past literature; as a result, it further considers structural changes and captures the relationship between structural changes such as R&D innovation, productivity, and operating performance.

Different from other studies, from the viewpoint of operational risk threshold, this paper observes an asymmetric effect of productivity and R&D innovation on performance in Taiwan's food industry. On the other hand, this paper revisits the non-linear relationship between productivity and R&D innovation for firm performance in the food industry.

The results of the recent literature on firm performance and productivity are fairly valuable. They mean that when it comes to high-end industries, the degree of emphasis on productivity should be on more professional performance because it is essential for improving overall firm performance. Regarding operational risk, as the food industry is in a highly competitive environment, the share price performance focuses on investors' attention. However, competent authorities, firms, and investors often ignore the impact of operational risk on this industry. Montani et al. (2019) shows that R&D innovation and productivity present an inverted U-shaped relationship, and an efficient workload is conducive to improving R&D innovation ability.

Arkolakis et al. (2018) pointed out that the country can focus on R&D innovation, and productivity is essential, especially since the government needs to focus on the added value of innovation. Acemoglu and Restrepo (2018) show the relationship between the R&D innovation capabilities of firms and productivity growth and find that innovation capabilities are indeed different from firms with varying growth rates. Pedersen et al. (2018) found that the effect of R&D innovation is more conducive to the firm's sustainability, and therefore, innovation ability affects the firm's operations, productivity, and sustainable development.

Priem et al. (1995) found that operational risk is a moderating factor in the corporate strategic decision-making process and firm performance. Operational risk will affect R&D innovation performance because the operational risks may affect the firm's overall performance.

Patel and Pavitt (1995) showed that R&D expenditure and patent rights could be indicators of firm innovation performance. The empirical results found that R&D expenditure, patent output, and corporate performance were significantly correlated.

Bettis and Mahajan (1985) showed a trade-off between profitability and operational risk and found that the operating performance of a diversified firm is poor. However, the diversified firm also has a lower standard deviation, which represents a lower operational risk.

Dai and Cheng (2018) note that the widely observed positive relationship between product innovation and revenue productivity should be interpreted with caution. Liu (2018) presents empirical evidence on the upward trend in the volatility of firm-specific productivity shocks, which is more robust for newer, smaller firms, and in the technology sector. Glaeser et al. (2020) argue that patents reflect, in part, management's decision to reveal the outcome of uncertain investments in innovation. Whether a manager seeks to maximize the firm's short-term stock price or long-term profits represents disclosure friction. Chen et al. (2018) find

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that an R&D subsidy has an inverted U-shape effect on performance, while non-R&D support positively impacts performance.

This paper sets second hypothesis (H_2). Productivity has a U-shape effect on performance because the literature has a lot of discussion on productivity in the past, including the increasing or decreasing influence of the firm's use of productivity on the performance. In particular, traditional industries used to use a lot of human resources in the past. Still, when the input of human resources into production reaches the limit, no amount of investment in human resources may improve productivity at this time. Especially in Taiwan, the industry has entered the technological environment, and the phenomenon of a declining birthrate has become severe. Effective use of productivity is essential for the performance of firms. The transformation of outstanding productivity and R&D and innovative technology, it can improve the quality and enhance the firm performance.

Therefore, productivity should be given full attention by the firm because the more human resources, it may not be converted into production efficiency. Still, it is a waste of the firm. The firm can think about the concepts and practices to improve productivity, such as introducing human resource professional training, technology management technology, and employee compensation systems, to maximize the firm's performance with a small amount of outstanding productivity.

H_1: R&D innovation has an inverted U-shape effect on performance.

H_2: Productivity has a U-shape effect on performance.

