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# Government R&D Subsidies and the Dual Performance of Marginal Firms: Divergent Effects on Financial and Technological Outcomes in South Korea

# 政府研发补贴与边缘企业的双重绩效：对韩国财务与技术结果的分化影响

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**Abstract:**
Government R&D subsidies are a key policy instrument for promoting innovation among small and medium-sized enterprises (SMEs), yet their effectiveness in revitalizing marginal or zombie firms remains conceptually contested and empirically insufficiently understood. This study addresses this gap by examining the differential effects of government R&D support on the financial and technological performance of 882 marginal firms in South Korea over the period 2012–2018. Using probit and Poisson regression models, we find that government R&D subsidies exert no statistically significant influence on financial performance indicators such as sales growth, but have a positive and statistically significant effect on technological performance, measured by the generation of domestic and

**Keywords:**
R&D subsidies;
Government R&D support;
Marginal firms;
Zombie firms;
Financial performance;
Technological performance;
Patent output;
Innovation performance;
Small and Medium-sized Enterprises (SMEs);

foreign patents. This study makes four main contributions. First, by jointly analyzing financial and technological outcomes, we identify heterogeneous effects of R&D subsidies on marginal firms and show that technological capabilities may persist even under conditions of prolonged financial distress. Second, we challenge "all-or-nothing" policy narratives that depict marginal firms as uniformly unproductive, demonstrating instead that a subset of these firms possesses latent innovative capacity that responds positively to targeted public support. Third, we advance a refined theoretical framework that helps reconcile mixed findings in prior research, arguing that limited absorptive capacity and structural market barriers constrain the commercial translation of innovation while leaving technological innovation pathways relatively intact. Fourth, we derive concrete policy implications by advocating for the development of integrated inter-ministerial information systems to identify and monitor marginal firms with genuine R&D potential, thereby enhancing the efficiency of resource allocation and reducing the risk of indiscriminate subsidization of persistently unproductive enterprises. Overall, our findings support a shift from uniform to differentiated innovation policy, prioritizing firms with credible recovery prospects and demonstrable innovative capacity. In doing so, the study offers a more nuanced understanding of how public R&D investment can catalyze sustainable innovation among SMEs operating at the margins of economic viability, with broader implications for innovation policy design in both emerging and advanced economies.

**摘要：**

政府研发补贴是促进中小企业（SMEs）创新的关键政策工具，但其在振兴边缘企业或所谓"僵尸企业"方面的有效性在概念上仍存在争议，在经验研究中也尚缺乏充分证据。本文通过考察政府研发支持对韩国 882 家边缘企业在 2012—2018 年期间财务绩效与技术绩效的差异化影响，以弥补这一研究空缺。基于 Probit 与 Poisson 回归模型的实证结果表明，政府研发补贴对销售增长等财务绩效指标不具有统计上显著的影响，但对以国内与国外专利产出衡量的技术绩效具有正向且统计显著的促进作用。本文主要有四方面贡献。第一，通过对财务与技术结果的联合分析，揭示了研发补贴对边缘企业产生的异质性效应，并表明即使在长期财务困境下，企业的技术能力仍可能持续存在。第二，我们质疑将边缘企业一概视为低效或无生产率主体的"全有或全无"政策叙事，证明其中一部分企业蕴含潜在创新能力，并能对有针对性的公共支持作出积极响应。第三，本文提出了一个更为精细的理论框架，以协调既有研究中相互矛盾的结论，指出有限的吸收能力与结构性市场障碍会制约创新成果的商业化转化，但相对保留技术创新路径的完整性。第四，我们从政策层面提出具体建议，主张构建部际一体化信息系统，以识别并持续监测具有真实研发潜力的边缘企业，从而提高公共资源配置效率，避免对持续低效企业实行无差别补贴。整体而言，研究结果支持将创新政策从"一刀切"模式转向差异化取向，优先支持具有可信复苏前景和可验证创新能力的企业，从新的视角阐明了公共研发投资如何在经济可持续性边缘运行的中小企业中催化可持续创新，并对新兴经济体与发达经济体的创新政策设计具有重要启示意义。

Absorptive capacity;
Innovation policy;
Public support programs;
Firm-level innovation;
Distressed enterprises;
South Korea

关键词：
研发补贴；
政府研发支持；
边缘企业；
僵尸企业；
财务绩效；
技术绩效；
专利产出；
创新绩效；
中小企业（SMEs）；
吸收能力；
创新政策；
公共支持项目；
企业层面创新；
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# 1. Introduction

In the era of rapid globalization and technological advancement, the innovation capacity of small and medium-sized enterprises (SMEs) has emerged as a cornerstone for fostering sustainable economic growth and industrial dynamism. Governments worldwide have recognized the pivotal role of SMEs in creating employment, driving sectoral transformation, and enhancing national competitiveness. Consequently, substantial public resources are allocated to support research and development (R&D) activities among SMEs, particularly those facing financial constraints or operating at the margins of economic viability. These "marginal" or "zombie" firms—characterized by persistent financial instability or chronic reliance on external resources present a unique and pressing challenge for policymakers seeking to balance the dual imperatives of promoting innovation and ensuring efficient allocation of public funds.

The COVID-19 pandemic precipitated an unprecedented surge in corporate finance facilities worldwide, measures that successfully prevented mass bankruptcies but simultaneously raised profound concerns about long-term resource misallocation and economic stagnation due to the proliferation of zombie firms (Yamada et al., 2023). In South Korea, these

concerns have been amplified by evidence suggesting that the benefits of R&D support provided to SMEs are disproportionately concentrated among a small number of firms, while "zombie" companies are allegedly mass-produced through the supplier-centered "spray" method of SME R&D distribution (Ahn, 2021). Considering the trend toward strengthening government functions related to industry, trade, and SMEs, as revealed in the results of a perception survey targeting central government officials in South Korea (Public Performance Management Research Center, 2021), there is a research gap to accumulate empirical evidence on the actual effectiveness of government support for businesses.

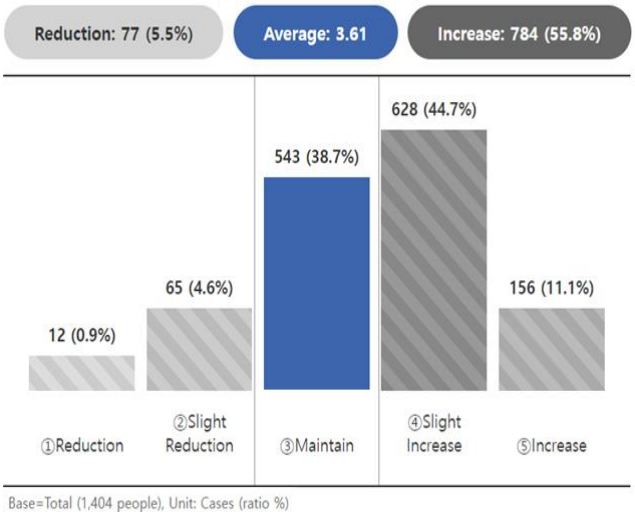


Figure 1. Changes in government functions within the next five years - industry, trade, and SMEs (Public Performance Management Research Center, 2021, p.258)

Academic scholars have consequently highlighted the urgent need for rigorous empirical research examining both the distribution patterns and impact trajectories of government R&D subsidies allocated to marginal firms. Such research is essential for enhancing the effectiveness of Korean Government R&D support mechanisms and proposing viable policy alternatives grounded in empirical evidence rather than ideological assumptions.

Despite the burgeoning literature on government R&D subsidy effectiveness, substantial knowledge gaps persist regarding their impact on marginal firms specifically. While previous studies have documented the potential of government R&D support to enhance technological innovation broadly (Wang & Jiao, 2022), the extent to which these subsidies translate into measurable financial performance improvements such as sales growth remains empirically contested and theoretically ambiguous. Furthermore, marginal firms often confront systemic barriers including inadequate access to private capital markets, low absorptive capacity for innovation, organizational rigidities, and heightened vulnerability to exogenous shocks, all of which complicate their ability to convert R&D investments into commercial success.

The relationship between government R&D subsidies and the innovation performance of marginal firms has attracted growing scholarly attention, yet findings remain contradictory. On one hand, evidence suggests that zombie firms demonstrate substantial commitment to innovation through increased R&D investment compared to non-zombie counterparts (Ryul & Dwyer, 2024), indicating latent technological capability despite financial distress. Conversely, critical perspectives argue that government subsidies may inadvertently perpetuate inefficiencies within zombie firms, leading to resource misallocation that could otherwise foster innovation in more economically viable enterprises. This perspective underscores the imperative for careful evaluation of subsidy programs to ensure alignment with broader economic development goals rather than merely prolonging the existence of structurally uncompetitive firms.

### *1.1. Selection of Research Objects: Conceptual Foundations and Operational Criteria*

The identification and selection of appropriate research subjects constitute a critical methodological foundation for this study, necessitating careful attention to definitional precision and operational feasibility. The concept of "zombie firms" lacks universally accepted definitional boundaries, creating significant challenges for empirical research. While various definitions exist in the academic literature, zombie firms are generally understood as entities "unable to cover debt servicing costs from current profits over an extended period" (Banerjee & Hofmann, 2018, p. 67) and that "manage to survive by tapping banks and capital markets" (Caballero, Hoshi, & Kashyap, 2008). However, the absence of standardized measurement protocols across different national contexts and institutional environments necessitates the development of context-specific operational criteria.

For this study, we adopt the "marginal company" framework as operationalized by the Bank of Korea, which defines marginal firms as those exhibiting an interest coverage ratio (ICR) calculated as the ratio of earnings before interest and taxes (EBIT) to interest expenses of less than 100% (or below 1.0) for three consecutive years. This criterion provides several methodological advantages that justify its selection as the primary filtering mechanism for our research sample. First, the three-year threshold distinguishes between firms experiencing temporary cyclical distress and those facing persistent structural challenges, thereby reducing the risk of misclassifying firms undergoing short-term difficulties as fundamentally unviable. Second, the ICR metric directly captures the core conceptual dimension of "zombie" status—namely, the inability to service debt obligations from operational

earnings—making it theoretically aligned with established definitions in the international literature. Third, this approach offers operational tractability, as the required financial data (EBIT and interest expenses) are consistently reported in standardized corporate financial statements, enabling systematic identification across diverse industries and firm sizes.

Our selection framework incorporates several additional qualifying criteria to ensure analytical rigor and policy relevance. We restrict our sample to firms that received government R&D support at least once during the observation period (2012-2018), as our research question specifically concerns the effectiveness of public R&D subsidies for marginal firms rather than marginal firms in general. This criterion enables direct examination of subsidy impact while controlling for selection effects inherent in government funding allocation processes. Furthermore, we require availability of comprehensive financial data from NICE Information Service and R&D project data from the National Science & Technology Information Service (NTIS), ensuring data quality and completeness for our empirical analyses. Firms with missing critical variables (sales, R&D expenditures, employee counts, or patent data) are excluded to maintain analytical consistency, though we report sample sizes for each specification to ensure transparency regarding data availability patterns.

