Article

Arthaniti: Journal of Economic Theory and Practice
1–20

DOI: 10.1177/09767479241247615
journals.sagepub.com/home/ath
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R&D, Product and Process Innovation, and Firm Performance: A Case Study of the Chinese Firms

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Abstract

Alongside rapid economic growth, the Chinese economy has witnessed a notable increase in research and development (R&D) expenditure, escalating from 0.56 per cent of GDP in 1996 to 2.43 per cent in 2021. Recognising the significance of innovation in economic growth, this article utilises unique firm-level data from China for the year 2012 to investigate the influence of R&D, product innovation and process innovation on firm productivity. The findings suggest that R&D positively affects the performance of Chinese firms, as measured by either firm sales or sales per permanent full-time employee. Moreover, product innovation may have a detrimental impact on firm performance, whereas the impact of process innovation lacks robustness.

Keywords

Process innovation, product innovation, research and development, firm performance, China

JEL: D22, N65, O32

I. Introduction

Economic growth is typically characterised by expansion in the industrial sector, which can take the form of increased output from existing firms and/or an increase in the number of firms and industries. The former can be accomplished by using more inputs, such as through the inflow of capital or skilled workers, while the latter may be achieved through innovation (Rosenberg, 2004). Innovation, as described by the Organisation for Economic Co-operation and Development

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(OECD), can be categorised into four forms: Product innovation, process innovation, marketing innovation and organisation innovation. Product innovation entails the development of new and improved goods or services, while process innovation involves enhancements to the production or delivery process. Marketing innovation and organisation innovation refer to the implementation of new marketing techniques and business practices, respectively (OECD Innovation Strategy, 2020).

A number of existing studies have highlighted the role that research and development (R&D) plays in enhancing labour productivity and industrial growth. Several studies have also considered the impact of innovation on economic growth.[1] The early work of Griliches (1979) showed a significant positive association between R&D spending and innovation.[2] Innovation promotes competition, which can improve the organisational structures, processes, products and as well as the services within a firm (Gunday et al., 2011). Furthermore, innovation increases firm productivity, which is also affected by firm size and industry-specific factors. Ericson and Pakes (1995) show that investment in R&D, along with other variables, affects the sales, profitability and growth of firms.[3] Using a Hansen-type threshold model, Chen and Ibhagui (2019) test for the presence of a non-linear relationship between R&D and firm performance. The empirical analysis based on a sample drawn from Nasdaq-listed firms shows that R&D has a positive effect on firm performance, but the performance of the firms does not vary much across R&D intensity. In a related study, Carvalho and de Avellar (2017) examine the effect of innovation on productivity of Brazilian firms. Using labour productivity and total factor productivity as measures of firm performance, they show that the impact of innovation on firm productivity varies across firm size, foreign investment and the level of technology. The relationship between innovation and productivity is stronger for high-technology firms. Using data on Thailand's manufacturing firms for the year 2017, Zhu, Qiu, et al. (2021) and Zhu, Li, et al. (2021) show that R&D plays a crucial role in boosting labour productivity.[4]

Although numerous studies have investigated the relationship between R&D and firm performance, relatively fewer studies have examined the effects of product and process innovation on firm performance. To address this gap, Waheed (2017) utilised World Bank enterprise survey data from Bangladesh covering the 2003–2006 period to investigate the impact of labour productivity on innovation in manufacturing firms. Through simultaneous equations estimation, Waheed found that process innovation plays a significant role in determining labour productivity in Bangladesh. Similarly, Nyeadi et al. (2018), using firm-level data from Ghana, report that both product and process innovations have a positive impact on productivity. Gunday et al. (2011) use data on 184 Turkish manufacturing firms to show that process, product and marketing innovations can have a positive impact on firm performance. Atalay et al. (2013) highlight the importance of innovation in firm survival and growth. They argue that innovation promotes efficiency, which can ultimately increase firm profitability. They also empirically evaluate the impact of different types on innovation on firm performance in the Turkish automotive industry. Their empirical analysis reveals that the effect of process innovation on firm productivity in Turkey is positive and statistically significant. Based on a survey of 150 high-tech firms located in two Turkish cities, Doğan and Doğan (2020) conclude that operational and financial performance of firms is affected by the speed and quality of innovation. Using data from Spain over the 2007–2016 period, Martínez-Alonso et al. (2023) examined how family involvement in management affects process innovation in family firms. They report that R&D collaboration with suppliers mediates the negative relationship, while technology protection can moderate and even turn it positive.

While distinguishing between the process and product innovation, Vivero (2012) examines the effect of process innovation on labour productivity in Spain. This study finds that impact of process innovation productivity is positive and statistically significant. Rochina-Barrachina et al. (2010) examine the effect of process innovations on total factor productivity of firms in Spain. Using survey data, which covers the 1991–1998 period, they show that process innovation is beneficial to both large and small firms. However, large firms experience a more persistent productivity increase.

Hervas-Oliver et al. (2014) investigate the impact of process innovation on growth strategy for small and medium-sized enterprises (SMEs). Their study posits that process innovation can enhance firm capabilities, leading to improved performance metrics. Based on empirical data collected from 2,412 Spanish firms, the authors demonstrate that process innovation fosters cost reduction, flexibility and capacity improvement, all of which contribute to enhanced firm performance. Furthermore, their research reveals that the effects of process innovation and product innovation strategies on firm performance differ significantly.