Esteve-Pérez et al. (2018) find that in the intermediate stage both age and productivity play a role in reducing firms' hazard rates. Golec and Vernon (2007) argue that food firms are exposed to greater financial risk than firms in other industries and are more sensitive to policy shocks that affect or could affect industry profitability. Bloom and Milkovich (1998) extended agency-based research by examining the role of risk in the structure of managerial compensation and its relationship to organizational performance. Their paper suggests that organizations facing higher risk do not emphasize short-term incentives more than other organizations but instead place less emphasis on them. Kren and Kerr (1993) note a moderate relationship between uncertainty and compensation system design. In non-monitoring firms, higher levels of uncertainty are associated with increased use of performance contingent compensation. We thus have the following two hypotheses.

H_3: There is a threshold effect between operational risk and firm performance.

H_4: The relationship between firm performance and productivity exhibits an asymmetric effect under the threshold of operational risk.

From the above discussion of the literature, we can see that productivity is an essential key factor, especially in the past, because the food industry always pays attention to continuous investment in R&D innovation. The effects of operational risk on the food industry are rarely explored in the literature. This paper considers the impact of productivity and R&D innovation on firm performance under the threshold of operational risk.

Looking at the past literature, we find that R&D innovation capabilities, productivity, and financial policies have fascinating effects on firm performance. There may be a non-linear relationship between the above variables, and operational risk is usually an essential factor that firms ignore. Still, the operational risk may be a critical factor that affects the firm's investment in R&D innovation and productivity performance.

Therefore, this paper looks forward to further capturing the impact of R&D innovation capabilities, productivity, and financial policies on different types of firm performance, considering the status of different thresholds of operational risks.

MATERIAL AND METHODS

Model basics. This paper's revisited the relationship between operational risk, productivity, and performance by using the panel data model on 35 Taiwanese food-listed firms during 2008–2020. The source of data supporting this paper calculation is based on data provided by the Taiwan Economic Journal (TEJ 2020). This paper considers the reasons for the completeness of the data, mainly using these 35 Taiwanese food-listed firm samples.

This model by Bendickson et al. (2018) and Bloom and Milkovich (1998) is derived from conventional theory and employs the panel data model to estimate correlations among R&D innovation, productivity, and firm performance. We set up panels on quarterly data frequencies and take our data from TEJ sources. We construct an equation as follows and main variable descriptions in Table 1:

$$\ln TQ_{it} = \beta_{1i} \ln RD_{it} + \beta_{2i} \ln PR_{it} + \beta_{3i} \ln OPE_{it} + \beta_{4i} \ln RISK_{it} + \beta_{5i} \ln SIZE_{it} + \beta_{6i} \ln CASH_{it} + \varepsilon_{it} \quad (1)$$

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where: TQ_{it}– Tobin's *Q*; RD_{it} – R&D innovation intensity; PR_{it} – productivity indicator; OPE_{it} – operating profit rate; $RISK_{it}$ – operational risk; $SIZE_{it}$ – firm size; $CASH_{it}$ – cash flow ratio; ε_{it} – error term; β – coefficient.

H_1: R&D innovation has an inverted U-shape effect on performance.

$$\ln TQ_{it} = \beta_{1i} \ln RD_{it} + \beta_{2i} \ln RD_{it}^2 + \beta_{3i} \ln PR_{it} + \beta_{4i} \ln OPE_{it} + \beta_{5i} \ln RISK_{it} + \beta_{6i} \ln SIZE_{it} + \beta_{7i} \ln CASH_{it} + \varepsilon_{it} \quad (2)$$

H_2: Productivity has a U-shape effect on performance.

$$\ln TQ_{it} = \beta_{1i} \ln RD_{it} + \beta_{2i} \ln PR_{it} + \beta_{3i} \ln PR_{it}^2 + \beta_{4i} \ln OPE_{it} + \beta_{5i} \ln RISK_{it} + \beta_{6i} \ln SIZE_{it} + \beta_{7i} \ln CASH_{it} + \varepsilon_{it} \quad (3)$$

Panel dynamic threshold model. Our study follows Gonzalez et al. (2005) and Acemoglu and Restrepo (2018) who examined the relationship between R&D innovation, productivity, and firm performance. This paper found that the threshold effect of operational risk should be considered when considering R&D innovation, productivity, and firm performance by panel smooth transition regression (PSTR) model and Matlab R2008b software. This paper also found a non-linear relationship between R&D innovation, productivity, and firm performance. This paper first models a threshold effect relationship and asymmetric effect between R&D innovation, productivity, and Tobin's *Q* under operational risk and operating profit rate threshold effect, expressing the log equation as follows.