Importantly, we distinguish analytically between "marginal firms" and "zombie firms," recognizing that these categories, while overlapping, are not coterminous. Marginal firms, as defined by our ICR criterion, include both firms lacking technological innovation potential (true "zombies" dependent solely on external life support) and firms possessing genuine innovative capabilities but experiencing temporary financial distress due to market conditions, investment cycles, or exogenous shocks. This distinction is theoretically crucial and empirically consequential: conflating these subcategories risks the policy error of "throwing the baby out with the bathwater" eliminating R&D support for all financially distressed firms when, in fact, a meaningful subset possesses recovery potential through innovation-driven revitalization. Our analytical approach is specifically designed to identify whether government R&D subsidies differentially affect technological versus financial outcomes, thereby providing empirical evidence regarding which marginal firms merit continued support.

The South Korean context offers particular advantages for examining these questions. Korea's comprehensive NTIS database provides detailed project-level R&D funding data across multiple government ministries, enabling precise tracking of subsidy amounts, timing, and project characteristics. The country's well-developed corporate information infrastructure, maintained by NICE Information Service, supplies standardized financial data with relatively high coverage of SMEs compared to many other national contexts. Furthermore, South Korea's aggressive R&D support policies for SMEs, combined with economic pressures that have generated significant numbers of marginal firms, create ideal conditions for empirical investigation of subsidy effectiveness. The 2012-2018 observation window captures a period of relative economic stability punctuated by sector-specific challenges, providing sufficient variation in both firm performance and policy interventions to support robust statistical inference.

### *1.2. Research Objectives and Empirical Strategy*

This study aims to fill critical gaps in the existing literature by empirically analyzing the financial and technological performance of marginal firms that received government R&D support in South Korea from 2012 to 2018. Our research addresses several interrelated questions: What is the current distribution pattern of government R&D support to marginal firms across ministries and project types? What characteristics distinguish marginal firms that receive R&D subsidies? Do government R&D subsidies significantly affect the financial performance (sales growth) of marginal firms? Do these subsidies enhance technological performance (patent generation) among marginal firms? What policy implications emerge regarding optimal targeting and monitoring of R&D support for this vulnerable yet potentially innovative segment of the SME population?

Using a robust dataset encompassing 882 firms and employing both probit regression (for binary financial performance outcomes) and Poisson regression (for count-based patent data), this research evaluates the differential effects of R&D subsidies on sales growth and patent generation. Our analytical strategy is designed to provide actionable insights for policymakers while contributing to theoretical understanding of innovation dynamics among financially distressed firms. The findings reveal a striking asymmetry: while government R&D support demonstrates no statistically significant impact on the financial performance of marginal firms, it positively and significantly enhances their technological output as measured by domestic and foreign patent counts.

These results underscore the imperative for nuanced R&D policy design that moves beyond simplistic binary classifications of firms as "viable" or "zombie." Instead, we advocate for targeting subsidies toward firms demonstrating clear innovative potential and recovery prospects, as evidenced by technological capability metrics rather than current financial performance alone. The study calls for establishment of interconnected information systems across government entities integrating data from ministries, the National Statistical Office, the National Tax Service, and private

information providers to identify and monitor marginal firms with genuine R&D capabilities. Such infrastructure would enable evidence-based allocation decisions that maximize public resource impact while avoiding both the Scylla of indiscriminate support and the Charybdis of premature abandonment of firms with latent innovation potential.

By addressing these critical policy and operational challenges through rigorous empirical analysis, this research seeks to advance both scholarly understanding and practical policy formulation regarding optimal strategies for supporting marginal firms in achieving sustainable recovery through innovation-driven transformation.

## 2. Literature Review

### *1.1. Government R&D support and innovation performance of SMEs*

A firm's innovation performance is a multifaceted concept that can be assessed across various dimensions. Robey (1991) categorizes technological innovation into three primary types: product or service innovation, technological innovation, and management innovation. Similarly, Barney and Griffin (1992) divide innovation into two distinct categories: technological innovation, encompassing both product and process innovation, and management innovation, which focuses on advancements in managerial processes. Rogers (1995) equates innovation with technology, defining technology as a process that reduces uncertainty regarding cause-and-effect relationships to achieve desired outcomes. Drawing on this multidimensional understanding of innovation, scholars in South Korea have conducted empirical studies analyzing the impact of government R&D support on the innovation performance of small and medium-sized enterprises (SMEs).

For example, Yoo and Park (2006) explored how variables such as the number of research personnel, research manpower quality, corporate R&D investment, and government R&D investment influence the technological and commercial performance of SMEs, employing regression analysis using self-reported survey data. Seo and Lee (2007) examined the effects of technological innovation factors and government R&D support on the likelihood of receiving Innobiz certification, adopting logit analysis with data from the Small and Medium Business Administration's technology management survey. Similarly, Shin and Choi (2008) analyzed the role of R&D employees, government financial support, technological support, and manpower assistance in fostering innovation, utilizing regression analysis based on self-reported survey data. Lee et al. (2009) investigated the relationship between government technology development subsidies, the proportion of development funding, and innovation outcomes, such as labor productivity and total factor productivity. Using panel data from the Small and Medium Business Administration between 2000 and 2007, they applied the Difference-in-Differences (DID) method coupled with traditional panel analysis. Ryu and Kim (2010) focused on how regulations, incentives, and information provision impact patent-related innovation outcomes, using regression analysis with data from the 2008 Korea Innovation Survey. Kim and Seong (2012) assessed how R&D subsidies, corporate and industrial characteristics, and the R&D environment influence innovation activities, technology commercialization, and intellectual property creation, employing generalized method of moments (GMM) analysis with data from the Small Business Technology Survey.

Further studies extended the scope of this research. Park and Lee (2012) analyzed the impact of financial tax support, mapping and information services, and infrastructure support on SMEs' technological competitiveness, relying on regression analysis of Small Business Technology Survey data. Seo and Lee (2014) evaluated the effects of factors such as government research funding, private R&D investment, research personnel, research focus, government support rates, skill levels, and technology types on outcomes like industrial property rights, technology advancement, sales contributions, and job creation. They used Data Envelopment Analysis (DEA) and self-reported survey data. Lee et al. (2014) employed Poisson regression analysis to uncover the relationship between government R&D support and patent generation among SMEs, leveraging data from the Innovative Enterprise Status Survey. Jang (2016) analyzed the influence of government subsidy collection and its impact on firms' technological, economic, and social performance, using regression analysis with data from the Small and Medium Business Administration's technology development and commercialization fund database. Oh and Kim (2017) investigated how government subsidies affect firms' economic, social, and innovative outcomes, applying propensity score matching combined with the DID method utilizing data from the Korea Small Business Innovation Research (KOSBIR) program. Finally, Choi (2018) analyzed the effects of funding, manpower assistance, and technological support on innovation performance using logistic regression with data from the 2016 Korean Enterprise Innovation Survey.

Despite the significant contributions of these studies, they exhibit several limitations. First, a number of studies (e.g., Yoo & Park, 2006; Shin & Choi, 2008; Jang, 2016) narrowly focus on independent variables like government funding and R&D manpower while neglecting critical socio-economic factors, firm-specific attributes, and market dynamics that may significantly influence innovation outcomes. Second, many studies

(e.g., Yoo & Park, 2006; Lee et al., 2014) have primarily evaluated innovation performance through patents or technological achievements, often excluding other vital dimensions such as groundbreaking innovations, long-term sustainability, and firms' creative capacities. Third, a reliance on self-reported survey data (e.g., Yoo & Park, 2006; Shin & Choi, 2008; Seo & Lee, 2014) introduces response bias, potentially distorting the accuracy of findings. Fourth, most studies (e.g., Ryu & Kim, 2010; Park & Lee, 2012; Choi, 2018) predominantly employ regression analysis without considering more advanced methodologies such as structural equation modeling (SEM) or machine learning—that could effectively address complex relationships, endogeneity concerns, and unobserved heterogeneity.

Fifth, several investigations (e.g., Jang, 2016; Oh & Kim, 2017) fail to adopt comprehensive conceptual frameworks, instead isolating variables like subsidies while overlooking broader determinants such as regulatory environments, cultural influences, or digital transformation.

Lastly, some studies (e.g., Kim & Seong, 2012; Lee et al., 2009) do not account for the intrinsic heterogeneity of SMEs, including variations in firm size, life cycle stage, industry type, and organizational culture, which may shape the effectiveness of government support.

Given these limitations, future research should adopt a more holistic approach to understanding the factors that drive SME innovation performance.

This includes examining an expanded set of determinants, such as socio-economic conditions, market characteristics, and organizational capabilities. In addition to measuring patents and technological progress, innovation metrics should encompass process innovations, eco-innovations, radical versus incremental advancements, and long-term sustainability.

Moreover, employing advanced analytical tools such as dynamic panel models, machine learning algorithms, and SEM would allow researchers to address complex, dynamic relationships and mitigate methodological biases. Future studies should also prioritize the development of integrated conceptual frameworks that incorporate funding mechanisms, firm-specific characteristics, market dynamics, and broader innovation ecosystems, capturing the multidimensional nature of innovation.

Furthermore, attention should be given to the heterogeneity of SMEs by segmenting firms based on size, age, industry, and innovation orientation to better understand how contextual factors influence R&D outcomes.

Lastly, research should focus on policy-oriented assessments that evaluate not only firm-level impacts but also macroeconomic and societal implications of government R&D support, ensuring alignment with national innovation and development goals.

By addressing these gaps, future studies can provide deeper insights and more actionable recommendations regarding the relationship between government support and SME innovation performance.