The present study employs an empirical approach to assess the effects of R&D, product and process innovation on firm performance in China. Notably, China's R&D expenditure as a percentage of GDP rose to 2.44 per cent in 2021 (China Daily, 2022), highlighting the significance of innovation in the country's economic landscape. In line with this, Lemus et al. (2015) posit that the institutional environment and intense competition in China foster innovation among firms. This is particularly crucial as failure to innovate can impede firms' survival and hinder their growth. Similarly, Sun and Anwar (2018) explore the determinants of innovation in China's food processing industries. Drawing on firm-level data spanning 2005–2007, their findings reveal that R&D and export intensities can positively and significantly influence product innovation in China's food processing industries.[5]

The extant literature primarily emphasises the influence of R&D on firm performance. However, the present study seeks to broaden this perspective by examining the impact of R&D, product innovation and process innovation on firm performance in China.[6] To achieve this goal, we employ a comprehensive data set from 2012, which is sourced from the World Bank Enterprise Surveys. We use the 2012 data set due to its unique characteristics, including its high level of detail and reliability. Unfortunately, comparable data for recent years are unavailable. Our work makes a novel contribution to existing literature by simultaneously considering three key aspects of innovation—R&D inputs, product innovations and process innovations.

The rest of this article is organised as follows. A brief review of economics of innovation literature is presented in Section II. The empirical model used in this article is specified in Section III. Section IV contains data description. The empirical results are presented and discussed in Section V. Section VI concludes the article.

II. Review of Related Economics of Innovation Literature

Over the years, several studies have considered the relationship between innovation, productivity and firm-level efficiency. These studies have employed different methodologies and data periods to analyse the causal relationship between R&D, innovation and productivity.

For example, Crépon et al. (1998) used a longitudinal data set of French firms from 1984 to 1990 and employed the control function approach to estimate the causal effect of R&D on firm-level productivity. Griffith et al. (2006) analysed the relationship between innovation and productivity in four European countries using firm-level data from the innovation surveys for the period of 1996–2000. Similarly, Hall et al. (2009) investigated the relationship between innovation and productivity in Italian SMEs,[7] using firm-level data from the community innovation survey for the period of 1998–2000. Using firm-level data from six Latin American countries for the period 2005–2007, Crespi and Zuniga (2012) examined the relationship between innovation and productivity. They reported a positive association that varies by across country and innovation intensity.

Most existing studies report a positive relationship between innovation and productivity, suggesting that firms that invest more in R&D are more productive. In addition, innovation activities were positively associated with export activities, contributing to higher productivity levels. However, other factors such as competition and firm-level characteristics can also influence the relationship between innovation, productivity and efficiency. Friesenbichler and Peneder (2016) investigated the impact of competition on innovation and productivity in Eastern Europe and Central Asia, using firm-level data from the Business Environment and Enterprise Performance Survey for the period of 2006–2013. They found that increased competition was associated with higher levels of innovation and productivity.

Baumann and Kritikos (2016) examined whether micro-firms experience different outcomes when it comes to innovation, productivity and R&D. They used data from the German KfW/ZEW Start-Up Panel covering the period from 2003 to 2009 and found that micro-firms experienced lower levels of productivity compared to larger firms despite investing less in R&D. Islam and Fatema (2021) conducted a comparative analysis of innovation and firm-level efficiency between China and India, using firm-level data from the World Bank Enterprise Surveys for the period of 2015–2018. They employed a stochastic frontier analysis and found that innovation was positively associated with firm-level efficiency in both countries. Bernini and Galli (2023) used Italian data over the 2011–2019 period to examine how innovation sources, both internal and external, affect the economic performance of Italian hotels. They showed that innovative activities generate both agglomeration and competition effects.

In conclusion, existing studies highlight the need to invest in R&D and innovation to improve productivity and competitiveness at the firm level. Our work expands this literature by providing a comprehensive analysis of simultaneous impact of three critical components of innovation—R&D inputs, product innovations and process innovations.

III. The Empirical Model

Conceptually, the innovation activities of a firm, comprising R&D as well as product and process innovations, can have an impact on its performance. Within the context of a knowledge production framework, R&D represents the input of the innovation activities, whereas product and process innovations represent the outputs. The effects of R&D on firm performance can be both direct and indirect. Directly, R&D can enhance productivity by reducing the marginal cost of production or by improving product quality, leading to a direct positive impact on firm performance. Indirectly, if R&D leads to the invention of new processes or products, namely product and process innovations, it can influence firm performance through its effects on these innovations.

Product innovation, as one of the outputs of innovation, is also recognised to impact firm performance. On the one hand, if newly introduced products are well-received by consumers, they can lead to increased sales, thereby positively affecting firm performance. On the other hand, the production of new products may involve higher marginal costs, which can potentially lower firm profits and hence negatively impact firm performance, ceteris paribus. The net effect of product innovation on firm performance, therefore, depends on the relative magnitude of these contrasting channels.

Similarly, with regards to process innovation, firms may adopt new processes with the intention of improving their performance. If these new processes prove to be effective, they can positively impact firm performance. However, if these new processes fail to deliver expected results, then firm performance may suffer as a consequence.