H_3: There is a threshold effect between operational risk and firm performance [Equation (4)].

H_4: The relationship between firm performance and productivity exhibits an asymmetric effect under the threshold of operational risk [Equation (5)].

$$TQ_{it} = \beta_{1i} \ln RD_{it} + \beta_{2i} \ln PR_{it} + \beta_{3i} \ln SIZE_{it} + \beta_{4i} \ln CASH_{it} + \varepsilon_{it} + \left[\beta_{1i} \ln RD_{it} + \beta_{2i} \ln PR_{it} + \beta_{3i} \ln SIZE_{it} + \beta_{4i} \ln CASH_{it}\right] g\left(RISKq_{it}; \gamma, c\right) + \varepsilon_{it} \quad (4)$$

where: *g* – transition function; $RISKq_{it}$ – transition variable; *c* – threshold parameter; γ – determines the speed and smoothness of the transition.

Table 1. Main variable descriptions

Variable	Description	Calculation
TQ	a comparison between the stock market value of the firm and the net book value of the firm	*TQ* = (total market value / total asset value) × 100%
RD	R&D innovation agent variables, using the ratio of research development costs to net sales	*RD* = (R&D expense / net operating income) × 100%
PR	the output value is a food firm's input per unit of human resources; an effective indicator for measuring the efficiency of human resource utilization and industrial competitiveness	*PR* = net operating income / number of employees
OPE	the profit generated by the food firm for each unit of revenue generated	*OPE* = (operating income / net sales) × 100%
RISK	operational risk is measured by the volatility of stock price return of the food firm; the fluctuation of stock price compensation not only reflects the firm's non-systematic risks but also reveals the rates among food firms	*RISK* = operational risk is measured by the annualized standard deviation calculated from the stock price return of the food firms
SIZE	this study uses a food firm's total assets as a measure of scale	*SIZE* = ln (firm total assets)
CASH	food firms' ability to obtain sufficient cash to repay their debts and honour their commitments through operations	*CASH* = (net cash flow from operating activities / current liabilities) × 100%

TQ – Tobin's *Q*; *RD* – R&D innovation intensity; *PR* – productivity; *OPE* – operating profit rate; *RISK* – operational risk; *SIZE* – firm size; *CASH* – cash flow ratio

Source: Authors' own calculations based on data provided by TEJ (2020) database

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$$TQ_{it} = \beta_{1i} \ln RD_{it} + \beta_{2i} \ln PR_{it} + \beta_{3i} \ln SIZE_{it} + \beta_{4i} \ln CASH_{it} + \varepsilon_{it}$$
$$+ \left[\beta_{1i} \ln RD_{it} + \beta_{2i} \ln PR_{it} + \beta_{3i} \ln SIZE_{it} + \beta_{4i} \ln CASH_{it}\right] g\left(OPEq_{it}; \gamma, c\right) + \varepsilon_{it} \tag{5}$$

where: $OPEq_{it}$ – transition variable.

This paper observes the structural changes in R&D innovation, productivity, and firm performance, which allow for estimating the parameters of a panel dynamic threshold model. See Gonzalez et al. (2005) for more details and the maximum number of transition functions, for which the model automatically determines the optimal number. The slope parameters and location parameters of the transition function and the slope parameters in each regime for all explicative variables are estimated by non-linear least square (NLS).

