



# Empirical Determinants of Research and Development (R&D) Investment in Chinese Manufacturing Companies

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## Abstract

**Background and Aim:** As manufacturing enters the fourth industrial revolution, R&D investments help in converting new ideas into innovative products and services. Manufacturing firms rely on R&D projects to improve product quality, increase productivity, reduce waste, and enhance operational efficiency. This study examined the empirical determinants of Research and Development (R&D) investment in Chinese manufacturing companies.

**Materials and Methods:** Data was obtained from the Oriana database, which keeps updated records regarding R&D investments across Southeast Asia. The database provides information about key R&D drivers and resources that companies are willing to invest as percentages of their revenues. A systematic analysis of data was used to identify the key determinants and their impact on R&D decisions and intensity. The FE model equations were used for calculating correlational relationships among variables.

**Results:** The study found that key determinants associated with R&D decisions and intensity include firm size, market power, demand-pull, technology opportunity, and appropriability. Technology opportunity and demand-pull had the strongest influence on R&D decisions and intensity. Firm size also showed a significant influence on research intensity and development decisions. However, market power showed limited impact on both R&D decisions and intensity.

**Conclusion:** Technology opportunity and demand-pull are the key determinants of Research and Development (R&D) investment in Chinese manufacturing companies.

**Keywords:** Industry 4.0; Research and Development; Manufacturing Firms; Technology Opportunity

## Introduction

Research and Development (R&D) programs drive organizational success by combining knowledge from various scientific sources into new ideas and products. R&D investments help organizations become more inventive and competitive (Wang et al., 2020). Innovative companies rely on research to improve processes, create new products, and solve operational challenges (Xu & Sim, 2018). Studies have shown how R&D investments assist organizations in identifying growth areas and creating new markets for their products (Shi & Wu, 2017). It is also difficult for firms to compete effectively without investing significant portions of their revenue in improving their products and services. Nearly 80 percent of manufacturing firms in China spend more than 10 percent of their revenue on Research and Development (Luan et al., 2019). However, the investment largely depends on the product life cycle. Yang et al. (2020) found that R&D as a percentage of revenue tends to decline as products become more mature. Besides, the demand for a product determines how much an organization is willing to invest in its R&D programs.

The main factors that drive investments in research and development include firm size, market power, technology opportunity, and demand-pull (Yang et al., 2020). This essay investigates how these factors determine research and development in both small and large organizations. For instance, the firm size mostly determines the amount of investment in R&D, where large firms are more likely to commit more resources while smaller firms are likely to invest very little (Shi & Wu, 2017). The need to take advantage of new technologies may also determine a firm's willingness to put more resources into R&D (Wang et al., 2020). Failure to take advantage of new opportunities is likely to make firms less competitive and may give better advantages to the competitors.

This study primarily aims to identify specific factors that determine R&D investments in Chinese manufacturing companies. Significant literature on R&D determinants has primarily focused on the two factors, giving minimal attention to other factors. The two factors include the size of the organization and market power (Xu & Sim, 2018). The greater part of the Schumpeterian hypothesis examines how firm size and market power drive R&D investment decisions (Wang et al., 2020). The Schumpeterian hypothesis argues that a large firm size enhances R&D investment decisions, making them more innovative than small firms (Zhou & Song, 2016). However, the Schumpeterian argument ignores other factors that greatly influence R&D decisions. There is a need for greater focus on factors



that have not been prioritized in the previous literature. Apart from the firm size and market power, the remaining factors addressed extensively in this study include demand-pull, technological opportunity, and appropriability. These factors are discussed among the potential challenges that may delay or diminish opportunities for R&D investments.

## Objectives

The main objective of this study is to investigate and explain key determinants of Research and Development investments in manufacturing firms. The other key objectives include:

- Investigating the empirical determinants of Research and Development (R&D) investment in Chinese manufacturing companies.
- Identifying a firm's Research and Development (R&D) investments about their revenue and profitability.
- Evaluating the effectiveness of each factor on a firm's R&D decisions and other long-term investment objectives.
- Identifying the effectiveness of Research and Development investments among Chinese manufacturing firms.
- Identifying challenges that may prevent organizations from investing significant percentages of their revenue in Research and Development.