Given the theoretical connections between innovation and firm performance, we employ an empirical model to assess the effects of R&D, product and process innovations on firm performance in China. The model is specified as follows:

$$y_i = \beta_0 + \beta_1 IN1_i + \beta_2 IN2_i + \beta_3 RD_i + X_i \beta_4 + \varepsilon_i$$

where y is the firm performance (measured by sales revenue and sales revenue per full-time permanent employee); *IN1* is product innovation; *IN2* is process innovation; *RD* is the firm R&D; X is a set of control variables that include the firm size, corruption, financial constraints (*FC*) and the number of competitors;

and, ε is the error term that captures the impact of other factors that affect firm performance.

The variable definitions and data sources are identified in Table 1. In this article, we use two alternative measures of firm performance: (a) Sales revenue and (b) sales revenue per full-time permanent employee. Later in our empirical estimation, as a robustness check, we also include the share of the sale of new products or services (*IN1s*) in total sales and the share of production volume associated with the new/improved processes (*IN2s*) in total production volume, respectively, to measure product and process innovation.

The set of control variables include the firm size, corruption, *FC* and the number of competitors. As described in Table 1, firm size is measured by the number of full-time permanent employees 3 fiscal years ago (i.e., at the end of the fiscal year 2009). Not surprisingly, larger firms tend to have higher sales revenue, and these firms are also likely to have higher productivity (as measured by the sales revenue per employee). The level of corruption is dummy variable, constructed from the response of the firm to the survey question 'to what degree is corruption an obstacle to the current operations of this establishment?' The response to this question ranges between 0 (no obstacle) and 4 (very severe obstacle), which captures the impact of business environment on firm performance. If corruption becomes a big obstacle, then the performance of the firm is expected to decline.

FC are likely to have a negative impact on financial performance of firms. *FC* limit the ability of firms to allocate resources to initiatives, which may improve the firm performance. We measure *FC* by a dummy variable constructed from the response of firm to the survey question 'to what degree is access to finance an obstacle to the current operations of this establishment?' A value of 0 indicates no financial obstacle, and 4 indicates severe obstacle. The number of competitors is a dummy variable, which takes a value of 1 if the firm reports that the number of its competitors is too many to count; 0 otherwise. This variable is a proxy for the degree of competition in the market. In the short run, the competition may have a negative effect on firm performance. However, in the long run, on average, competition may improve the firm performance. Market competition, which drives less capable firms out of the market, provides an incentive to the firms to improve their productivity and perform well.

IV. The Data

The data set is a cross-sectional firm survey sourced from the World Bank Enterprise Surveys.[8] The data are collected by the World Bank survey team in China between December 2011 and February 2013, where all survey questions refer to the last complete fiscal year of 2011. The survey covers 2,700 privately-owned enterprises, which, due to missing values for some explanatory variables, are not fully used in our estimation.[9] The World Bank survey is based on a stratified random sample. The survey involves three levels of stratification: (a)

Table 1. Definitions of Variables.

Variable	Definition
y1	Total sales revenue
y2	Sales revenue per full-time permanent employee
IN1	Dummy variable, equal to 1 if in the last 3 years an establishment introduced any new products or services
IN2	Dummy variable, equal to 1 if in fiscal year 2011, an establishment has annual production volume associated with new or improved processes introduced over the last 3 years
IN1s	Percent of annual sales accounted for by new products or services
IN2s	Percent of production volume associated with new/improved processes
RD	Dummy variable, equal to 1 if in the last 3 years an establishment spend on R&D activities within the establishment
Employees	The number of full-time permanent employees in the establishment 3 fiscal years ago (at the end of fiscal year 2009)
Corruption	Dummy variable, constructed from a firm's response to 'to what degree is corruption an obstacle to the current operations of this establishment?' (0 being no obstacle and 4 denoting very severe obstacle). This variable takes a value of 1 if the firm's response is 2–4 and 0 if the firm's response is 0–1
FC	Financial constraints, constructed from a firm's response to 'to what degree is access to finance an obstacle to the current operations of this establishment?' (0 being no obstacle and 4 denoting severe obstacles). This variable takes a value of 1 if the firm's response is 2–4 and 0 if the firm's response is 0–1
IsComp	Dummy variable, takes a value of 1 if a firm reports that the number of competitors is too many to count

Notes: *y1* is firm sales, *y2* is firm sales per full-time employees, *IN1* and *IN2* are measures of product and process innovation respectively, *IN1s* and *IN2s* are alternative measures of product and process innovation respectively, *RD* is R&D, *FC* is financial constraints, *IsComp* is the presence of a large number of competitors.

The industry, (b) establishment size and (c) the region. The details of the sampling procedure are provided by the World Bank on their website (please refer to the World Bank Enterprise Surveys section).