This paper models the relationship between operational risk, productivity, and Tobin's *Q*, using the panel approach that considers food industry to set up threshold variables for operational risk (*RISK*) and operating profit rate (*OPE*) to explore the relationship between operational risk, productivity, and Tobin's *Q*.

RESULTS AND DISCUSSION

Descriptive statistics. Table 2 shows the operational performance of the R&D innovation, R&D innovation, and productivity, and thus it is important for food firms or investors and authorities to identify those sustainability factors that can create performance. This study observes that operational risks are extremely volatile, meaning that their impact on the food industry cannot be ignored. The minimum (–2 383.860%) and the maximum (38.570%) belongs to the operating profit ratios of food firms, which means that the operating profits generated by the food industry are heterogeneous.

The difference in cash flow rates (*CASH*) within the food industry is large, indicating that the food industry has a wide range of cash flow strategies. This article also observes that firms with negative cash flow (–0.566) will burden firm plans to engage in R&D innovation. It is necessary to continuously provide R&D innovation funds for the food industry.

Correlation coefficients. Table 3 shows that firm performance has a positive correlation with R&D innovation (0.082) and has a negative correlation with productivity (–0.108), implying different correlations between productivity and R&D innovation on firm performance. In the long run, it is important for many food firms to integrate R&D innovation with productivity and to realize contributions toward positive firm performance. The production, quality, service, and other management capabilities of food firms help extend the additional value of R&D innovation. In addition, operational risk is related to a food firm's enterprise value (0.200) and is the external pressure of many industries. However, for the food industry, operational risk is a source of competitiveness, because its stimulation will be able to bring more competitiveness to the industry. There is a positive correlation between the cash flow ratio and firm performance (0.271) because, for the food industry, which needs a lot of funds for R&D innovation, cash flow is indeed indispensable.

Panel data regression models. From Table 4, panel A we find that the productivity of the food industry has a negative relationship with firm performance (–0.388). It is obvious that firms initially invest in productivity and need to invest resources in training professional personnel, but this may not be able to produce benefits in the short term. However, an initial investment in R&D innovation can indeed have a positive relationship with firm performance (2.806). Operational risk has a positive

Table 2. Descriptive statistics

Variable	*TQ*	*RD*	*PR*	*OPE*	*RISK*	*SIZE*	*CASH*
Mean	1.779	0.174	3.250	–12.118	12.499	6.374	0.034
Median	1.510	0.044	3.267	7.140	9.132	6.352	0.025
Minimum	0.440	0.000	1.530	–2 383.860	0.020	5.084	–0.566
Maximum	7.660	16.802	4.522	38.570	110.258	7.583	0.357
SD	1.022	0.904	0.403	134.232	12.360	0.435	0.079

TQ – Tobin's *Q*; *RD* – R&D innovation intensity; *PR* – productivity indicator; *OPE* – operating profit rate; *RISK* – operational risk; *SIZE* – firm size; *CASH* – cash flow ratio

Source: Authors' own calculations based on data provided by TEJ (2020) database

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Table 3. Correlation coefficients

Variable	*TQ*(1)	*RD*(2)	*PR*(3)	*OPE*(4)	*RISK*(5)	*SIZE*(6)	*CASH*(7)
TQ(1)	1	–	–	–	–	–	–
RD(2)	0.082***	1	–	–	–	–	–
PR(3)	–0.108***	–0.340***	1	–	–	–	–
OPE(4)	–0.038	–0.992***	0.358***	1	–	–	–
RISK(5)	0.200***	0.129***	–0.046***	–0.124***	1	–	–
SIZE(6)	–0.131***	–0.055***	0.275***	0.082***	–0.107***	1	–
CASH(7)	0.271***	–0.182***	0.293*	0.227***	–0.009***	0.131***	1

*, ***Significance at the 0.1 and 0.01 levels, respectively; *TQ* – Tobin's *Q*; *RD* – R&D innovation intensity; *PR* – productivity indicator; *OPE* – operating profit rate; *RISK* – operational risk; *SIZE* – firm size; *CASH* – cash flow ratio
Source: Authors' own calculations based on data provided by TEJ (2020) database

relationship with firm performance (0.012), which may be related to the characteristics of the industry. It must have forward-looking technology or successful biological research to break through the industry and create stronger industrial competitiveness. In addition, with the prevalence of capital market financing, investors mostly buy or sell their holdings through market information and technology leadership in the food industry.