Table 1. Prior research on the effect of government R&D support on innovation performance of SMEs

| Literature | Independent Variables | Dependent Variables | Research method | Data |
|---|---|---|---|---|
| Yoo & Park (2006) | •Number of Research Personnel<br>•Research manpower quality<br>• Corporate R&D investment<br>•Government R&D investment | •Technological performance<br>•Commercial performance | Regression Analysis | Self-Survey |
| Seo & Lee (2007) | •Technology Innovation Factors<br>•Government R&D support | •Innobiz Certification | Logit Analysis | Small and Medium Business Administration technology management survey |
| Shin & Choi (2008) | •R&D employee<br>•Government funding support<br>•Government Technological support<br>•Government Manpower Support | •Innovation | Regression Analysis | Self-Survey |
| Lee et al. (2009) | •Government technology development subsidy<br>•Proportion of technology development support | •Labor productivity<br>• Total factor productivity | DID technique and Combined with traditional panel analysis | 2000-2007 Small and Medium Business Administration Technology development support data |
| Ryu & Kim (2010) | •Regulation<br>•Incentive<br>•Information provision | •Innovation-related patent | Regression Analysis | Korea Innovation Survey 2008 |
| Kim & Seong (2012) | •R&D subsidy<br>• Corporate Characteristics<br>•Industrial characteristics<br>•R&D Environment | •Innovation Activities<br>• Technology commercialization<br>• Intellectual Property | GMM | Small and Medium Business Administration Small Business Technology Survey |
| Park & Lee (2012) | • Financial Tax Support<br>• Map and information support<br>•Infrastructure | •Technological competitiveness | Regression Analysis | Small and Medium Business Administration |

| | | | | |
|---|---|---|---|---|
| | support | | | Small Business Technology Survey |
| Seo & Lee (2014) | •Government-funded research fund<br>•Privately invested research funds<br>• Research personnel<br>•Number of knowledge holdings<br>•Research concentration<br>•Government support rate<br>• Skill level<br>•Technology type | •Industrial property rights<br>• Technology level improvement<br>• Contribution to sales<br>• Job Creation | DEA Model | Self-Survey |
| Lee et al.(2014) | •Government R&D support | •Number of patents | Poisson Regression Analysis | Innovative Enterprise Status Survey |
| Jang (2016) | •Government support collection<br>•Government subsidy | •Technological performance<br>• Economic performance<br>•Social performance | Regression Analysis | Small and Medium Business Administration technology development commercialization fund DB |
| Oh & Kim (2017) | •Government subsidy | •Economic performance<br>•Social performance<br>•Innovative performance | PSM-DID | Department of Small and Medium Venture Business R&D and KOSBIR support task information |
| Choi (2018) | •Funding<br>• Manpower support<br>•Technological support | •Innovative performance | Logistic regression model | 2016 Korean Enterprise Innovation Survey |

Source: Developed by the authors

### *1.2. Government R&D subsidies and performance of marginal companies*

Government R&D subsidies have multifaceted effects on firm innovation performance, influencing both R&D investment and overall productivity. While subsidies can stimulate research and development activities and improve total factor productivity (Liu & Xu, 2024), their impact is often contingent on firm-specific characteristics and the continuity of funding. Marginal firms, commonly referred to as zombie firms, are typically defined as businesses incapable of covering their interest payments from operating profits, often measured by an interest coverage ratio (ICR) below one. These firms persist primarily due to external financial support, such as government subsidies or bank loans, despite exhibiting poor performance and limited recovery prospects. Zombie firms are characterized by inefficiency, low productivity, high levels of debt, and weak competitiveness. Their presence hampers economic efficiency by preventing the reallocation of resources capital, labor, and managerial capacity—to more productive firms and sectors.

Zombie firms distort resource allocation by tying up resources that could otherwise be utilized more effectively by healthier enterprises. This misallocation undermines overall productivity and economic growth (Mao & Xu, 2023; Rashid et al., 2022). Evidence from Pakistan demonstrates that zombie firms negatively affect industrial growth by increasing indebtedness and limiting opportunities for new entrants or healthy competitors (Rashid et al., 2022). Similarly, in China, zombie firms have been linked to reductions in manufacturing capacity utilization rates, both within individual industries and throughout supply chains due to propagation effects. These findings underscore their broader detrimental impact on economic efficiency (Mao & Xu, 2023).

Governments face significant trade-offs when addressing the issue of zombie firms. During periods of economic crisis, financial support measures may effectively prevent widespread bankruptcies in the short term. However, such interventions risk extending the survival of unproductive firms, thereby exacerbating inefficiencies in the long term. This pattern has been observed in various contexts, including Japan following its asset bubble collapse, Europe in the aftermath of the global financial crisis, and globally during the COVID-19 pandemic (Yamada et al., 2023).

While zombie firms may provide a degree of short-term stability during economic downturns, their prolonged existence poses significant risks to economic growth and efficiency. To address these challenges, policymakers must strike a careful balance between providing financial support and implementing structural reforms to spur productivity and innovation. Notably, innovation activities are critical for marginal firms seeking to escape zombie status. Empirical research indicates that fostering innovation can help struggling firms improve performance and regain competitiveness, particularly in manufacturing industries (Lee et al., 2023).

The effects of government R&D subsidies on the innovation performance of zombie firms reveal a nuanced interplay between funding, firm characteristics, and innovation outcomes. While subsidies generally promote innovation across firms, their impact on zombie firms remains complex. Subsidized zombie firms often exhibit increased R&D investment, suggesting a commitment to innovation in spite of their precarious status (Ryul & Dwyer, 2024). However, government subsidies do not consistently translate into commercial success for zombie firms. For instance, research indicates that although zombie firms may

achieve technological advancements, their commercial outcomes remain statistically comparable to non-zombie firms (Ryul & Dwyer, 2024). Additionally, fiscal subsidies have been shown to prolong the survival of zombie firms, decreasing their likelihood of exiting the market (Deng & Wang, 2022). This prolonged survival, while temporarily stabilizing, can disrupt market dynamics by impeding the process of natural selection that typically eliminates less viable firms (Deng & Wang, 2022).

Though much of the existing literature focuses on the general effects of R&D subsidies, insights specific to marginal firms reveal both potential benefits and critical challenges. On a positive note, subsidies reduce financial constraints and share the risk associated with R&D investments, encouraging even marginal firms to pursue innovative activities (Wenyi, 2024; Wang & Jiao, 2022). This is particularly important for firms with limited access to private funding due to their poor financial health or high-risk profiles. Additionally, subsidies can foster technological collaboration between marginal firms and external partners—such as universities and research institutions—enhancing innovation performance (Wang & Jiao, 2022). This collaborative network-mediated effect suggests that even resource-constrained firms may benefit from increased R&D investment and knowledge transfer. Moreover, evidence suggests that government R&D subsidies significantly enhance corporate innovation outcomes in high-tech industries, such as renewable energy, where technological progress is central to competitiveness (Wenyi, 2024; Wang & Jiao, 2022).

However, challenges associated with government subsidies for marginal firms must also be acknowledged. Studies indicate that while subsidies positively influence innovation, the marginal returns diminish as subsidy amounts increase. This finding implies that excessive reliance on subsidies may fail to produce proportional gains in innovation output (Wu et al., 2020; Yi et al., 2021). Furthermore, some firms, particularly those in weaker financial or competitive positions, may adopt opportunistic or manipulative behaviors to capitalize on subsidies. For instance, firms may focus on increasing the quantity of patents or projects without prioritizing quality, a trend observed in Chinese renewable energy firms operating in regions characterized by low marketization and unfair competition (Ying et al., 2022). This strategic misalignment undermines the transformative potential of R&D funding. Additionally, over-dependence on government support risks perpetuating inefficiencies and stifling the development of sustainable innovation capabilities, ultimately hindering long-term competitiveness (Yi et al., 2021).

In conclusion, while government R&D subsidies offer substantial potential for fostering innovation even among marginal firms they also present inherent risks and limitations. Researchers and policymakers must address these challenges by developing targeted intervention strategies that maximize the transformative impact of subsidies while mitigating dependency and inefficiency. Policymakers should consider designing mechanisms that reward quality outcomes over quantity, encourage collaboration across institutions, and differentiate support based on firm-specific characteristics. Future research should explore the long-term impacts of subsidies on firm innovation capacities, market dynamics, and economic efficiency in greater depth, ensuring a comprehensive understanding of the nuanced relationship between government funding and marginal firm performance.

# 3. Methodology

### *3.1. Research Questions*

The issue of small and medium-sized enterprises' (SMEs) research and development (R&D) funds being channeled into sustaining so-called "zombie firms" economically unviable companies reliant on government support has garnered significant attention. However, a major challenge lies in the difficulty of clearly identifying such firms due to the lack of a consistent and universally accepted definition of a zombie company. While no formal definition exists, zombie firms are generally understood as entities that are "unable to cover debt servicing costs from current profits over an extended period" (Banerjee and Hofmann, 2018, p. 67) and "manage to survive by tapping banks and capital markets" (Caballero, Hoshi, and Kashyap, 2008). Consequently, it becomes imperative to develop clear standards for identifying insolvent firms those incapable of generating sufficient profits to meet debt obligations and reliant on external borrowing from credit markets or government subsidies to remain operational.

To address the issue of supporting zombie firms, an alternative approach involves identifying such entities through the concept of marginal companies. A marginal company, as defined by the Bank of Korea, refers to a firm with an interest coverage ratio (ICR) the ratio of earnings before interest and taxes (EBIT) to interest expenses of less than 100% for three consecutive years. In this context, marginal companies are those that are financially unstable or have lost self-sustainability due to poor market competitiveness, yet manage to survive through government R&D funding. This method provides a practical framework for identifying zombie companies by focusing on firms that exhibit persistent financial distress and lack market viability.

The key research questions concerning the support provided to marginal companies are as follows: What is the current status of government support provided to marginal firms, categorized by department and business type? What are the defining characteristics of these

marginal companies? Are there firms among this group that possess technological innovation capabilities? If so, do such firms achieve superior performance outcomes? Finally, what strategic direction should government support take in the future to ensure the effective allocation of resources? Addressing these questions is critical for formulating policies that distinguish between firms with potential for innovation and growth and those that perpetuate inefficiencies within the economy.

### *3.2. Data and Methods*

#### *3.2.1. Data Sources and Sample Construction*

To examine the current state of government R&D subsidies provided to marginal companies, we constructed an integrated panel dataset by merging multiple administrative and commercial data sources. The primary data sources include:

Government R&D Project Data: We extracted comprehensive information on SME R&D project support from the National Science & Technology Information Service (NTIS), Korea's centralized database for national R&D activities. The NTIS platform captures project-level details including funding amounts, project duration, ministry affiliation, project type classification, and performance outcomes for all government-funded R&D initiatives. We obtained data covering the period 2012–2018, encompassing all R&D projects implemented under SME supervision across multiple government ministries.

Corporate Financial Data: Firm-level financial information was obtained from NICE Information Service (www.niceinfo.co.kr), a leading Korean credit rating and business information provider. NICE maintains comprehensive financial databases covering Korean corporations, including SMEs, with standardized accounting information collected from mandatory financial disclosure statements. Key financial variables extracted include annual sales revenue, earnings before interest and taxes (EBIT), interest expenses, total assets, R&D expenditures, and employee counts.

Patent Data: Technological performance indicators, specifically domestic and foreign patent applications and grants, were obtained through the NTIS performance reporting system, which aggregates intellectual property outcomes from government-funded R&D projects. Patent data were linked to firm identifiers to enable tracking of technological outputs over time.

#### *3.2.2. Sample Selection Procedure*

The sample construction followed a systematic multi-stage filtering process designed to identify marginal firms that received government R&D support:

Stage 1. Initial Universe: We began with the universe of all SMEs that received government R&D project support at least once during 2012–2018, yielding a total of 59,648 firm-year observations across the seven-year period.