Table 2 reports the summary statistics of the dependent and explanatory variables. The summary statistics exhibit substantial variations. For example, for the range of the sales revenue (in natural logarithm) is close to 20, and the standard deviation is around 10 per cent of the sample mean. For product innovation, around 47 per cent of the enterprises surveyed reported that they had product innovation in the last 3 fiscal years, and on average around 11 per cent of the sales revenue was associated with new products/services. The surveyed enterprises appear to have more process innovation than product innovation, with about 96 per cent reporting process innovation (2,603 out of 2,700 enterprises). On average,

Table 2. Summary Statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
ln(*y*1)	2,694	16.6726	1.7345	4.6052	24.4122
ln(*y*2)	2,693	12.5199	1.1836	–2.5649	19.5193
IN1	2,692	0.4681			
IN2	2,700	0.9641			
IN1s	2,692	0.1116	0.1821	0	1
IN2s	1,683	0.1442	0.1773	0	1
RD	1,679	0.4127			
ln(Employees)	2,620	3.9703	1.3855	0.6931	10.23996
Corruption	2,700	0.0641			
FC	2,700	0. 2052			
IsComp	1,326	0.8356			

Notes: *y*1 is firm sales, *y*2 is firm sales per full-time employees, *IN1* and *IN2* are measures of product and process innovation respectively, *IN1s* and *IN2s* are alternative measures of product and process innovation respectively, *RD* is R&D, *FC* is financial constraints, *IsComp* is the presence of a large number of competitors.

around 14 per cent of their production volume is associated with new/improved processes. R&D activities appear to be prevalent as well, with about 41 per cent reporting that they participated in R&D activities in the last 3 fiscal years.

Enterprises appear to operate in a very competitive environment, with close to 84 per cent (out of 1,326 enterprises) reporting that their competitors are too many to count. Corruption (*Corruption*) and *FC* are dummy variables constructed from categorical variables taking integer values between 0 and 4, where 0 represents no obstacles and 4 represents severe obstacles. It appears that, on average, the enterprises surveyed did not face significant *FC*. Also, corruption was also not found to be a concern. For *FC*, 43.3 per cent of enterprises reported that access to finance was not an obstacle to them, while only 18 enterprises reported that severe financial obstacles (0.67 per cent). For corruption, only seven enterprises (0.26 per cent) report that corruption is a very severe obstacle.

Table 3 presents the correlation matrix of the explanatory variables. Pairwise linear correlations between the explanatory variables are generally low, suggesting that multicollinearity may not be a concern. The highest correlation is 0.67 between *IN1* and *IN1s*, which is not surprising as both of these variables are alternative measures product innovation.

V. Empirical Results

We start by discussing the strategy used to deal with possible endogeneity of R&D, product and process innovation in Section 'Endogeneity of the Explanatory Variables'. Specifically, we use the ways that R&D and innovations are conducted

Table 3. Pairwise Correlation Matrix.

	IN1	*IN2*	*IN1s*	*IN2s*	*RD*	*ln(Employees)*	*IsComp*	*Corruption*	*FC*
IN1	1								
IN2	0.1694*	1							
IN1s	0.6535*	0.1098*	1						
IN2s	0.2971*	0.2012*	0.4331*	1					
RD	0.5086*	0.2024*	0.3986*	0.2877*	1				
ln(Employees)	0.0985*	–0.0356	0.0473*	0.1162*	0.2098*	1			
IsComp	–0.0880*	–0.1059*	–0.1494*	–0.1746*	–0.1702*	–0.0316	1		
Corruption	0.0487*	0.0424*	0.026	0.0086	0.0599*	0.015	–0.0194	1	
FC	0.0758*	0.0833*	0.0287	0.0147	0.1349*	–0.0087	0.0327	0.1142*	1.0000

Notes: * denotes significance at the 5 per cent level. *y1* is firm sales, *y2* is firm sales per full-time employees, *IN1* is product innovation, *IN2* is process innovation, *RD* is R&D, *FC* is financial constraints, *IsComp* is the presence of a large number of competitors.

as excluded instruments and find no evidence of endogeneity. In Section 'Estimation Results', we present the model estimation results, where the product and process innovations, respectively, are measured by dummy variables *IN1* and *IN2*. In Section 'Robustness Check', we check robustness of our results by using alternative measures of product and process innovations (*IN1s* and *IN2s*). Furthermore, we also (a) separately estimate our regression equation for SMEs and large firms, and (b) estimate a structural model of R&D, innovation and firm performance.

Endogeneity of the Explanatory Variables

In Equation (1), the firm size is a 3-year lagged variable (i.e., the number of full-time permanent employees 3 fiscal years ago; fiscal year 2009). Given that we are using a 3-year lag, it is reasonable to assume that this variable is uncorrelated with the error term. The level of corruption (*Corruption*) and the number of competitors (*IsComp*) capture the environment in which firms operate. Given that firms are small relative to the market/economy, we do not expect significant reverse causality from firm performance to the level of corruption and the number of competitors. In other words, it is reasonable to assume that these two variables are exogenous.