## Literature Review

As manufacturing enters Industry 4.0, automation has become a major point of differentiation among competing firms. Investment in R&D enables manufacturing firms to gain advantages that set them apart from their rivals. Xu & Sim (2018) argue that the greatest beneficiaries of R&D have been large manufacturing firms with significant revenue and workforce to support their research and development goals. In China, major manufacturing firms across the country invest more than 13% of their revenue in R&D (Luan et al., 2019). The primary aim of such investments is to gain key competitive advantages and minimize pressure from their rivals (Alam et al., 2019; Zhou & Song, 2016). However, most small firms have limited revenue to spare for R&D initiatives. Compared to larger manufacturing firms, most small firms can invest about 5% of the revenue to support various R&D objectives (Yang et al., 2020). This, according to Zhang et al. (2020), is too little to make a significant impact or bring them closer to their larger competitors.

The R&D research indicates four benefits to large and small manufacturing firms in line with the fourth industrial revolution, commonly referred to as Industry 4.0. The main benefits include process automation, product quality, operational efficiency, and productivity (Zhang et al., 2020). Unlike previous manufacturing, modern production is highly dependent on technology for enhanced productivity and operational efficiency. According to Wang et al. (2020), businesses begin by assessing their operations to identify key challenges they can solve through automation. Motor vehicle manufacturers such as BYD rely on process automation to eliminate excessive paperwork, manual operations, and human errors (Yang et al., 2020). BYD believes that investing in process automation also enhances the chances of developing electric vehicles to compete with major players such as Tesla Motors based in the United States of America (Seenaiyah & Rath, 2018). Technology enables manufacturers to become more efficient in their productions, reduce material waste, and minimize their carbon footprints. Xu & Sim (2018) argue that even small-scale manufacturers in China cannot meet their business objectives without incorporating technology into their operations.

However, R&D is more than just research and new product development. It is an opportunity to demonstrate strength, consistency, and ability to solve modern problems (Bai et al., 2019). Unlike the past, Luan et al. (2019) argue that modern businesses exist for reasons beyond profits and earnings. Modern manufacturers operate under higher expectations than the previous organizations (Zhou & Song, 2016). Apart from generating profits, businesses have to think about the impact of their operations on the environment and the surrounding communities. For businesses to become sustainable, they have to examine the impact of their operations on the people, the planet, and profits (Min et al., 2020; Anwar & Sun, 2013). Research and development help businesses to become sustainable in their operations. This includes identifying suitable materials and strategies to replace plastics and fossil fuels along their supply chains (Wang et al., 2020). Apart from replacing potential polluters, businesses also rely on R&D to recycle their materials and minimize pressure on natural resources.



This study considers R&D investments as a major driver of business and industrial success (Wu et al., 2020). Although China is among the global economic giants, its manufacturing has been largely accused of copying the West and doing little to drive innovation (Bai et al., 2019). Chinese manufacturing firms have been accused of copying Western R&D blueprints. For instance, Baidu, Tencent, and Xiaomi have long been criticized for copying Western internet firms, including the development of smartphones that look similar to Apple Company's products. Wu et al. (2020) argue that identifying the purpose of R&D not only assists in reducing costs but can make organizations more efficient and innovative. The determinants of R&D explain the purpose of investment and contributions towards organizational uniqueness and success (Shi & Wu, 2017). Information from this study may help the Chinese manufacturing industry to improve R&D investments and stay ahead of the Western economic giants (Xu & Sim, 2018). If China must take its place as the global economic powerhouse, it has to make its manufacturing more effective and technology-driven.

To avoid issues such as intellectual property concerns, most Chinese manufacturers are transforming their operations using research and development. However, it is difficult for firms to succeed in R&D without a competent workforce (Wang et al., 2020). The first step towards succeeding in R&D is hiring competent staff with sufficient experience in technology. More than 90% of China's listed companies have a collective 3.08 million researchers and other employees working in R&D (Nikkei Asia, 2023). Some organizations have more than 15% of their workforce working in R&D. Jiangsu Shemar, for instance, has more than 216 employees working in R&D, accounting for more than 14% of their workforce (Nikkei Asia, 2023). China's automaker BYD has the biggest R&D team, consisting of more than 69,690 employees (Nikkei Asia, 2023). At least 590 employees working in the BYD's R&D team have doctorate degrees, while over 7,800 have master's degrees (Nikkei Asia, 2023). This indicates how competency and experience are major considerations that organizations should make when developing an effective R&D team.