Stage 2. Marginal Firm Identification: We applied the Bank of Korea's marginal company criterion, calculating the Interest Coverage Ratio (ICR) for each firm-year observation as:

ICR = EBIT / Interest Expenses

Firms were classified as marginal if they exhibited ICR < 1.0 (or < 100%) for three consecutive years within the observation period. This three-year threshold ensures that we capture persistent financial distress rather than temporary cyclical difficulties. The consecutive-year requirement distinguishes structurally challenged firms from those experiencing transient shocks.

Stage 3. Data Integration and Validation: We merged the NTIS R&D project data with NICE financial data using unique firm identification numbers (business registration numbers). To ensure data quality, we implemented several validation procedures: (a) verification of temporal alignment between R&D project years and financial reporting periods; (b) identification and correction of duplicate records; (c) cross-validation of firm characteristics (industry classification, establishment year) across data sources; and (d) outlier detection for key financial variables using interquartile range methods.

Stage 4. Sample Restrictions: We applied the following exclusion criteria to ensure analytical consistency: (a) firms with missing critical financial variables (sales, EBIT, interest expenses, R&D expenditures, or employee counts) were excluded from relevant analyses; (b) firms operating in financial services or public administration sectors were excluded due to distinct accounting practices and regulatory environments; (c) observations with logical inconsistencies (e.g., negative employee counts, sales values coded as zero but with positive operating expenses) were removed after manual verification; and (d) firms that appeared in only one year of the panel were excluded to enable longitudinal analysis.

The final analytical sample comprises 882 unique marginal firms that received government R&D support at least once between 2012 and 2018, yielding varying numbers of firm-year observations depending on data availability for specific variables: 756 observations for sales analysis, 527 for sales growth analysis, 635 for patent analysis, and 508 for employment analysis.

#### *3.2.3. Variable Operationalization*

Dependent Variables:

Financial Performance—Sales Growth: We calculated annual sales growth rate as the percentage change in nominal sales revenue from year t-1 to year t:

Sales Growth Rate = [(Sales_t - Sales_{t-1}) /

Sales_{t-1}] × 100

For regression analysis, we transformed this continuous variable into a binary outcome indicating positive growth (coded as 1 if sales growth > 0%, coded as 0 otherwise) to accommodate the probit regression framework and address the highly skewed distribution of growth rates.

Technological Performance Patent Counts: We measured technological innovation output through the count of domestic and foreign patents (applications and grants combined) generated in each year. Patent counts represent a widely accepted proxy for technological innovation output, capturing the codified knowledge generated through R&D activities (Hausman et al., 1984). We aggregated both domestic (Korean Intellectual Property Office) and foreign (international patent offices) patents to capture the full scope of technological achievement.

Independent Variables:

Government R&D Support Amount: The primary explanatory variable represents the total value of government R&D subsidies (in millions of Korean won) received by each firm in a given year. This variable captures direct financial support across all government ministries and project types. For firms receiving multiple projects in a single year, we aggregated the total funding amount. The variable exhibits substantial variation, ranging from small-scale projects (approximately 20 million won) to large-scale initiatives (exceeding 1 billion won).

Number of Employees: Firm size, operationalized through employee count, serves as a control variable capturing organizational capacity, absorptive capability for innovation, and scale effects. We used the natural logarithm transformation in sensitivity analyses to address right-skewed distribution, though main specifications employ the raw count to facilitate interpretation.

Industry Classification: We constructed three industry dummy variables based on Korean Standard Industrial Classification (KSIC) codes: (a) Manufacturing (reference category, coded as 0); (b) Information and Communication industry (coded as 1 for firms in KSIC sections 58-63); and (c) Professional, Scientific and Technological Services (coded as 1 for firms in KSIC section 70-73). These categories capture systematic differences in innovation patterns, capital intensity, and technology appropriability across sectors.

Year Fixed Effects: To control for time-varying macroeconomic conditions, policy regime changes, and aggregate trends affecting all firms, we included year dummy variables for 2013–2017 (or 2018 for certain specifications), with 2012 serving as the reference year. These fixed effects absorb systematic temporal variation, including business cycle effects, changes in government R&D budget allocations, and shifts in patent examination standards.

*3.2.4. Analytical Methods*

We employed two complementary regression techniques designed for different dependent variable structures, ensuring appropriate statistical modeling of binary and count outcomes.

Probit Regression for Binary Financial Performance:

To analyze the determinants of sales growth, we employed binary probit regression, a specific case of the Generalized Linear Model (GLM) appropriate when the dependent variable is dichotomous. The probit model assumes that the probability of positive sales growth follows a cumulative standard normal distribution:

$P(Y_i = 1 \mid X_i) = \Phi(X_i'\beta)$

where $Y_i$ represents the binary sales growth outcome for firm i, $X_i$ is the vector of independent variables, $\beta$ represents the parameter vector to be estimated, and $\Phi$ denotes the cumulative distribution function of the standard normal distribution.

The probit model offers several advantages over linear probability models: (a) predicted probabilities are constrained to the [0,1] interval; (b) marginal effects vary with covariate levels, reflecting nonlinear relationships; and (c) the normality assumption provides theoretical consistency with latent variable interpretations of binary outcomes. We estimated the model using maximum likelihood estimation (MLE), with standard errors clustered at the firm level to account for potential within-firm correlation of residuals across multiple years.

The estimating equation takes the form:

$P(\text{Sales Growth} > 0) = \Phi(\beta_0 + \beta_1 \cdot \text{Gov\_RD\_Support} + \beta_2 \cdot \text{Employees} + \beta_3 \cdot \text{Manufacturing} + \beta_4 \cdot \text{ICT} + \beta_5 \cdot \text{Prof\_Sci\_Tech} + \Sigma\beta_t \cdot \text{Year\_t} + \varepsilon)$

Model diagnostics included: (a) likelihood ratio tests comparing the full model to restricted specifications; (b) pseudo-$R^2$ measures (McFadden's $R^2$) assessing overall model fit; and (c) examination of predicted probability distributions to detect specification problems.

Poisson Regression for Count-Based Technological Performance:

For patent count analysis, we employed Poisson regression, the canonical model for count data where the dependent variable consists of non-negative integers (Hausman et al., 1984). The Poisson model assumes that patent counts follow a Poisson distribution with parameter $\lambda_i$:

$P(Y_i = k) = \exp(-\lambda_i) \cdot \lambda_i^k / k!$

where the log of the expected count is modeled as a linear function of predictors:

$\log(\lambda_i) = X_i'\beta$

The exponential mean function ensures non-negative predictions, while the log-link naturally accommodates the multiplicative effects common in innovation

processes. The Poisson specification is particularly appropriate for patent data given: (a) the discrete, non-negative nature of patent counts; (b) the right-skewed distribution with substantial mass at zero; and (c) theoretical consistency with stochastic models of innovation output.

The estimating equation for patent counts is:

$\log(E[\text{Patents}]) = \beta_0 + \beta_1 \cdot \text{Gov\_RD\_Support} + \beta_2 \cdot \text{Employees} + \beta_3 \cdot \text{Manufacturing} + \beta_4 \cdot \text{ICT} + \beta_5 \cdot \text{Prof\_Sci\_Tech} + \Sigma\beta_t \cdot \text{Year\_t} + \varepsilon$

We estimated Poisson models using maximum likelihood, with robust standard errors (Huber-White sandwich estimators) to accommodate potential overdispersion (variance exceeding the mean). We conducted diagnostic tests for overdispersion using the Cameron-Trivedi test, with results indicating that the equidispersion assumption was reasonable for our data (dispersion parameter ≈ 1.1, not significantly different from 1 at conventional levels).

# 4. Results

### *4.1. Distribution of Government R&D Support Provided to Marginal Companies*

Examining the trend in the number and proportion of marginal companies among the beneficiaries of government R&D support between 2012 and 2018, as shown in Table 2, reveals that in 2012, 179 marginal companies accounted for 2.7% of the total 6,622 beneficiaries. From 2013 onward, the number and proportion of marginal firms initially declined between 2015 and 2016 but subsequently began to increase, continuing this upward trend from 2016 to 2018.

Table 2. Trends in number and percentage of marginal companies among companies that more than once benefited (2012-2018)

| Year | Number of total beneficiary companies | Number of marginal companies | Ratio of marginal companies (%) |
|---|---|---|---|
| 2012 | 6,622 | 179 | 2.70 |
| 2013 | 6,865 | 94 | 1.37 |
| 2014 | 7,367 | 87 | 1.18 |
| 2015 | 8,171 | 72 | 0.88 |
| 2016 | 8,699 | 82 | 0.94 |
| 2017 | 10,252 | 121 | 1.18 |
| 2018 | 11,672 | 247 | 2.12 |
| Total | 59,648 | 882 | 1.48 |

Source: Developed by the authors

An analysis of the number of marginal companies across the manufacturing and non-manufacturing sectors and the average government R&D support they received during 2012–2018, as presented in Table 3, indicates that the average support amount provided to non-manufacturing industries was higher than that provided to manufacturing industries in all years except 2017.

Table 3. Average government R&D support by marginal companies in manufacturing/non-manufacturing sector (2012-2018)

| Year | Marginal Number of Companies (Ratio) | | Average Government R&D Support (KRW million) | |
|---|---|---|---|---|
| | manufacturing | non-manufacturing | manufacturing | non-manufacturing |
| 2012 | 128(72%) | 51(28%) | 288 | 436 |
| 2013 | 62(67%) | 31(33%) | 356 | 438 |
| 2014 | 62(72%) | 24(28%) | 446 | 472 |
| 2015 | 47(65%) | 25(35%) | 445 | 496 |
| 2016 | 52(66%) | 27(34%) | 444 | 448 |
| 2017 | 63(52%) | 58(48%) | 435 | 317 |
| 2018 | 151(62%) | 92(38%) | 343 | 384 |

Source: Developed by the authors

Regarding the distribution of government R&D support by ministry, as summarized in Table 4, the Ministry of SMEs and Startups provided the largest share of support to marginal companies, accounting for 640 instances (approximately 48%). This was followed by the Ministry of Trade, Industry, and Energy with 328 instances (25%), the Ministry of Science and ICT with 98 instances (7%), the Ministry of Agriculture, Food, and Rural Affairs with 64 instances (5%), and the Ministry of Health and Welfare with 63 instances (5%). In terms of the average amount of R&D support provided, the Ministry of Trade, Industry, and Energy offered the highest average of 471 million won per instance, followed by the Ministry of Science and ICT at 456 million won, and the Ministry of Health and Welfare at 280 million won. By contrast, the Ministry of SMEs and Startups provided the lowest average support amount, at 127 million won per instance.