Panel B shows that R&D innovation and performance in the food industry have an inverse U-shaped relationship, as seen from *RD* (3.585) and RD^2 (–0.042) on firm performance, implying that when the food industry initially invested in R&D innovation, it indeed generated support for corporate performance, but when the industry expanded R&D innovation inputs at that time, it was obvious that there was a reversal effect on corporate performance. This study is a reminder to the food industry that it is not the expansion of R&D innovation that creates corporate performance, because unmanaged R&D investment may have a negative impact on corporate financial risks and investor rights. This study finds that operational risks have a positive relationship with the performance of companies in the food industry, showing that such risks can drive competitiveness in the industry.

The industrial nature of the food industry is different from traditional industries – for example, the food industry has created new technologies, new patents, and other functions that are important investment targets for investors in the capital market. Therefore, R&D and technological innovation in the food industry will, more importantly, include operational achievements such as talent cultivation and productivity, which the capital market will respond to immediately. This study finds that the cash flow ratio has a positive relationship with firm performance, which means that the food industry needs huge capital turnover. Adequate cash flow is important, but the food industry must also have a standard for managing cash flow, as an individual firm receives the greatest benefit from cash flow.

Panel C presents that the square of productivity in the food industry has a U-shaped relationship on performance, as seen in *PR* (–4.511) and PR^2 (0.632) on firm performance. It is obvious that firms have increased their input in productivity and have been able to generate benefits to firm performance in the long run. In the past, the food industry's resources invested in R&D innovation were mostly very high, but it was also possible to achieve professional productivity. However, there is no long-term or professional training mechanism. This study offers a reminder that when the food industry has a certain R&D innovation base, it should invest in more powerful resources, exude strong professional productivity, enhance the professional productivity of firms, and innovate to a wider degree. Therefore, in terms of the long-term operations of the food industry, professional productivity is a very important observational indicator. We also note that investors participating in the holding or selling of the food industry should observe the performance of a firm's professional productivity. The study also suggests that competent authorities, in addition to investing heavily in R&D resources and focusing on the food industry, need to enhance professional productivity resources in order to make Taiwan's food industry more competitive in the long term.

In panel D and panel E, the robustness regression results show that R&D innovation has an inverted U-shape, as seen in *RD* (0.326) and RD^2 (–0.021) on firm performance. The U-shaped productivity results, shown by *PR* (–3.259) and PR^2 (0.466) on firm performance, are consistent with panel B and panel C, under the condition for considering control variables.

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Table 4. Parameter estimation results for panel ordinary least-squares (OLS) models

Variable	Panel A	Panel B	Panel C	Panel D	Panel E
Tobin's *Q*					
Constant	5.432*** (0.411)	5.001*** (0.409)	12.037*** (1.206)	1.793*** (0.030)	1.793*** (0.030)
RD	2.806*** (0.257)	3.585*** (0.278)	3.003*** (0.256)	0.326*** (0.084)	–
RD^2	–	–0.042*** (0.006)	–	–0.021*** (0.007)	–
PR	–0.388*** (0.072)	–0.330*** (0.071)	–4.511*** (0.712)	–	–3.259*** (0.696
PR^2	–	–	0.632*** (0.108)	–	0.466*** (0.108)
OPE	0.018*** (0.001)	0.020*** (0.001)	0.020*** (0.001)	–	–
RISK	0.012*** (0.002)	0.013*** (0.002)	0.0125*** (0.002)	–	–
Control variables					
SIZE	–0.460*** (0.062)	–0.436*** (0.061)	–0.460*** (0.061)	–0.356*** (0.062)	–0.392*** (0.065)
CASH	3.131*** (0.359)	3.280*** (0.354)	2.850*** (0.358)	4.365*** (0.353)	4.410*** (0.353)
R^2	0.249	0.276	0.270	0.013	0.027
Adjusted R^2	0.245	0.272	0.266	0.012	0.025