The main gap identified in the existing literature is a limited discussion regarding the key determinants of R&D investments in China's manufacturing firms. While most studies have examined the impact and benefits of R&D investments on a firm, few have examined the main factors that motivate organizations to invest significant portions of their revenue in R&D (Habib et al., 2019). There have only been fewer studies covering the Schumpeterian hypothesis, with a key focus on the firm size and market power as the main drivers of R&D investments. There is a need for more research on various key determinants that have not been fully discussed in the previous studies examined by the researchers. Apart from expanding the literature, this study provides more factors that decision-makers can examine before making major investments to support an organization's R&D objectives.

Based on the above literature review, the current and future studies should focus on the main factors that drive R&D because not enough evidence can be found in this area. While most researchers have examined the effects of R&D investments on a firm's competitiveness and profitability, very few researchers have examined the specific factors that give larger firms more advantage over smaller organizations when it comes to research and development. This study joins a growing literature that will assist businesses and even non-profit organizations to prioritize their R&D investments around factors that are more likely to increase their competitiveness and overall profitability.

## Conceptual Framework

As stated under objectives, the purpose of this study is to examine the empirical determinants of R&D investments in China's manufacturing companies. The following conceptual framework examines the process and outcomes associated with the R&D, including the determinants. Experience refers to the current and previous R&D investments. Even before considering the determinants of R&D, most large firms examine their current and previous R&D investments to identify key challenges they need to address. Experience plays a significant role in determining actions that should be taken in the future to improve performance. The theory and actions refer to making informed decisions. The literature or theory provides evidence and a framework that should be considered before making decisions. This includes firm size, market power, demand-pull, technological opportunity, and appropriability. The outcomes represent the effects of R&D investments. This includes financial performance and market value. The figure below shows the conceptual framework that defines the process of converting R&D ideas into organizational success.



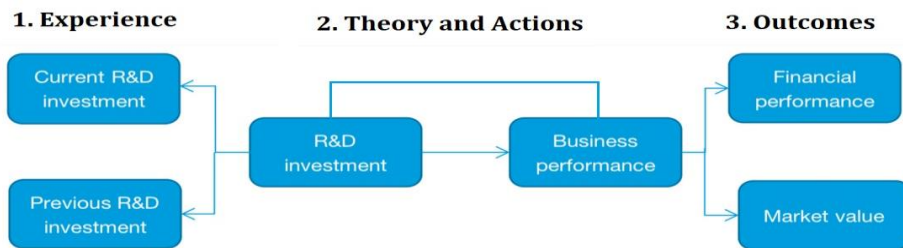


Figure 1: The conceptual framework showing the experience, theory actions, and outcomes.

## Methodology

This study relied on a systematic analysis of data obtained from the Oriana database. The Oriana system collects data from various organizations across Southeast Asia to determine the intensity of R&D investments against a country's GDP. The data indicates the number of times and amount invested by a company in its Research and Development programs. The R&D refers to both the frequency and amount of resources that a firm invests in its research and development objectives. The data also provides information about firm size (employees) and the period in which the R&D investments were made. The data was valuable in calculating an organization's R&D intensity against its size, market power, demand-pull, technological opportunity, and appropriability.

The sample consisted of the top 100 firms in terms of their R&D investments over 10 years. The study restricted itself to R&D investments between 2012 and 2022. The fixed effects (FE) model was used in estimating a firm's R&D intensity against dependent variables, including firm size, market power, demand-pull, technological opportunity, and appropriability. The FE model was suitable for this study due to its flexibility and scalability. Researchers can add dependent variables to the equation depending on the type of information needed. The FE model is highly accurate and has been used in various studies to estimate statistical measurements. The FE model's equation is a linear equation that examines the impact of action X on the Y outcomes. An example of the FE model's equation used in the study is shown below.