Table 4. Status of Support for Marginal Enterprises by Ministry (2012-2018)

| Name of department | Number of times of application | Ratio (%) | Cumulative ratio (%) | Average amount of government R&D support (million won) |
|---|---|---|---|---|
| Ministry of SMEs and Startups | 640 | 48.34 | 96.37 | 127 |
| Ministry of Trade, Industry and Energy | 328 | 24.77 | 47.73 | 471 |
| Ministry of Science and ICT | 98 | 7.4 | 7.48 | 456 |
| Ministry of Agriculture, Food and Rural Affairs | 67 | 5.06 | 13.67 | 97.9 |
| Ministry of Health and Welfare | 63 | 4.76 | 22.58 | 280 |

| | | | | |
|---|---|---|---|---|
| Rural Development Administration | 29 | 2.19 | 15.86 | 69.6 |
| Ministry of Environment | 22 | 1.66 | 100 | 358 |
| Ministry of Oceans and Fisheries | 21 | 1.59 | 98.26 | 161 |
| Ministry of Culture, Sports and Tourism | 12 | 0.91 | 17.6 | 383 |
| Multi-Departmental Joint | 11 | 0.83 | 16.69 | 490 |
| Ministry of Land, Infrastructure and Transport | 10 | 0.76 | 8.53 | 331 |
| Korea Forest Service | 5 | 0.38 | 22.96 | 85.8 |
| Korea Coast Guard | 4 | 0.3 | 96.68 | 347 |
| Ministry of Education | 3 | 0.23 | 7.7 | 111 |
| Defense Acquisition Program Administration | 2 | 0.15 | 17.75 | 274 |
| Nuclear Safety and Security Commission | 2 | 0.15 | 48.04 | 218 |
| National Police Agency | 1 | 0.08 | 0.08 | 110 |
| Ministry of Public Safety and Security | 1 | 0.08 | 7.78 | 33.5 |
| Korea Meteorological Administration | 1 | 0.08 | 8.61 | 120 |
| Ministry of Justice | 1 | 0.08 | 17.82 | 27 |
| National Emergency Management Agency | 1 | 0.08 | 47.81 | 20 |
| Ministry of Food and Drug Safety | 1 | 0.08 | 47.89 | 190 |
| Ministry of the Interior and Safety | 1 | 0.08 | 98.34 | 250 |

Source: Developed by the authors

Analysis of the government R&D support provided to marginal companies by project type[i], as shown in Table 5, reveals that the most frequently supported project was SME technological innovation development, which received 168 instances of support. This was followed by startup growth technology development (111 instances), industry-university-research cooperative technology development (106 instances), SME commercialization technology development (91 instances), and support for joint use of research equipment (52 instances). These projects were primarily conducted by the Ministry of SMEs and Startups and the Ministry of Trade, Industry, and Energy. While the Ministry of SMEs and Startups supported a greater number of beneficiaries, the Ministry of Trade, Industry, and Energy provided a higher average amount of R&D funding. Additionally, within the projects supported by the Ministry of SMEs and Startups, selective-focused projects—such as technology innovation development for SMEs and technology development for SME commercialization—received higher average funding than base-expansion projects (e.g., startup growth technology development and industry-university-research cooperation technology development) or infrastructure-building projects (e.g., joint research equipment utilization).

Table 5. Status of support for marginal companies by business (2012-2018, top 10 based on number of beneficiaries)

| Project name | Department name | Number of beneficiaries | Average amount of government R&D support (million won) |
|---|---|---|---|
| SME technological innovation development (selection-focused type) | Ministry of SMEs and Startups | 168 | 197 |
| Start-up growth technology development (base expansion type) | Ministry of SMEs and Startups | 111 | 112 |
| Industry-university-research cooperation technology development (base expansion type) | Ministry of SMEs and Startups | 106 | 60.2 |
| SME commercialization technology development (selective focus type) | Ministry of SMEs and Startups | 91 | 154 |
| Support for joint use of research equipment (infrastructure molding) | Ministry of SMEs and Startups | 52 | 13.3 |
| Fostering regional specialized industries (Ministry of Industry) | Ministry of Trade, Industry and Energy | 36 | 211 |
| Fostering a leading industry in the regional economy | Ministry of Trade, Industry and Energy | 31 | 414 |
| Strengthening the competitiveness of industrial clusters | Ministry of Trade, Industry and Energy | 24 | 173 |
| SME convergence technology development | Ministry of SMEs and Startups | 24 | 246 |
| Material parts technology development | Ministry of Trade, Industry and Energy | 20 | 683 |

Source: Developed by the authors

### *4.2. Performance of Marginal Firms*

The financial and technological performance of marginal companies from 2012 to 2018 (or 2017[ii]) is detailed in Tables 6, 7, and 8. These tables provide insights into the performance of marginal companies in both the manufacturing and non-manufacturing sectors over the specified period[iii].

Table 6. Financial and Technological Performance of Marginal Firms (2012-2017/2018)

| Category | | Number of Samples | Mean | Standard Deviation | Min. | Max. |
|---|---|---|---|---|---|---|
| Financial Performance | Sales (million won) | 756 | 12,200 | 34,200 | 16 | 612,000 |
| | Sales growth rate (%) | 527 | 0.26 | 1.48 | -0.95 | 26.16 |
| | Number of employees | 508 | 56.37 | 73.62 | 1 | 757 |
| Technological Performance | Number of domestic and foreign patents | 635 | 0.43 | 1.39 | 0 | 14.5 |
| | Number of technology fees | 635 | 0.01 | 0.17 | 0 | 4 |
| | Technology fee collection (1,000 won) | 635 | 76,029 | 1,694,122 | 0 | 42,500 |
| | Number of commercialization cases | 635 | 0.20 | 0.75 | 0 | 13 |

Source: Developed by the authors

Table 7. Financial Performance of Marginal Companies in Manufacturing/Non-Manufacturing Industry by Year (2012-2017/2018)

| Year | Sales (KRW million) | | Sales growth rate (%) | | Number of employees | |
|---|---|---|---|---|---|---|
| | Manufacturing | Non-manufacturing | Manufacturing | Non-manufacturing | Manufacturing | Non-manufacturing |
| 2012 | 25,600 | 9,195 | 9 | 14 | 67 | 47 |
| 2013 | 10,700 | 7,805 | 79 | 18 | 36 | 46 |
| 2014 | 10,300 | 19,200 | 9 | 12 | 51 | 73 |
| 2015 | 16,000 | 7,453 | 2 | 21 | 76 | 36 |
| 2016 | 8,975 | 4,914 | 14 | 20 | 54 | 46 |
| 2017 | 13,900 | 2,269 | 39 | 71 | 70 | 23 |
| 2018 | 13,400 | 3,774 | - | - | 78 | 34 |
| Average | 15,500 | 6,415 | 24 | 31 | 63 | 42 |
| Number of companies* | 489 | 260 | 351 | 172 | 347 | 159 |

Note: *excluding missing values
Source: Developed by the authors

Table 8. Technological Performance of Marginal Companies in Manufacturing/Non-Manufacturing Industry by Year (2012-2017/2018)

| Year | Number of domestic and foreign patents | | Number of technology fees | | Technology fee collection (1,000 won) | | Number of commercialization cases | |
|---|---|---|---|---|---|---|---|---|
| | Manufacturing | Non-manufacturing | Manufacturing | Non-manufacturing | Manufacturing | Non-manufacturing | Manufacturing | Non-manufacturing |
| 2012 | 0.21 | 0.24 | 0 | 0 | 0 | 0 | 0.18 | 0.16 |
| 2013 | 0.61 | 0.53 | 0 | 0.03 | 0 | 106,452 | 0.16 | 0.19 |
| 2014 | 0.18 | 0.67 | 0 | 0 | 0 | 0 | 0.19 | 0.13 |
| 2015 | 0.15 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 |
| 2016 | 0.66 | 0.37 | 0 | 0.04 | 0 | 91,789 | 0.12 | 0.44 |
| 2017 | 1.01 | 0.65 | 0 | 0.07 | 0 | 732,759 | 0.21 | 0.24 |
| Average | 0.44 | 0.43 | 0 | 0.03 | 0 | 223,511 | 0.16 | 0.20 |
| Number of companies* | 414 | 216 | 414 | 216 | 414 | 216 | 414 | 216 |

Note: *excluding missing values
Source: Developed by the authors

### *4.3. Empirical Analysis of Factors Affecting the Performance of Marginal Companies*

The empirical analysis of factors affecting the performance of marginal companies that received at least one government R&D support project between 2012 and 2017 produced the following results. First, a probit regression model was employed to analyze the relationship between government R&D support and one aspect of financial performance: sales growth. The dependent variable was sales growth, while government R&D support was the primary independent variable. Control variables included the company's number of employees, and dummy variables for company type and year (with 2012 as the baseline). As shown in Table 9, government R&D support had no statistically significant effect on sales growth for marginal companies.

Table 9. Factors Affecting Sales Growth of Marginal Firms: Probit Analysis Results

| Probit regression | Regression coefficient | Standard error | z-value | P-value |
|---|---|---|---|---|
| government R&D support amount | **0.00** | **0.00** | **0.16** | **0.87** |
| Number of employees | **0.00** | **0.00** | **1.50** | **0.13** |
| Manufacturing | **0.33** | **0.24** | **1.40** | **0.16** |
| Information and communication industry | **0.15** | **0.29** | **0.51** | **0.61** |
| Professional, scientific and Technological | **0.24** | **0.31** | **0.75** | **0.45** |

| | | | | |
|---|---|---|---|---|
| service industry | | | | |
| 2013 year dummy | **0.24** | **0.20** | **1.23** | **0.22** |
| 2014 year dummy | **-0.14** | **0.20** | **-0.71** | **0.48** |
| 2015 year dummy | **-0.03** | **0.22** | **-0.15** | **0.88** |
| 2016 year dummy | **-0.25** | **0.25** | **-1.00** | **0.32** |
| 2017 year dummy | **0.09** | **0.22** | **0.40** | **0.69** |
| Constant term | **-0.13** | **0.25** | **-0.53** | **0.60** |

Number of obs=379; LR chi2(9)=9.84; Prob > chi2=0.3637; Log likelihood=-250.70873; Pseudo R2=0.0192; * p<.1; ** p<.05; *** p<.01

Source: Developed by the authors

Next, a Poisson regression model was used to examine the relationship between government R&D support and technological performance, measured as the number of domestic and foreign patents. As presented in Table 10, the analysis revealed that the amount of government R&D support provided to marginal companies had a statistically significant positive effect on the number of patents held by the firms.