FC are likely to be endogenous. Conceptually, on the one hand, a firm with *FC* has more limited scope to allocate its scarce resources, which can negatively affect its performance. On the other hand, a better-performing firm is more likely to have better access to finance. To address the possible endogeneity, we use a dummy variable that takes a value of 1 if a firm's annual financial statements is checked and certified by an external auditor in the fiscal year 2011; 0 otherwise. Whether the financial statements are checked and certified externally affects the ability to access finance. In addition, external checking and certification of financial statements cannot directly affect the financial performance of a firm.[10]

The R&D, product and process innovations are also likely to be endogenous. On the one hand, these factors can affect (improve or decrease) firm performance. On the other hand, a better-performing firm is more likely to engage in R&D and product and process innovations. To address the endogeneity issue, we assume that the way R&D and product and process innovations are conducted does not affect the firm performance directly[11] and use them as excluded instruments in our regressions. For R&D, the excluded instrument is a dummy variable that takes a value of 1 if the firm spends on R&D activities that are contracted with other companies in the last 3 years. For product and process innovations, the excluded instruments are a set of eight dummy variables (four for each variable) that take a value of 1 if the product/process innovation is developed/adapted in-house, developed in cooperation with suppliers, developed in cooperation with client firms and introduced by using own version of a product already supplied by another firm (i.e., the licensed technology or process from another firm).

Using the excluded instruments, we apply the limited information maximum likelihood (LIML) estimator, which is more robust in the presence of weak instruments. We also check for the relevance (correlation between instruments and endogenous variables) and validity (no correlation between instruments and error term) of the instruments by utilising the under-identification and over-identification tests. Furthermore, we implement an endogeneity test to check whether the endogenous explanatory variables are indeed endogenous.

When the dependent variable is sales revenue (in natural logarithms), the Kleibergen-Paap rk *LM* test of under-identification yields the statistic of 28.562, with a *p* value of .0002. As the *p* value is low, we reject the null hypothesis of under-identification with a high degree of confidence. Hence, the excluded instruments are relevant. Hansen's over-identification test yields the *J* statistic of 1.732, with a *p* value of .9426. Based on the high *p* value, we cannot reject the null hypothesis that the instruments are valid, and the excluded instruments are correctly excluded from the estimated equation. The endogeneity test obtains the χ^2 statistic of 2.102, with a *p* value of .5515. Owing to the high *p* value, we cannot reject the null hypothesis that the regressors can be treated as exogenous.

When the dependent variable is sales revenue per full-time permanent employee, the situation is similar. The Kleibergen-Paap rk *LM* test yields a statistic of 28.562 (*p* value of .0002). The Hansen *J* test yields a statistic of 1.995 (*p* value of .9202), and the χ^2 test statistic is 1.334 (*p* value of .721). Based on these results, the explanatory variables can be treated as exogenous. The estimated results using the alternative dependent variables are presented in Sections 'Estimation Results and Robustness Check'. We use the ordinary least squares and assume exogeneity of explanatory variables.

Estimation Results

The model estimation results, when logarithm of firm sales is used as the dependent variable (i.e., a measure of firm performance), are reported in Table 4. Empirical results suggest that the impact of product innovation on firm sales is not statistically significant. It can be argued that product innovation, which contributes to increase in firm sales, leads to product substitution. It seems that introduction of new products leads to decrease in sales of other products, and hence the firm sales do not change much. However, process innovation can have a positive and statistically significant effect on firm sales. Firms that conduct R&D experience a 0.351–0.927 per cent increase in sales, and this effect is statistically significant. Firm size has a positive effect on firm sales. Presence of large number of competitors reduces firm sales, but this effect is significant only at the 10 per cent level. Level of corruption and the presence of *FC* do not appear to have a significant impact on firm sales.

We now consider the estimation results when sales per full-time employee is used as the dependent variable. The estimation results are shown in Table 5. Results presented in columns 3–5 suggest that product innovation can have a negative impact on sales per full-time employee, which is significant at the 5 per cent level in the full model (see column 6). It seems that introduction of the new products increases the marginal cost of production, resulting in a reduction in the sales revenue per full-time employee. Like in Table 4, the impact of process innovation and R&D activities on sales per full-time employee is positive and statistically significant. The estimated results suggest that R&D can increase sales

Table 4. Regression Results for Sales Revenue.

Variables	(1)	(2)	(3)	(4)	(5)
IN1	0.134	–0.0347	–0.0843	–0.0838	–0.0874
	(0.0892)	(0.0608)	(0.0669)	(0.0669)	(0.0670)
IN2	0.112	0.326**	0.350**	0.341**	0.359**
	(0.175)	(0.147)	(0.155)	(0.155)	(0.156)
RD	0.927***	0.461***	0.357***	0.351***	0.363***
	(0.0912)	(0.0621)	(0.0694)	(0.0697)	(0.0714)
ln(Employees)		0.920***	0.925***	0.925***	0.923***
		(0.0238)	(0.0272)	(0.0271)	(0.0271)
IsComp			–0.171*	–0.171*	–0.163*
			(0.0893)	(0.0892)	(0.0900)
Corruption				0.201	0.212
				(0.138)	(0.138)
FC					–0.103
					(0.0711)
Constant	16.35***	12.49***	12.65***	12.65***	12.65***
	(0.167)	(0.173)	(0.205)	(0.205)	(0.205)
Observations	1,675	1,633	1,289	1,289	1,289
R-squared	0.091	0.591	0.584	0.585	0.585

Notes: Robust standard errors in parentheses; ***, **, and *, respectively, represent significance at less than 1 per cent, 5 per cent and 10 per cent. *IN1* is product innovation, *IN2* is process innovation, *RD* is R&D, *FC* is financial constraints, *IsComp* is the presence of a large number of competitors. Logarithm of firm sales is the dependent variable.

per full-time employee by 0.302–0.413 per cent. An increase in the number of competitors decreases sales per full-time employee, but this effect is not highly significant. Corruption and *FC* do not seem to affect the sales per full-time employee at the 5 per cent significance level.