$$RInt_{it} = \alpha_{1r}Size_{it-1} + \alpha_{2r}SizeSq_{it-1} + \alpha_{3r}MarkPower_{it-1} \\ + \alpha_{4r}MarkPowerSq_{it-1} + \alpha_{5r}Dpull_{it-1} + \alpha_{6r}TechOpp_{it-1} \\ + \alpha_{7r}Appr_{it-1} + \mu_{ir} + \varepsilon_{itr}$$

The FE model equation shown above shows R&D intensity ( $RInt_{it}$ ) as the independent variable while the firm size ( $Size_{it}$ ), market power ( $MarkPower_{it}$ ), demand-pull ( $Dpull_{it}$ ), technology opportunity ( $TechOpp_{it}$ ), and appropriability ( $Appr_{it}$ ) as the dependent variables. The equation can also be used in calculating the development intensity ( $DInt_{it}$ ) as a ratio between the development expenditures and the number of employees in a firm. The research component of the R&D examines the various activities and investigations that an organization performs to find solutions to its challenges (Seenaiah & Rath, 2018). The development component of R&D refers to the investments made by an organization to convert the idea (developed during research) into a physical product or service (Chen & Yang, 2019). For instance, the resources that a firm invests in creating the prototype of a new product fall under the development quotient of R&D. The development intensity shows how a firm takes the R&D ideas seriously and willingness to convert them into meaningful products and services. The following is the FE model equation for the development quotient of the R&D investments.

$$DInt_{it} = \alpha_{1d}Size_{it-1} + \alpha_{2d}SizeSq_{it-1} + \alpha_{3d}MarkPower_{it-1} \\ + \alpha_{4d}MarkPowerSq_{it-1} + \alpha_{5d}Dpull_{it-1} + \alpha_{6d}TechOpp_{it-1} \\ + \alpha_{7d}Appr_{it-1} + \mu_{id} + \varepsilon_{itd}$$

The two FE model equations demonstrate a linear concept or correlation between R&D investments with the various dependent variables. Data from the Oriana database were also used in



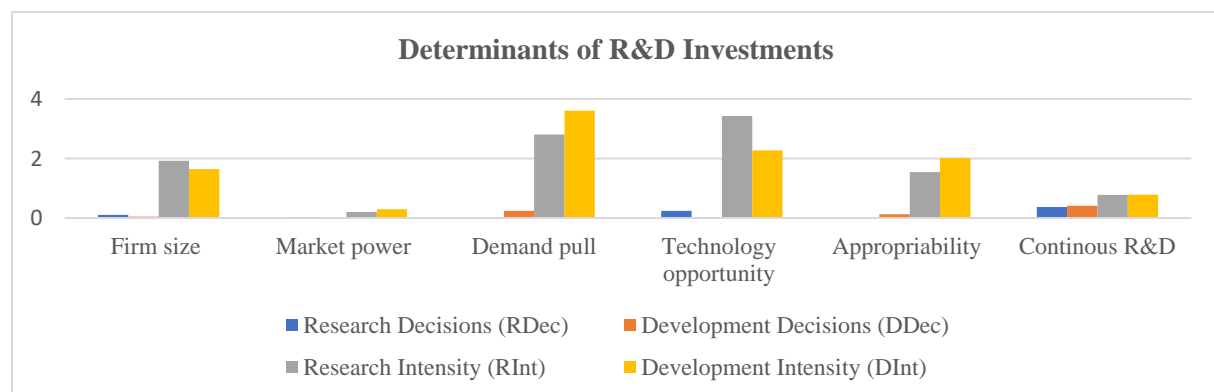
calculating various descriptive statistics to provide better explanations for the observations made during the study. The descriptive statistics focused on the mean, standard deviation, and variances. The researchers combined the outcomes from the two equations to draw logical conclusions.

## Results

The table below shows the findings obtained after conducting analysis using the FE model equations. The results indicate the impact of each determinant on R&D decisions and intensity. From the table below, it emerges that demand-pull has the highest impact on development intensity and research intensity. Technology opportunity also has a significant impact on research intensity and development intensity. The study also found that market power has minimal impact across the four domains. However, firm size showed a significant influence on research intensity and development decisions or intensity. The study also found that firms invest in R&D because it is an appropriate decision. Appropriability showed a strong influence on both research intensity and development intensity. Further analysis indicates that continuous R&D is more likely to influence both decisions and intensity. The study found that manufacturing firms are more likely to continue channeling more resources to their R&D objectives if it yields a positive impact on financial performance and market value.