Table 10. Factors affecting the number of domestic and foreign patents of marginal firms: Poisson analysis results

| Poisson regression | Regression coefficient | Standard error | z-value | P-value |
|---|---|---|---|---|
| government R&D support amount | 0.00 | 0.00 | 10.11 | 0.00*** |
| Number of employees | 0.00 | 0.00 | 2.75 | 0.01*** |
| Manufacturing | 0.58 | 0.35 | 1.67 | 0.10* |
| Information and communication industry | 0.67 | 0.38 | 1.75 | 0.08* |
| Professional, scientific and Technological service industry | -0.27 | 0.43 | -0.63 | 0.53 |
| 2013 year dummy | 1.23 | 0.25 | 4.88 | 0.00*** |
| 2014 year dummy | 0.66 | 0.28 | 2.39 | 0.02** |
| 2015 year dummy | -0.60 | 0.45 | -1.32 | 0.19 |
| 2016 year dummy | 1.25 | 0.28 | 4.54 | 0.00*** |
| 2017 year dummy | 1.65 | 0.23 | 7.06 | 0.00*** |
| Constant term | -2.63 | 0.38 | -6.87 | 0.00*** |

Number of obs=404; LR chi2(9)=215.29; Prob > chi2=0.0000; Log likelihood=-426.29811; Pseudo R2=0.2016; * p<.1; ** p<.05; *** p<.01

Source: Developed by the authors

Among the 882 marginal companies that benefited from government R&D projects hosted by SMEs between 2012 and 2018, further analysis confirmed that government R&D support had no statistically significant effect on financial performance, such as sales growth. However, it did have a significant positive impact on technological performance, as measured by the number of domestic and foreign patents.

The findings underscore the necessity of designing specialized R&D support plans tailored to marginal companies. While government R&D support does not significantly influence the sales growth of marginal firms, it does positively and significantly affect their technological performance, particularly in terms of patent generation. Given the many uncertainties surrounding financial outcomes, such as sales, and the various factors influencing technological performance, it is essential to develop measures to provide R&D support opportunities for marginal firms, even if they are in temporary financial distress. Excluding these companies from government R&D support on the assumption that they lack R&D capabilities is not advisable.

Instead, SMEs with a proven history of technological performance should be afforded the opportunity to rebound through R&D investment. Furthermore, policymakers should consider increasing the proportion of R&D investments directed toward SMEs, with the goal of enhancing their innovation capabilities. This strategic focus would not only support marginal firms with recovery potential but also enable startups that have not yet had opportunities in the existing market to enter and grow through technological innovation.

To achieve this, it is critical to establish a system of interconnection and cooperation among the SME-related information systems maintained by government ministries, the National Statistical Office, the National Tax Service, and private company data providers. Such a system would facilitate the identification and monitoring of marginal companies with innovative potential, ensuring that R&D subsidies are allocated effectively to achieve sustainable recovery and innovation.

# 5. Discussion

Small and medium-sized enterprises (SMEs) constitute a vital engine of innovation-driven growth, job creation, and industrial dynamism in modern economies. Yet within this heterogeneous population exists a troubling subset of firms—commonly labeled "marginal" or "zombie" enterprises—that exhibit chronic financial fragility and structural inefficiencies undermining their competitive viability. While these marginal firms share the common characteristic of persistent financial distress necessitating external

support for survival, they remain fundamentally heterogeneous in their underlying capabilities. Critically, some harbor latent technological capacities that, if strategically mobilized through appropriate policy interventions, could yield meaningful contributions to innovation ecosystems and long-term economic sustainability. The central challenge confronting policymakers is thus one of differentiation: distinguishing firms possessing genuine recovery potential and innovative capabilities from those merely subsisting on perpetual life support without generating commensurate economic or technological value.

Government-sponsored research and development (R&D) subsidy programs have emerged as a principal policy instrument for addressing these challenges, providing targeted financial support designed to stimulate innovation performance among resource-constrained SMEs. An extensive body of empirical literature has documented positive associations between public R&D subsidies and various measures of technological advancement, including patent generation, new product development, and process innovation. However, the relationship between R&D subsidies and financial performance outcomes particularly for marginal firms operating at the periphery of economic viability remains theoretically contested and empirically ambiguous. This knowledge gap assumes particular significance given the substantial public resources allocated to SME R&D support and growing concerns about potential resource misallocation to persistently unproductive enterprises.

The present study addresses this critical lacuna by examining the differential effects of government R&D subsidies on both financial and technological performance dimensions among marginal firms in South Korea during the 2012-2018 period. Drawing upon comprehensive firm-level data integrating government R&D project records with corporate financial information, we employ complementary analytical strategies probit regression for binary financial outcomes and Poisson regression for count-based innovation metrics to evaluate the multifaceted impact of public R&D support. Our empirical findings reveal a striking asymmetry in subsidy effects: government R&D support demonstrates no statistically significant influence on sales growth among marginal firms, yet generates robust and statistically significant positive effects on technological performance as measured by domestic and foreign patent generation.

These results illuminate a fundamental tension in R&D policy design for marginal firms. On one hand, the absence of significant financial performance effects suggests that R&D subsidies alone cannot overcome the complex market barriers, organizational rigidities, and resource constraints that impede commercial success among financially distressed enterprises. This finding aligns with theoretical perspectives emphasizing the importance of absorptive capacity, complementary assets, and market positioning for translating technological capabilities into commercial returns. On the other hand, the significant positive impact on patent generation indicates that marginal firms retain meaningful innovative capacity despite financial distress, and that targeted R&D support can effectively mobilize this latent potential to generate technological outputs. This pattern suggests that financial distress and technological capability represent partially independent dimensions rather than perfectly correlated attributes, contradicting simplistic assumptions that equate poor financial performance with absence of innovation potential.

Our findings contribute to scholarly discourse by providing empirical evidence that challenges the prevailing binary classification of firms as either "viable" or "zombie." Instead, the results support a more nuanced conceptual framework recognizing multiple firm archetypes within the marginal category: (1) firms possessing both financial distress and genuine innovation incapacity, representing true "zombies" requiring restructuring or exit; (2) firms experiencing temporary financial difficulties while maintaining substantial technological capabilities, representing promising candidates for recovery through innovation-driven revitalization; and (3) intermediate cases exhibiting varying combinations of financial and technological characteristics requiring differentiated policy responses. This heterogeneity demands sophisticated targeting mechanisms capable of identifying firms within the second category those for whom R&D subsidies can serve as catalytic interventions enabling technological advancement that may ultimately facilitate financial recovery.

The observed decoupling of technological performance from immediate financial outcomes carries important implications for understanding innovation dynamics among resource-constrained firms. Patent generation, while representing a tangible innovation output, constitutes an intermediate outcome in the commercialization pathway rather than a terminal indicator of innovation success. The temporal gap between patent filing and commercial realization, combined with the substantial complementary resources required for technology commercialization including manufacturing capabilities, marketing expertise, distribution networks, and working capital helps explain why enhanced patenting activity does not immediately translate into sales growth among marginal firms. Furthermore, financially distressed firms may face particular challenges in appropriating returns from their innovations due to weak bargaining positions in licensing negotiations, limited ability to enforce intellectual property rights, and vulnerability to imitation by better-resourced competitors.

These patterns align with prior research

documenting that government R&D subsidies positively influence innovation performance through R&D investment as an intermediary mechanism (Wang & Jiao, 2022), while zombie firms' technological advancements frequently fail to generate commercial outcomes statistically distinguishable from those of non-zombie counterparts (Ryul & Dwyer, 2024). Our findings extend this literature by simultaneously examining financial and technological dimensions within a unified analytical framework, thereby providing direct empirical evidence of differential subsidy effects across performance domains. This approach moves beyond prior studies that typically examine either financial or technological outcomes in isolation, offering a more comprehensive assessment of R&D subsidy effectiveness for marginal firms.

The policy implications emerging from these findings are substantial and multifaceted. First, the results challenge indiscriminate approaches to R&D subsidy allocation that either provide blanket support to all financially distressed firms or categorically exclude marginal enterprises from eligibility. Instead, our evidence supports selective targeting strategies that identify and prioritize marginal firms demonstrating technological capability as evidenced by prior innovation outputs, qualified research personnel, or promising R&D projects while experiencing temporary financial difficulties potentially surmountable through innovation-driven recovery. Second, the findings suggest that R&D subsidies for marginal firms should be conceived as components of integrated support packages combining financial assistance with complementary interventions addressing commercialization barriers, such as market access facilitation, management capacity building, and strategic partnership brokering. Third, the persistence of financial performance challenges despite technological advancement underscores the importance of realistic expectations regarding subsidy impact timelines and the need for patient capital approaches that recognize extended periods may be required for technological investments to yield commercial returns.

From a resource allocation perspective, our findings highlight the critical importance of developing sophisticated information systems enabling evidence-based identification and continuous monitoring of marginal firms receiving R&D support. The establishment of integrated data infrastructure connecting ministry-level R&D project databases, national statistical office corporate records, tax authority financial data, and private credit information repositories would facilitate several essential functions: (1) systematic identification of marginal firms possessing genuine innovative capabilities meriting continued support; (2) early detection of firms exhibiting persistent underperformance across both technological and financial dimensions, signaling potential resource misallocation; (3) longitudinal tracking of performance trajectories enabling assessment of recovery potential and subsidy effectiveness; and (4) knowledge accumulation regarding firm characteristics, subsidy modalities, and contextual factors associated with successful innovation-driven revitalization. Such infrastructure represents a prerequisite for evidence-based policy learning and continuous improvement in R&D subsidy program design and implementation.

The heterogeneity of marginal firms also suggests the potential value of differentiated subsidy mechanisms tailored to specific firm circumstances and recovery strategies. For instance, firms possessing strong technological capabilities but facing acute liquidity constraints might benefit primarily from financial support enabling continuation of ongoing R&D projects. Conversely, firms with promising technologies but lacking commercialization expertise might derive greater value from subsidies conditional upon participation in accelerator programs, mentorship arrangements, or collaborative partnerships with established industry players. Similarly, firms in sectors characterized by long development cycles and high capital intensity may require extended support periods and larger subsidy amounts compared to those in rapidly evolving digital sectors. Recognizing and accommodating this heterogeneity through flexible, context-sensitive support mechanisms could substantially enhance subsidy effectiveness.

Our analysis also illuminates tensions inherent in balancing multiple policy objectives when supporting marginal firms. From an economic efficiency perspective, concentrating resources on firms demonstrating high recovery probability maximizes expected returns on public R&D investment. However, social welfare considerations including employment preservation, regional economic stability, and supply chain continuity may justify supporting some marginal firms even when recovery prospects appear uncertain. These competing objectives necessitate explicit policy dialogue regarding priorities and trade-offs, alongside transparent criteria for adjudicating cases where efficiency and equity considerations diverge. The analytical framework developed in this study, distinguishing financial from technological performance dimensions, provides a useful foundation for such deliberations by revealing that technological capability can persist amid financial distress, suggesting potential pathways for value creation even among struggling enterprises.

Finally, the temporal context of our study period (2012-2018) merits consideration when interpreting results and drawing policy conclusions. This period largely predated the COVID-19 pandemic, which generated unprecedented numbers of marginal firms through exogenous demand shocks rather than

endogenous competitive failures. The pandemic experience underscores the importance of distinguishing cyclical from structural distress when formulating R&D support policies for marginal firms. Enterprises rendered financially marginal by temporary macroeconomic disruptions while maintaining intact technological capabilities represent particularly compelling candidates for strategic R&D support enabling innovation-driven recovery as economic conditions normalize. This distinction reinforces our central argument against categorical exclusion of marginal firms from R&D subsidy programs, while simultaneously highlighting the necessity of sophisticated diagnostic capabilities for differentiating among firm types meriting different policy responses.