Based on the results presented in Tables 4 and 5, it can be argued that product innovation does not contribute to improvement in firm performance. However, process innovation and R&D do make a positive contribution to the performance of Chinese firms. We now consider the robustness of our empirical results.

Robustness Check

To check the robustness of our results, we (a) use alternative measures of product and process innovation, (b) separately estimate the model for SMEs and large firms and (c) estimate a structural model of R&D, innovation and firm performance.

Table 5. Regression Results for Sales Revenue per Permanent Full-time Employee.

Variables	(1)	(2)	(3)	(4)	(5)
IN1	–0.0872	–0.0802	–0.138**	–0.137**	–0.140**
	(0.0576)	(0.0583)	(0.0641)	(0.0640)	(0.0642)
IN2	0.360**	0.336**	0.388**	0.377**	0.389**
	(0.151)	(0.151)	(0.158)	(0.158)	(0.159)
RD	0.400***	0.413***	0.309***	0.302***	0.310***
	(0.0586)	(0.0597)	(0.0668)	(0.0671)	(0.0685)
ln(Employees)		–0.0315	–0.0268	–0.0266	–0.0278
		(0.0230)	(0.0265)	(0.0265)	(0.0265)
IsComp			–0.144*	–0.144*	–0.139
			(0.0844)	(0.0842)	(0.0850)
Corruption				0.237*	0.245*
				(0.136)	(0.136)
FC					–0.0683
					(0.0689)
Constant	12.00***	12.14***	12.26***	12.26***	12.26***
	(0.148)	(0.174)	(0.206)	(0.206)	(0.205)
Observations	1,675	1,633	1,289	1,289	1,289
R-squared	0.041	0.041	0.033	0.036	0.037

Notes: Robust standard errors in parentheses; ***, **, and *, respectively, represent significance at less than 1 per cent, 5 per cent and 10 per cent. *IN1* is product innovation, *IN2* is process innovation, *RD* is R&D, *FC* is financial constraints, *IsComp* is the presence of a large number of competitors. Logarithm of firm sales per full-time employee is the dependent variable.

Empirical results presented in Table 6 show that product innovation has a negative impact on firm sales, and this effect is highly significant, which is different from the results presented in Table 4. In Table 6, we use the share of the sale of new products and/or services in total sales as a proxy for product innovation. This result suggests the presence of strong substitution effect where introduction of new goods and/or services leads to a relatively large decrease in demand for existing goods and/or services. It seems that the estimated result concerning the impact of product innovation on firm sales in Table 4 is not robust. Alternatively, it can also be argued that the share of the sales of new products and/or services in total sales is a better measure of product innovation. When we use the share of production volume associated with the new or improved process in total production as an alternative measure of process innovation, we find that the impact of process innovation on firm sales is statistically insignificant, which is very different from the results reported in Table 4. This result suggests that our earlier result, that process innovation improves firm performance as measured by firm sales, is not robust.

Table 6. Regression Results for Sales Revenue.

Variables	(1)	(2)	(3)	(4)	(5)
IN1s	–0.477*	–0.389**	–0.446**	–0.440**	–0.454**
	(0.251)	(0.181)	(0.204)	(0.203)	(0.203)
IN2s	0.554**	0.195	–0.0444	–0.0478	–0.0398
	(0.261)	(0.175)	(0.201)	(0.201)	(0.200)
RD	1.024***	0.513***	0.424***	0.416***	0.427***
	(0.0870)	(0.0582)	(0.0661)	(0.0666)	(0.0683)
ln(Employees)		0.915***	0.921***	0.921***	0.919***
		(0.0240)	(0.0276)	(0.0276)	(0.0276)
IsComp			–0.208**	–0.207**	–0.201**
			(0.0898)	(0.0896)	(0.0903)
Corruption				0.213	0.224
				(0.142)	(0.142)
FC					–0.0883
					(0.0700)
Constant	16.44***	12.80***	13.01***	13.00***	13.02***
	(0.0546)	(0.101)	(0.143)	(0.143)	(0.143)
Observations	1,668	1,626	1,286	1,286	1,286
R-squared	0.094	0.590	0.583	0.584	0.585

Notes: Robust standard errors in parentheses; ***, **, and *, respectively, represent significance at less than 1 per cent, 5 per cent and 10 per cent. *IN1* is product innovation, *IN2* is process innovation, *RD* is R&D, *FC* is financial constraints, *IsComp* is the presence of a large number of competitors. Logarithm of firm sales is the dependent variable.

We now turn our attention to the effect on sales per full-time employee. The empirical results presented in Table 7 show that when alternative measures of product and process innovations are used, product innovation has a negative and highly significant impact on sales per full-time employee. However, the effect of process innovation on sales per full-time employee is statistically insignificant. We therefore conclude that our earlier result, that product innovation generates a strong negative substitution effect, is robust, but the effect of process innovation on sales per full-time employee reported in Table 5 is not robust.