*Table 1: Determinants of R&D investments among China's manufacturing firms.*

Determinants of R&D Investments	Research Decisions (RDec)	Development Decisions (DDec)	Research Intensity (RInt)	Development Intensity (DInt)
Firm size	0.108	0.048	1.924	1.645
Market power	0.031	0.009	0.204	0.292
Demand-pull	0.013	0.242	2.804	3.608
Technology opportunity	0.241	0.031	3.432	2.276
Appropriability	0.009	0.126	1.542	2.018
Continuous R&D	0.367	0.412	0.776	0.782



*Figure 2: Graphical illustration of the determinants of R&D investments among China's manufacturing firms.*

The above table (Table 1) shows the impact of each factor on research decisions (RDec), development decisions (DDec), research intensity (RInt), and development intensity (DInt). Research intensity shows the amount of investment and frequency that a firm is willing to make, while development intensity shows the level and frequency of investments in developing the idea created during research. The bar graph (Figure 2) demonstrates the impact of each factor on research decisions, development decisions, research intensity, and development intensity.

## Discussion

Determinants of R&D investments are key factors that drive a firm's decisions and intensity of investments in improving their products and services. The key determinants found by the study include firm size, market power, demand-pull, technology opportunities, and appropriability (Barge-Gil &



López, 2014). The firm size mainly refers to the number of employees in a manufacturing firm (Shi & Wu, 2017). Studies have shown that R&D investments can only succeed if an organization assembles a highly qualified and experienced team (Ndlovu & Inglesi-Lotz, 2020). Doctorate and master's degrees are key considerations for selecting qualified candidates to work in a firm's R&D programs (Nikkei Asia, 2023). China's leading automaker, BYD, for instance, has at least 590 employees with doctorate degrees working in the R&D team. The organization's R&D team also has over 7,800 employees with master's degrees (Nikkei Asia, 2023; Wang et al., 2020). A highly talented workforce enhances an organization's innovativeness and encourages investments in research and development projects.

Firm size showed a positive association with both research intensity and development intensity. However, firm size is likely to influence both research and development decisions. According to Seenaiah & Rath (2018), firms invest in R&D not because they have a larger workforce than their competitors. However, a highly talented workforce encourages organizations to invest more resources in various R&D objectives to gain competitive advantages and generate more revenue (Xu & Sim, 2018). The study has found that a highly talented workforce encourages research intensity through more investments and expansion of research facilities (Zhou & Song, 2016; Papanastassiou et al., 2020). Some organizations purchase better machines and channel more resources into improving the R&D facilities to meet their objectives. The large number of employees also supports R&D decisions by giving organizations more people to work on various research and development projects. According to Luan et al. (2019), successful R&D teams account for at least 10 percent of the workforce.

Market power refers to an organization's sales in comparison to industry sales. Bai et al. (2019) argue that firms may invest more resources in R&D to improve their sales or match industry standards. The R&D investments drive sales by improving product quality, operational efficiency, and productivity (Xu & Sim, 2018). Despite previous studies, including the Schumpeterian hypothesis, supporting market power's impact on R&D decisions, this study only found a small association between research intensity and decisions. Evidence indicates that manufacturing firms are less likely to invest in R&D to increase their sales (Luan et al., 2019). Instead, one of the goals of R&D is to improve productivity and operational efficiency. Moreover, gaining competitive advantages enables organizations to minimize competitive pressure and generate more revenue (Yang et al., 2020). Market power is more likely to influence development decisions and intensity. This enables organizations to gain key competitive advantages in their various industries (Wang et al., 2020). Xiaomi, for instance, relies on R&D to create new and innovative products to rival the ones generated by key competitors such as Samsung, Huawei, and Apple Company.