# 6. Conclusion

This study demonstrates that the relationship between government R&D subsidies and marginal firm performance is far more nuanced than dichotomous "support or abandon" frameworks acknowledge. By revealing that technological capability can persist and even flourish amid financial distress when supported by targeted public investment, we challenge simplistic narratives equating economic marginality with comprehensive organizational failure. Our findings vindicate neither unconditional support for all financially struggling enterprises nor wholesale withdrawal of assistance from firms experiencing temporary distress.

Instead, we advocate for sophisticated, evidence-based support systems that carefully distinguish marginal firms possessing genuine innovative capacity from those lacking fundamental technological competencies—what we characterize as avoiding "throwing the baby out with the bathwater." Such differentiation requires substantial investment in information infrastructure, analytical capability, and monitoring systems, but promises more efficient resource allocation and better innovation policy outcomes than current approaches permit.

As governments worldwide confront the dual challenges of supporting innovation among vulnerable enterprises while ensuring efficient public resource deployment, the framework and evidence presented in this study offer actionable guidance for policy design. The path forward requires moving beyond ideological positions toward empirically grounded, differentiated interventions that recognize and respond to the heterogeneity inherent in marginal firm populations. By doing so, innovation policy can simultaneously foster technological advancement, prevent premature destruction of valuable organizational capabilities, and maintain appropriate accountability structures ensuring public resources generate genuine social returns.

The stakes extend beyond individual firm outcomes to encompass broader questions of national innovation capacity, economic resilience, and the appropriate role of government in stewarding technological development through periods of economic turbulence. Our research contributes to these fundamental policy debates by providing empirical evidence that technological capability and commercial viability, while related, represent distinct organizational dimensions requiring differentiated policy responses. This insight will inform more sophisticated and effective approaches to supporting innovation among enterprises operating at the challenging intersection of technological potential and financial fragility.

This study provides important implications for marginal firms, suggesting that government R&D subsidies can serve as a lifeline by providing critical resources for innovation and survival. However, the effectiveness of such subsidies depends on their proper targeting to ensure they are allocated to firms with potential for recovery, rather than perpetuating inefficiency. Furthermore, it is essential to strengthen monitoring mechanisms to prevent misuse of funds and to encourage high-quality innovation.

The study furnishes critical empirical evidence regarding the differentiated impacts of government R&D subsidies on marginal firms, yielding profound implications for both theoretical understanding and policy architecture. Our analysis reveals a striking asymmetry: while government R&D subsidies exert no statistically significant effect on the financial performance of marginal firms—as measured by sales growth—they generate substantive and positive impacts on technological performance, evidenced by increased domestic and foreign patent generation. This bifurcated outcome pattern illuminates fundamental tensions inherent in innovation support policies targeting financially distressed enterprises and necessitates a comprehensive reconsideration of how policymakers conceptualize, implement, and evaluate interventions directed toward this heterogeneous firm population.

### *6.1. Novel Contributions to Existing Literature*

This study's originality lies in its systematic challenge to the monolithic treatment of marginal firms in existing scholarship. While previous research has predominantly examined either zombie firms' negative externalities or general R&D subsidy effectiveness, we pioneer a middle-ground perspective that recognizes heterogeneity within the marginal firm population. Our dual-outcome analytical approach simultaneously examining financial and technological performance represents a methodological innovation that reveals the asymmetric effects of R&D support previously obscured in single-dimension analyses. Moreover, we introduce the conceptually critical distinction between "true zombies" lacking innovation potential and marginal firms possessing latent technological capabilities but experiencing temporary financial

distress. This distinction fundamentally reframes policy discourse, moving beyond simplistic binary classifications toward a more sophisticated understanding of how public R&D investment can selectively catalyze sustainable innovation among SMEs operating at the margins of economic viability.

### *6.2. Academic Contributions*

This research makes distinctive academic contributions to the innovation policy literature. First, we advance scholarly understanding by empirically disentangling the heterogeneous effects of R&D subsidies on marginal firms through simultaneous analysis of financial and technological outcomes, thereby revealing that technological capability can persist even amid financial distress. Second, we contribute to resource allocation theory by demonstrating that marginal firms are not uniformly unproductive, challenging the prevailing "all-or-nothing" policy discourse. Third, we develop a nuanced theoretical framework that reconciles contradictory findings in prior research by explicating how absorptive capacity and market barriers constrain commercial translation while leaving technological innovation pathways intact. Fourth, we extend institutional theory by illuminating the mechanisms through which targeted public support can catalyze innovation among financially distressed SMEs, providing empirical evidence for differentiated intervention strategies that balance efficiency concerns with innovation potential.

### *6.3. Theoretical Implications*

Our findings advance theoretical discourse across multiple dimensions of innovation studies and policy research. First, we contribute to absorptive capacity theory by demonstrating that technological capability and financial viability represent distinct, partially decoupled organizational dimensions. The persistence of innovative output amid financial distress challenges deterministic assumptions that equate economic marginality with comprehensive organizational dysfunction. Instead, our results suggest that absorptive capacity for technological knowledge can remain intact—or even be enhanced through targeted public investment—even when commercial translation mechanisms are impaired. This finding extends Cohen and Levinthal's (1990) foundational framework by revealing that absorptive capacity operates with considerable autonomy from immediate market performance, particularly when buttressed by external resource infusions.

Second, we enrich resource-based theory by identifying circumstances under which public resources substitute for, rather than merely complement, private capital in sustaining innovation trajectories. For marginal firms, government R&D subsidies function as critical lifelines that preserve technological capabilities during financial turbulence, effectively preventing the premature destruction of valuable knowledge stocks and organizational competencies. This dynamic suggests that public intervention can serve as a bridging mechanism, maintaining innovation potential until market conditions improve or alternative commercialization pathways emerge. Our evidence thus supports a more nuanced understanding of resource heterogeneity, wherein public and private capital exhibit differential effects contingent upon firm financial status and innovation stage.

Third, our research contributes to the emerging literature on organizational resilience and adaptive capacity by demonstrating that innovation persistence represents a distinct form of organizational survival strategy. Marginal firms that sustain R&D activities despite financial constraints exhibit a form of "selective resilience" maintaining core technological competencies while other organizational functions atrophy. This pattern suggests that innovation may serve as both a potential escape route from marginality and a strategic bet on future viability, even when immediate commercial returns remain elusive. Such behavior aligns with real options theory, wherein firms preserve optionality for future value creation by maintaining technological capabilities through periods of adversity.

Fourth, we advance policy feedback theory by revealing how government interventions shape organizational behavior and capabilities in ways that may diverge from stated policy objectives. The differential impact on technological versus financial performance indicates that R&D subsidies create specific incentive structures that channel marginal firm behavior toward patenting activities while leaving commercial capability gaps unaddressed. This finding underscores the importance of examining not only whether policies "work" in aggregate terms but also how they work—through what mechanisms, with what unintended consequences, and with what distributional effects across different performance dimensions.

### *6.4. Practical and Policy Implications*

The practical implications of our findings necessitate fundamental reforms in how governments design, target, and evaluate innovation support programs for financially vulnerable enterprises.

#### *6.4.1. Differentiated Support Architecture*

Policymakers must abandon monolithic approaches that treat all marginal firms identically. Our evidence demonstrates that a meaningful subset of financially distressed enterprises possesses genuine technological capabilities that respond positively to public R&D investment. This heterogeneity demands the construction of differentiated support architectures that distinguish between firms exhibiting recovery potential through innovation and those lacking fundamental

technological competencies. Operationally, this requires developing sophisticated screening mechanisms that assess not only current financial metrics but also technological trajectory, human capital quality, patent history, collaborative network positioning, and absorptive capacity indicators.

Such differentiation could be implemented through multi-stage evaluation processes wherein initial eligibility is determined by financial distress indicators (as in current practice), but continued support or enhanced funding levels are contingent upon demonstrated technological performance milestones. This staged approach would ensure that public resources flow preferentially toward marginal firms capable of converting R&D investment into technological advancement, while providing exit pathways for enterprises showing persistent inability to generate innovative outputs.

*6.4.2. Integrated Information Infrastructure*

The effective implementation of differentiated support requires establishing comprehensive inter-ministerial information systems that synthesize financial data (from the National Tax Service and financial institutions), technological performance metrics (from the National Science & Technology Information Service), market positioning indicators (from industry associations), and innovation ecosystem connections (from university-industry collaboration databases). Such integration would enable real-time monitoring of marginal firm trajectories and facilitate evidence-based allocation decisions.

This infrastructure should incorporate predictive analytics capabilities that identify early warning signals of both impending marginality (allowing for preemptive support) and genuine recovery potential (justifying sustained investment). Machine learning algorithms could be deployed to identify patterns distinguishing temporary distress from structural unviability, thereby reducing both Type I errors (supporting true zombies) and Type II errors (abandoning viable innovators).

*6.4.3. Complementary Commercialization Support*

Our finding that R&D subsidies enhance technological but not financial performance reveals a critical gap in current policy portfolios. Marginal firms require not merely funding for technical development but also comprehensive commercialization support addressing market access, customer development, business model innovation, and organizational capability building. This suggests the need for bundled interventions that combine R&D subsidies with mentoring programs, market development assistance, strategic partnership facilitation, and management capability enhancement.

Governments should consider establishing specialized commercialization support mechanisms specifically designed for marginal firms, recognizing that their market access challenges differ from those facing typical startups or established SMEs. Such mechanisms might include public procurement preferences, demonstration project funding, export promotion assistance, and risk-sharing arrangements with private sector partners willing to pilot innovations developed by financially vulnerable but technologically capable firms.

*6.4.4. Performance Metric Recalibration*

Current evaluation frameworks that emphasize short-term financial returns systematically disadvantage support programs targeting marginal firms, whose path to commercial viability may extend over longer time horizons. Our findings suggest that technological performance metrics—including patent generation, technology transfer success, collaborative network expansion, and human capital development—should receive greater weight in program evaluation, particularly for interventions targeting financially distressed enterprises.

This recalibration must be accompanied by realistic timelines that acknowledge the extended recovery periods required for marginal firms to translate technological capabilities into commercial success. Multi-year assessment frameworks with intermediate technological milestones would provide more appropriate evaluation structures than annual financial performance reviews.

*6.4.5. Conditional and Adaptive Support Mechanisms*

Rather than providing unconditional subsidies, governments should implement adaptive support mechanisms that adjust funding levels, support types, and continuation criteria based on ongoing performance monitoring. Firms demonstrating technological progress but continued financial struggles might receive intensified commercialization support; those showing technological stagnation despite adequate funding should face support withdrawal; and those achieving both technological advancement and financial stabilization might transition to standard SME support programs.