***Significance at the 0.01 level; *TQ* – Tobin's *Q*; *RD* – R&D innovation intensity; *PR* – productivity indicator; *OPE* – operating profit rate; *RISK* – operational risk; *SIZE* – firm size; *CASH* – cash flow ratio; the numbers in brackets indicate *P*-values
Source: Authors' own calculations based on data provided by TEJ (2020) database

Panel dynamic threshold model. We use the excess return for operational risk ($RISK_{it}$) and operating profit rate (OPE_{it}) as the transition variables. In Table 5 we can reject the null hypothesis (H_0) of linearity, as the likelihood ratio test (LRT) support a non-linear relationship between R&D innovation, productivity, and Tobin's *Q*.

The determination of the number of regimes ($r + 1$) is shown in Table 6 and Figure 1. Two location parameters are present; in other words, it is a two-regime PSTR model This paper tests Tobin's *Q* for operational risk ($RISK_{it}$) and operating profit rate (OPE_{it}), whereby each one has a threshold.

Table 5 found that the threshold model has a non-linear relationship, which means this relationship between operational risk, productivity, and Tobin's *Q* have a non-linear structure. Further, this paper tests the threshold effect of the model from Table 6 and finds that there is a threshold value. From the different threshold effects of *RISK*, *OPE*, this paper finds structural changes between variables such as productivity, R&D innovation, and Tobin's *Q*. From Figure 1, observe the non-linear structural changes caused by the set threshold (*RISK*, *OPE*), and combine Table 5 and Table 6 to capture the threshold effect of the set model.

Table 7 shows that productivity has an asymmetric effect on the performance of food firms under the thresh-

Table 5. Panel dynamic threshold model test

Test	*RISK*	*OPE*
Non-linear test		
Wald test	59.220***	191.876***
Fisher test	4.971***	18.253***
LRT	60.748***	209.288***
Constancy test		
Wald test	59.220***	31.036***
Fisher test	4.971***	7.625***
LRT	60.748***	31.449***

***Significance at the 0.01 level; *OPE* – operating profit rate; *RISK* – operational risk; LRT – likelihood ratio test
Source: Authors' own calculations based on data provided by TEJ (2020) database

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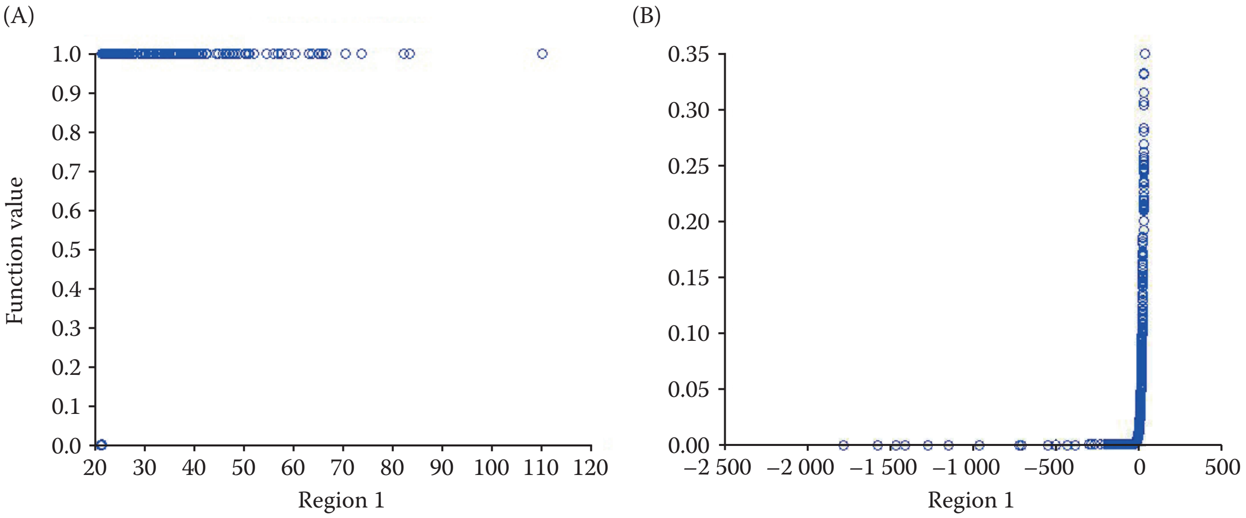