Since consumers constantly demand new and improved products, R&D provides opportunities for organizations to meet new market demands. Jiangsu Shemar, for instance, has been facing a growing demand for innovative products to overcome potential challenges associated with electric power supply (Seenaiah & Rath, 2018). Examples include innovative insulators and transmission lines that can resist potential and sudden power surges and minimize the chances of fire outbreaks (Wu et al., 2019; Anwar & Sun, 2013). The study found that demand-pull has a significant influence on research and development decisions. The demand-pull encourages organizations to improve their products and services to make them more competitive in the market (Wang et al., 2020). Apart from being competitive, high-quality products are likely to attract consumers and assist organizations in expanding their sales and profit margins (Shi & Wu, 2017). The demand-pull drives investment decisions regarding product improvement or new product developments. According to Yin et al. (2020), R&D investments among small manufacturing firms are more focused on generating new products to enhance diversification and sales.

Technology opportunities emerged as one of the most effective determinants for research and development intensities. For manufacturing firms to succeed in the era of Industry 4.0, they have to remain ahead of competitors regarding technology and competitive advantages (Shen & Lin, 2020). New technologies offer opportunities for growth and competitiveness. Besides, failure to invest in new technologies can be catastrophic even for major manufacturing firms (Seenaiah & Rath, 2018). In China, taking advantage of new technologies can make a significant difference between organizations in an industry. Early adopters are more likely to create new growth areas and gain first-mover advantages in the market (Xu & Sim, 2018). Late adopters are more likely to spend significant resources in catching up with the rivals and may not enjoy potential advantages in the market, including consumer loyalty (Liu et al., 2020). Research and development investments help organizations to become first movers and win the loyalty of consumers.





The study found that most Chinese manufacturing firms choose R&D investments because it is the most appropriate direction for sustainability. Research and Development has become one of the best tools for assisting manufacturing firms to minimize their carbon footprints and make their operations more sustainable (Chen & Yang, 2019). Among manufacturing facilities in China, massive pressure has been on reducing dependence on potential polluters such as plastics and fossil fuels (Wang et al., 2020). Most organizations have relied on R&D to identify alternative sources of energy (Bai et al., 2019). Other firms recycle plastics to minimize the impact of their products on the environment. This also explains why appropriability had a significant impact on both research and development intensities (Seenaiiah & Rath, 2018). The data shows how R&D investments have become major tools for solving sustainability challenges and improving the relationship between firms and their stakeholders, including regulators.

## Conclusion

This study examined the empirical determinants of Research and Development (R&D) investment in Chinese manufacturing companies. The study found that key determinants associated with R&D decisions and intensity include firm size, market power, demand-pull, technology opportunity, and appropriability. The empirical findings show that demand-pull has the highest impact on both research and development intensity. Technology opportunity also has a significant impact on research intensity and development intensity. However, market power has minimal impact across the four domains. Firm size showed a significant influence on research intensity and development decisions. Moreover, appropriability showed a strong influence on both research intensity and development intensity. As for the benefits of R&D, the study found improved processes, product quality, productivity, and enhanced operational efficiency. The main challenges that R&D investments try to solve include lack of innovation and sustainability. Across manufacturing firms in China, R&D has become a significant tool for addressing environmental challenges and eliminating sustainability challenges within the supply chain.

The study shows that demand-pull is more effective in driving development intensity (2.804) and research intensity (3.608). The data also shows that technological opportunity is more effective in driving research intensity (3.432) and development intensity (2.276). The two diagrams (Table 1 and Figure 2) show how other factors drive both research and development intensity. The two diagrams indicate that organizations invest in R&D to enhance demand for their products and take advantage of new technological opportunities. The firm size determines the level of investment that an organization can put into its R&D programs. Failure to invest in a new development or technological opportunities is likely to reduce an organization's competitiveness and profitability.

## Recommendation

The study recommends early adoption of R&D projects to gain competitive advantages. Manufacturing firms should rely on R&D to create growth opportunities, improve product quality, and increase market demand. Both technology opportunity and demand-pull showed significant influence on R&D decisions made by manufacturing firms across China. The study recommends training the workforce to make them aware and understand the impact of R&D in creating new business opportunities and reducing competitive pressure. Apart from training the workforce, the study also recommends hiring highly competent and experienced staff to work in the R&D team. The experienced workers will guide the less experienced colleagues, creating an effective mentorship program. The study also recommends investing at least 10% of revenue to support various R&D initiatives. Larger manufacturing firms can invest up to 15% of their revenue in R&D projects.

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