Such adaptive mechanisms could be structured as renewable grants with performance-contingent renewal criteria, requiring firms to demonstrate specified technological outputs (patent applications, prototype development, technology validation) to maintain eligibility. This approach would simultaneously provide necessary resources for genuine innovators while creating accountability structures that prevent indefinite support for persistently unproductive enterprises.

*6.4.6. Industry-Specific Calibration*

Our analysis reveals that marginal firms in manufacturing and high-technology sectors exhibit

different performance patterns than those in service industries. This heterogeneity necessitates industry-specific support calibration that recognizes varying innovation cycles, capital intensity requirements, patent propensities, and commercialization pathways across sectors. What constitutes appropriate technological performance benchmarks for manufacturing firms may differ substantially from relevant metrics for software or service enterprises.

Policymakers should develop sector-specific evaluation frameworks and support modalities that reflect these structural differences while maintaining consistent underlying principles regarding the distinction between temporary distress and fundamental unviability.

### *6.5. Broader Economic and Social Implications*

Beyond immediate policy architecture, our findings carry significant implications for broader economic development and social equity concerns. The discovery that a subset of marginal firms retains genuine innovative capacity suggests that indiscriminate exit policies while appealing for their simplicity and apparent efficiency gains risk destroying valuable knowledge assets and human capital. During economic downturns or sector-specific shocks, firms with strong technological foundations may find themselves in temporary financial distress through no fault of their innovation capabilities. Policies that support technological continuity during such periods effectively preserve national innovation capacity and prevent the permanent loss of organizational capabilities that may prove valuable under future market conditions.

This perspective is particularly salient in the context of systemic shocks such as the COVID-19 pandemic, which pushed numerous otherwise viable enterprises into marginal status through demand disruptions unrelated to their fundamental capabilities. Our framework suggests that differentiated support allowing technologically capable firms to "hibernate" through crisis periods maintaining core innovation activities while reducing other operations may represent an efficient response to such exogenous shocks.

Furthermore, our findings have equity implications for workers and communities. Marginal firms with genuine technological capabilities employ skilled technical personnel whose expertise represents valuable human capital. Supporting continued innovation activities during financial distress periods preserves these employment relationships and prevents the dispersion of specialized knowledge and teams. This consideration is particularly relevant in regions where specific marginal firms constitute significant employers or anchor institutions within local innovation ecosystems.

### *6.6. Policy Recommendations*

To maximize the impact of R&D subsidies on the innovation performance of marginal firms, several evidence-based policy interventions are recommended. First, allocation criteria should be refined to prioritize firms demonstrating clear recovery potential and technological capability, as evidenced by prior patent generation, R&D personnel quality, or collaborative research networks, rather than distributing support to firms surviving solely on external aid. Second, monitoring mechanisms must be enhanced through the establishment of integrated inter-ministerial information systems connecting data from the Ministry of SMEs and Startups, National Statistical Office, National Tax Service, and private information providers (e.g., NICE Information Service). This infrastructure would enable real-time tracking of subsidy recipients' technological outputs, financial trajectories, and strategic behavior patterns, facilitating early identification of manipulative practices or persistent underperformance. Third, collaboration should be actively promoted by incentivizing partnerships between marginal firms and universities, research institutions, or technologically advanced enterprises to facilitate knowledge transfer, enhance absorptive capacity, and accelerate commercialization pathways.

Fourth, differentiated support mechanisms should be implemented based on firm-specific characteristics, including industry sector, technology lifecycle stage, and innovation orientation. For instance, manufacturing marginal firms may benefit more from equipment-sharing infrastructure and process innovation support, while information technology firms may require greater emphasis on intellectual property protection and market access facilitation. Fifth, policymakers should consider establishing a "graduation pathway" system that progressively reduces direct financial support while increasing access to venture capital networks, technology commercialization services, and market expansion programs as firms demonstrate sustained innovation performance and financial improvement.

## 7. Limitations and Further Study

While our study provides robust evidence regarding the differential effects of R&D subsidies on marginal firms, several limitations warrant acknowledgment and suggest avenues for future research. First, our analysis focuses on observable technological outputs (patents) as proxies for innovation performance, potentially understating innovations that do not culminate in formal intellectual property protection. Future research should incorporate alternative innovation metrics including process innovations, organizational innovations, and market introductions to provide a more comprehensive assessment of technological performance.

Second, our study examines aggregate effects across all marginal firms receiving support, without fully exploring the mechanisms through which some firms

successfully translate technological capability into commercial recovery while others do not. Qualitative case study research examining successful and unsuccessful recovery trajectories would illuminate the causal pathways and complementary factors enabling commercial translation of technological capabilities.

Third, our analysis covers the period 2012-2018, which preceded both the COVID-19 pandemic and recent shifts in South Korean innovation policy priorities. Extending the analysis to more recent periods would reveal whether the observed patterns persist under different macroeconomic conditions and policy regimes. Comparative research examining marginal firm support policies across different national contexts would further illuminate which institutional arrangements most effectively balance the dual imperatives of supporting genuine innovators while avoiding resource misallocation to persistently unproductive enterprises.

Fourth, our study does not fully address the dynamic selection effects whereby government support itself may influence which firms survive long enough to be classified as marginal. Panel data approaches with careful attention to survival bias and selection into marginal status would strengthen causal inference regarding subsidy effects.

Finally, future research should examine longer-term outcomes extending beyond our observation window, tracking whether marginal firms exhibiting strong technological performance eventually achieve commercial recovery, undergo strategic acquisition by more viable enterprises, or fail despite continued innovation activity. Such longitudinal analysis would provide more definitive evidence regarding the wisdom of supporting technologically capable but financially distressed enterprises.

Future research should explore several critical dimensions to advance scholarly understanding and policy effectiveness. First, longitudinal studies examining the long-term trajectories of marginal firms receiving R&D subsidies would illuminate whether initial technological gains translate into sustained competitive advantage and financial recovery over extended periods (5-10 years). Second, comparative international research investigating how different institutional contexts, financial market structures, and innovation ecosystem characteristics moderate the relationship between R&D subsidies and marginal firm performance would enhance external validity and cross-national policy learning. Third, qualitative case study investigations could provide rich insights into the organizational mechanisms, strategic decision-making processes, and capability-building activities through which some marginal firms successfully leverage R&D support for revival while others fail to capitalize on similar resources.

Fourth, future scholars should employ more sophisticated econometric techniques—such as regression discontinuity designs, instrumental variable approaches, or synthetic control methods—to strengthen causal inference regarding subsidy effects, addressing endogeneity concerns inherent in government funding allocation processes. Fifth, research examining the network effects and spillover impacts of supporting marginal firms would illuminate whether and how innovation activities among subsidized marginal firms generate positive externalities for regional innovation ecosystems or industry value chains. Sixth, investigations into the optimal timing, duration, and intensity of R&D support for different types of marginal firms would inform more efficient subsidy design, potentially revealing whether concentrated short-term support or sustained low-intensity funding proves more effective for innovation revival.

In conclusion, while government R&D subsidies possess substantial potential to stimulate innovation in marginal firms, their effectiveness depends critically on careful policy design, rigorous implementation, and continuous monitoring. Addressing challenges such as dependency, resource misallocation, and opportunistic behavior is essential for achieving sustainable innovation outcomes. It is imperative to recognize that not all marginal firms are "zombie" companies lacking innovation potential. True zombie firms are characterized by their absence of technological innovation capability and complete reliance on external resources. Thus, policymakers must assiduously avoid a "throw the baby out with the bathwater" approach. Instead of providing unconditional support or implementing blanket exclusions, customized interventions should be directed toward marginal firms with demonstrable innovative capabilities experiencing temporary financial difficulties—particularly relevant in contexts of global or temporary exogenous shocks, such as the COVID-19 pandemic, which pushed many viable firms into marginal status.

The empirical findings of this study unequivocally indicate that government R&D support for marginal firms does not significantly affect sales growth but does exert a positive and statistically significant effect on technological performance, measured through domestic and foreign patent generation. However, given the inherent uncertainties surrounding commercial outcomes and the multifaceted factors influencing technological performance, it is imperative to develop nuanced measures that provide R&D support opportunities for marginal firms demonstrating innovation potential. Excluding these firms from government R&D support based solely on temporary financial distress, without assessing their underlying technological capabilities, represents a profound policy error that risks abandoning potentially valuable innovation assets.

SMEs with proven track records of technical capabilities should be afforded opportunities to achieve financial recovery through strategic R&D investment. Specifically, systematic assessment of how many marginal firms possess genuine R&D capacity, coupled with continuous performance monitoring, should inform allocation decisions. The establishment of an interconnected system facilitating cooperation among SME-related information platforms maintained by government ministries, statistical agencies, tax authorities, and private data providers represents an essential institutional innovation. Such infrastructure would enable effective identification and monitoring of marginal firms with authentic innovative potential, ensuring that R&D subsidies are allocated strategically to firms with the greatest likelihood of achieving sustainable recovery, generating meaningful technological advancements, and contributing productively to national innovation capacity and economic dynamism.

**Author Contributions**

Conceptualization, S.A.; methodology, K.-H.L.; software, K.-H.L.; resources, S.P.; data curation, S.A.; writing—original draft preparation, K.-H.L.; writing—review and editing, K.-H.L.; supervision, S.A.; project administration, S.A.; funding acquisition, S.A., S.P. and K.-H.L.

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Not applicable. The study did not involve human participants or animals.

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**Data Availability Statement**

The data that support the findings of this study are available from the corresponding author upon reasonable request. Access to the dataset is subject to confidentiality constraints associated with the original data provider.

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**Competing Interests**

The authors have declared that no competing interests exist.

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[i] The R&D support provided by the Ministry of SMEs and Startups is broadly categorized into three types: selection-focused projects, base expansion-type projects, and infrastructure construction-type projects (Small and Medium Business Technology Development Business Comprehensive Management System, https://www.smtech.go.kr/front/SBA/SA/ApplGuid_appl.do). Although the ultimate goal of these three types of support is the same, each type has distinct objectives and offers different forms of assistance. Selection-focused projects target companies with high innovation capabilities, such as Innobiz companies and venture firms. In contrast, base expansion-type projects aim to intensively foster small- and medium-sized enterprises (e.g., startups) operating in emerging industrial fields where the market has not yet been established. Lastly, infrastructure development projects support SMEs in conducting R&D effectively and include initiatives such as R&D planning assistance, research equipment utilization support, and research manpower support.

[ii] Only data from 2012 to 2017 were available for the sales growth rate and technological performance metrics (e.g., the number of domestic and foreign patents, the number of patents and fees collected, and the number of commercialization cases), while data from 2018 were used for other financial performance indicators. Missing values were excluded from the corporate financial data provided by NICE.

[iii] Examining the marginal companies with high technological performance reveals that those primarily operating in the manufacturing, biotech, medical, and IT sectors demonstrated relatively high technological performance.