Figure 1. Transition function plot: (A) operational risk and (B) operating profit rate for Tobin's Q whereby each has a threshold

Source: Authors' own calculations based on data provided by TEJ (2020) database

Table 6. Determination of the number of thresholds [number of threshold $r(m)$ = 1]

Statistic	*RISK*	*OPE*
H_3: $B3 = 0$	0.618	2.197
H_2: $B2 = 0 \mid B3 = 0$	0.757	4.122
H_1: $B1 = 0 \mid B2 = B3 = 0$	3.567***	11.181***

***Significance at the 0.01 level; *B*1, *B*2, and *B*3 – slope coefficients; *RISK* – operational risk; *OPE* – operating profit rate

Source: Authors' own calculations based on data provided by TEJ (2020) database

old of operational risk. First, in the high operating risk interval, this study finds that productivity has a positive and significant relationship with performance (0.487); in the low operational risk interval, productivity negatively correlates with performance (–0.088). The food industry faces high operational risks; it needs to pay more attention to and enhance productivity. A robust production process, quality, service, and good brand value will help firms' productivity. However, suppose food firms add investment in R&D innovation in the high-operational risk interval. In that case, it is a very cautious

Table 7. Panel dynamic threshold model estimation results

Variables	*RISK* dynamic threshold		*OPE* dynamic threshold	
	low *RISK*	high *RISK*	low *OPE*	high *OPE*
RD	–0.064*** (0.029)	–0.015 (0.057)	–0.068** (0.156)	70.810*** (0.079)
PR	–0.088 (0.068)	0.487*** (0.294)	–0.174*** (0.081)	9.763** (3.803)
SIZE	–0.064 (0.152)	–0.307 (0.150)	–0.270** (0.122)	–3.336 (1.743)
CASH	2.043*** (0.354)	0.490* (1.228)	0.626*** (0.363)	6.931*** (13.942)
Estimated location parameters	–	49.365	–	21.472
Estimated slope parameters	–	0.104	–	2.768
RSS	–	311.770	–	398.164

*, **, and *** denote 10, 5, and 1% significance levels, respectively; *RISK* – operational risk; *OPE* – operating profit rate; *RD* – R&D innovation intensity; *PR* – productivity indicator; *SIZE* – firm size; *CASH* – cash flow ratio; RSS – residual sum of squares; the numbers in brackets indicate *P*-values

Source: Authors' own calculations based on data provided TEJ (2020) database

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strategy because this study finds that R&D innovation negatively affects performance when it is in the high operational risk interval.

Second, the study also finds that productivity (9.763) and R&D innovation (70.810) positively and significantly affect performance in the high operating profit rate interval. However, in the low operating profit rate interval, productivity (–0.174) and R&D innovation negatively affect performance (–0.068), demonstrating productivity and R&D innovation are important factors for food firms while in the high operating profit rate interval.