Table 8 reports the estimation results by firm scale (SMEs and large firms). Estimation results show that the effects of product and process innovations are statistically significant for SMEs but not for large firms, which highlights the role of innovation for SMEs. R&D appears to exert a significantly positive effect, irrespective of the firm scale. For the other control variables, the point estimates of their coefficients exhibit variations but are largely consistent with expectations.

Table 7. Regression Results for Sales Revenue per Permanent Full-time Employee.

Variables	(1)	(2)	(3)	(4)	(5)
IN1s	–0.411**	–0.424**	–0.521***	–0.513***	–0.522***
	(0.171)	(0.173)	(0.195)	(0.195)	(0.195)
IN2s	0.0363	0.107	–0.0927	–0.0967	–0.0920
	(0.165)	(0.167)	(0.193)	(0.193)	(0.193)
RD	0.447***	0.458***	0.370***	0.360***	0.367***
	(0.0546)	(0.0560)	(0.0634)	(0.0638)	(0.0653)
ln(Employees)		–0.0365	–0.0317	–0.0312	–0.0323
		(0.0233)	(0.0271)	(0.0271)	(0.0271)
IsComp			–0.188**	–0.187**	–0.184**
			(0.0848)	(0.0845)	(0.0852)
Corruption				0.251*	0.257*
				(0.139)	(0.139)
FC					–0.0513
					(0.0678)
Constant	12.32***	12.46***	12.66***	12.65***	12.66***
	(0.0368)	(0.0980)	(0.139)	(0.139)	(0.138)
Observations	1,668	1,626	1,286	1,286	1,286
R-squared	0.038	0.039	0.031	0.034	0.034

Notes: Robust standard errors in parentheses; ***, **, and *, respectively, represent significance at less than 1 per cent, 5 per cent and 10 per cent. *IN1* is product innovation, *IN2* is process innovation, *RD* is R&D, *FC* is financial constraints, *IsComp* is the presence of a large number of competitors. Logarithm of firm sales per full-time employee is the dependent variable.

It is likely that our estimations with excluded instrumental variables are subject to the problem of weak instruments, which is a limitation of this study. To address this concern, we employ a structural model of R&D, innovation and firm performance, following the approach of Crépon et al. (1998). In this model, R&D is a linear function of the number of full-time permanent employees, competition and *FC*, while product and process innovations are linear functions of R&D, the number of full-time permanent employees, competition and *FC*. Furthermore, firm performance (measured by sales and sales per full-time permanent employee) is a linear function of R&D, product and process innovations, the number of full-time permanent employees, competition, *FC* and corruption. We estimate the model using Zellner's seemingly unrelated regression method and present the estimation results in Table 9.

The coefficient estimates for R&D, product and process innovations and other variables align consistently with those presented in Tables 4 and 5. Specifically, the point estimates of coefficients in column 4 of Table 9 mirror those in column 5 of Table 4, albeit with slightly varied standard errors. Likewise, column 5 of

Table 8. Estimation by Firm Scale.

	SMEs		Large Firms	
Variables	[1]	[2]	[1]	[2]
IN1	–0.139*	–0.187**	0.0103	–0.0498
	(0.0782)	(0.0760)	(0.126)	(0.118)
IN2	0.363**	0.399**	0.380	0.378
	(0.174)	(0.182)	(0.297)	(0.301)
RD	0.306***	0.242***	0.486***	0.453***
	(0.0841)	(0.0815)	(0.132)	(0.125)
ln(Employees)	0.831***	–0.0873**	0.979***	0.0277
	(0.0373)	(0.0367)	(0.0617)	(0.0605)
IsComp	–0.0723	–0.0444	–0.315**	–0.299**
	(0.113)	(0.107)	(0.142)	(0.137)
Corruption	0.299*	0.304*	0.0782	0.161
	(0.162)	(0.160)	(0.254)	(0.251)
FC	–0.185**	–0.138*	0.0451	0.0696
	(0.0823)	(0.0795)	(0.135)	(0.132)
Constant	12.92***	12.42***	12.41***	12.02***
	(0.243)	(0.245)	(0.448)	(0.448)
Observations	887	887	402	402
R-squared	0.433	0.033	0.518	0.083

Notes: [1]: Sales revenue; [2]: Sales revenue per full-time employee; robust standard errors in parentheses; ***, **, and *, respectively, represent significance at less than 1 per cent, 5 per cent and 10 per cent. *IN1* is product innovation, *IN2* is process innovation, *RD* is R&D, *FC* is financial constraints, *IsComp* is the presence of a large number of competitors.

Table 9 corresponds to column 5 of Table 5, with minor discrepancies in standard errors. Consequently, the results demonstrate robustness to the alternative estimation method.

In the equations for R&D, product and process innovation, the coefficient estimates generally appear reasonable, except for the coefficient of *FC*. Notably, this coefficient exhibits a surprisingly significant positive value in the R&D and process innovation equations.

VI. Concluding Remarks

Innovation plays a critical role in fostering economic growth. R&D is an essential input into the innovation process, which enhances firm productivity. Additionally, product and process innovations represent the outputs of the innovation process and can substantially improve firms' productivity. However, the vast majority of

Table 9. Alternative Estimations.

	(1)	(2)	(3)	(4)	(5)
Variables	*RD*	*IN1*	*IN2*	lny1	lny2
IN1				–0.0874	–0.140**
				(0.0691)	(0.0671)
IN2				0.359***	0.389***
				(0.120)	(0.117)
RD		0.492***	0.111***	0.363***	0.310***
		(0.0258)	(0.0148)	(0.0719)	(0.0698)
ln(Employees)	0.0804***	0.0179*	–0.00948*	0.923***	–0.0278
	(0.0100)	(0.00949)	(0.00545)	(0.0233)	(0.0226)
IsComp	–0.221***	–0.00723	–0.0529***	–0.163**	–0.139*
	(0.0352)	(0.0330)	(0.0190)	(0.0811)	(0.0787)
Corruption				0.212	0.245*
				(0.132)	(0.128)
FC	0.168***	–0.0214	0.0645***	–0.103	–0.0683
	(0.0321)	(0.0300)	(0.0172)	(0.0741)	(0.0719)
Constant	0.216***	0.194***	0.954***	12.65***	12.26***
	(0.0540)	(0.0503)	(0.0289)	(0.167)	(0.162)
Observa-tions	1,289	1,289	1,289	1,289	1,289
R-squared	0.091	0.246	0.070	0.585	0.037

Notes: (4) lny1: Sales revenue; (5) lny2: Sales revenue per full-time employee; robust standard errors in parentheses; ***, **, and *, respectively, represent significance at less than 1 per cent, 5 per cent and 10 per cent. *IN1* is product innovation, *IN2* is process innovation, *RD* is R&D, *FC* is financial constraints, *IsComp* is the presence of a large number of competitors.

existing research focuses on the impact of R&D on firms' performance in various industries.

This study employs cross-sectional survey data from China to examine the impact of R&D, product innovation and process innovation on firm performance, as measured by sales or sales per full-time employees. We conduct endogeneity tests on R&D, product and process innovations. After establishing the exogeneity of the regressors, we find that R&D has a positive and statistically significant impact on both sales and sales per full-time employees of Chinese firms.

Conversely, product innovation seems to generate a negative substitution effect, offsetting the increase in sales of new products and/or services, resulting in an overall negative impact on firm performance. Regarding the impact of process innovation on firm performance, we do not find a robust result. We observe that process innovation improves firm performance when a dummy variable is used to capture it. However, when the output volume share of products associated with new processes in total output volume is employed as a proxy for process innovation, the impact on firm performance is statistically insignificant. Additionally, corruption and *FC* do not have a statistically significant effect on firm sales or sales per full-time employee.

The findings of this study have significant implications for policymakers and practitioners seeking to understand the role of innovation in economic growth and the factors that impact firm performance. Despite several data availability-related limitations, this article adds a unique perspective to the existing literature by comprehensively examining three critical components of innovation—R&D inputs, product innovations and process innovations—concurrently. Our study also presents an opportunity for future research using more recent firm-level panel data (when available) to gain additional insights. It is essential to note that the results presented in this article are based on cross-sectional data, which suffers from the problem of weak instruments that do not allow for new insights.

Acknowledgements

This article has greatly benefitted from very helpful comments and suggestions received from two anonymous reviewers. However, the authors are responsible for all remaining errors and/or imperfections.

Declaration of Conflicting Interests

The authors declared no conflict of interest with respect to the research, authorship and/or publication of this article.

Funding

The authors received no financial support for the research, authorship and/or publication of this article.

Notes

1. For example, Pece et al. (2015), among others, show that innovation can contribute to economic growth. Using the China Industrial Enterprises Data over the 2006–2016 period and employing the GMM methodology, Zhu, Qiu, et al. (2021) and Zhu, Li, et al. (2021) investigate the impact of information and communication technology (ICT) and R&D on firm-level productivity in China. The authors find that both ICT and R&D have a positive and significant impact on firm-level productivity in China.
2. R&D spending can also be regarded as an input into the innovation process, whereas product and process innovations can be viewed as output dimensions of innovation. See Sun and Anwar (2018) and references therein.
3. The literature that deals with the impact of R&D on firm performance and economic growth is very large, and hence in this article, we only refer to a small number of studies.
4. Zhu, Qiu, et al. (2021) and Zhu, Li, et al. (2021) show that innovation stimulates employment in China.

5. The empirical work of Charoenrat and Amornkitvikai (2021) suggests that R&D also affects the export intensity of Chinese firms.
6. Using data set collected from the China Industrial Enterprises Database over the 1998–2007 period, Dai and Cheng (2018) examined the relationship between product innovation and firm-level markup and productivity in China. They find that firms with higher levels of product innovation tend to have higher markups and productivity, which implies that product innovation can lead to higher profitability and competitiveness.
7. Using data from World Bank innovation survey 2014 and World Bank enterprise survey (WBES) 2014 for India, Islam (2022) showed that service and process innovation have a significant effect on a firm's financial and nonfinancial performance, while marketing and organisational innovation take longer to contribute. No synergy effects were found, and there were distinctions between small and medium-sized and large firms.
8. Details can be found at http://www.enterprisesurveys.org/.
9. The data set also covers 148 state-owned enterprises, which are not used in this study.
10. There will, of course, be an indirect effect through access to finance.
11. Note they still affect firm performance indirectly via R&D, product and process innovations.

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