Finally, this study shows that productivity and R&D innovation are necessary operational functions for firm performance, and the firm's biggest goal is to be sustainable. In the past, many food firms only paid attention to investment in R&D innovation while neglecting the management mechanism other than R&D innovation. Thus, food firms could not be competitive during a period when facing operational risks. This study suggests that food firms strengthen professional productivity, which is the critical factor in creating synergies in R&D innovation and sustainable management.

Operational risk is an environmental condition that the food industry must face. Operational risk can drive competition and progress in the food industry, but it also tests how the sector can enhance the competitiveness of all the firms. Aside from the function of R&D innovation, the professional mechanism of productivity is even more critical.

CONCLUSION

This paper employs a panel dataset of 35 Taiwanese food firms during 2008–2020 and observes the relevance of R&D innovation, productivity, and operational risk on firm performance. We also investigate R&D innovation, the asymmetric effects of productivity under the operational risk, and the operating profit rate threshold. The empirical results of this study support all our hypotheses.

According to the results of the panel regression models, a U-shaped relationship was found between productivity and performance. Conversely, finding an inverse U-shaped relationship between food firm performance and R&D innovation. In the long run, expanding professional productivity has a marginal incremental effect on firm performance, strengthening the firm's professional production process, professional quality, brand value, etc., which enhances the food firm's performance. However, expanding R&D innovation has a marginal diminishing effect on firm performance.

Table 4 found that R&D innovation has an inverted U-shaped relationship to the firm's performance, and productivity is a U-shaped relationship, which shows that the firm should pay attention to the substantial benefits of R&D innovation or productivity to firm performance. Table 7 shows that firms with high operating profit can invest in R&D innovation or productivity to remain competitive compared to firms with low operating profit.

On the whole, when a food firm invests in R&D innovation or productivity, it is essential to use a professional management mechanism. It is not about investing heavily in R&D innovation or productivity, and the key should be that R&D innovation or productivity can be converted into a substantial benefit for the firm.

According to the panel dynamic threshold model results, in the high operational risk interval, productivity has a positive and significant relationship with performance. However, in the low operating risk interval, productivity has a negative association with performance. The research results support productivity asymmetric effects on firm performance at different operational risk thresholds. The food industry has a high operating profit margin, which simultaneously offers the necessary condition for good R&D innovation and productivity.

This study suggests that firms, investors, and competent authorities should pay attention to the professional and synergetic effects of R&D innovation and productivity in the food industry. For the sustainable development of this industry, it is necessary to strengthen firms' comprehensive management mechanisms. For future research, we will consider the impact of R&D innovation, productivity, and life cycle on firm performance, as the life cycle is a significant issue for the food industry. Most of the literature and theories in the past consider the impact of individual factors such as R&D innovation or productivity on firm performance.

However, this paper attempts to re-examine the new state of these phenomena from operational risk factors that are relatively easy to be overlooked. Through the panel threshold model, this paper capture that operational risks make R&D innovation or productivity have different interpretations of firm performance in different threshold ranges. Especially in areas with high operational risks, firms will have better competitiveness in R&D and innovation or productivity. Therefore, this paper reminds the food industry that investment in R&D and innovation is an essential key factor in policy recommendations.

In addition, improving productivity is also a necessary measure for the food industry to maintain com-

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petitiveness. Operational risks have an incentive effect on the food industry and can drive the positive development of the food industry. Finally, corporate social responsibility is already a global importance issue, and the food industry should have a high standard of corporate social responsibility attitude. Therefore, whether using R&D innovation or productivity to make excellent progress in food safety will undoubtedly benefit society. Since the characteristics of the food firm may be different, such as the firm's age or the firm's size, the gap between individual firms is significant.

Therefore, if these characteristics are taken into account in this paper, the representativeness is limited. In the future, this paper will consider the operational aspects of food firms, such as the age or scales of the firm and even the differences in the firms' financial policies. From the differences in the operating characteristics of these firms, an extended analysis of the heterogeneity between operating risks and firm performance by different firms' age or scales.

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