

Impact of Government Subsidies on Green Innovation in Polluting Enterprises: A Review

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Abstract: To address the increasingly severe environmental challenges and achieve the "dual carbon" goals, the Chinese government has implemented a series of subsidy policies to promote green innovation and transformation of heavily polluting enterprises. However, against the backdrop of fierce market competition and tightening resource constraints, many companies still lack sufficient inherent motivation for green innovation. This study employs a systematic literature review method, analyzing relevant research from databases such as Web of Science, Scopus, and CNKI, aiming to systematically elucidate the research trajectory of government subsidies' impact on the green innovation performance of heavily polluting enterprises, thereby providing a theoretical perspective for improving relevant policy designs. The paper first posits that the logical starting point for government subsidies in green innovation lies in correcting environmental externalities, laying the foundation for subsequent discussions. It then examines the "incentive effect" and "crowding-out effect" of government subsidies on enterprises' green innovation performance, analyzes the non-linear relationship between government subsidies and corporate green innovation performance, and discusses the limitations of existing research from three aspects: relationship complexity, classification mechanisms, and influencing factors. Building on this, the paper integrates institutional theory with principal-agent theory to construct a multi-level analytical framework. This framework emphasizes the regulatory role of external institutional pressures, such as environmental regulations, on the effectiveness of subsidy implementation, while also focusing on how internal agency problems within enterprises may lead to inefficient utilization of subsidies, and how environmental information disclosure can help mitigate this issue. The study finds that there exists a non-linear relationship between subsidy intensity and green innovation performance, exhibiting "incentive effects" and "crowding-out effects" at different subsidy levels. Concurrently, factors such as environmental regulations, enterprise characteristics, and information disclosure practices play a moderating role in the effectiveness of subsidies. These findings have significant implications for policy-making, including designing subsidy schemes that avoid potential crowding-out effects at high subsidy levels, strengthening environmental regulations to enhance the effectiveness of R&D subsidies, implementing robust environmental information disclosure mechanisms, and formulating differentiated subsidy policies based on enterprise characteristics.

Keywords: Government subsidies, Enterprise green innovation performance, Institutional theory, Principal-agent theory, Environmental regulations.

1. Introduction

As the world's largest developing nation, China faces unprecedented environmental challenges amid global climate change and ecological degradation. In response, the Chinese government has set ambitious "dual carbon" objectives: aiming to peak carbon emissions before 2030 and achieve carbon neutrality by 2060. These goals demonstrate China's commitment to global climate governance and provide a clear trajectory for corporate green transformation. However, the translation of these policies into developmental opportunities for enterprises largely depends on their strategic responses.

While China has made significant strides in green innovation through government subsidies, similar efforts in countries like Germany and the United States show varying levels of success due to different regulatory environments and market dynamics. For instance, Germany's *Energiewende* (energy transition) policy has driven substantial investment in renewable energy (Steinbacher & Röhrkasten, 2019), whereas the United States has seen a mix of federal and state-level initiatives, with some states making considerable progress in clean energy adoption (Carley & Konisky, 2020). Comparatively, China's centralized approach allows for more coordinated and large-scale implementation of green policies,

potentially accelerating the pace of innovation in polluting industries.

Under the dual pressures of economic development and ecological preservation, green innovation has emerged as the cornerstone for achieving synergy between economic and environmental benefits in China (Guo et al., 2021). Nevertheless, enterprises face numerous hurdles in implementing green innovation: firstly, compared to traditional innovation, green innovation requires higher capital investment; secondly, when enterprises apply green innovation outcomes, they are susceptible to imitation and replication by competitors, potentially dampening innovation enthusiasm (Roper & Tapinos, 2016; Wang et al., 2022); thirdly, in the absence of pollution pricing mechanisms, enterprises confront the dilemma between environmental costs and profits, lacking endogenous motivation to proactively engage in green innovation (Wu et al., 2022).

Government functions play a pivotal role in incentivizing enterprise green innovation: on one hand, the government can promote green innovation through research and development subsidies and tax incentives; on the other hand, it can compel enterprises to reduce environmental externalities through stringent environmental regulations and pollution pricing mechanisms. Furthermore, government efforts in intellectual

property protection can mitigate the risk of green innovation outcomes being imitated, thereby enhancing innovation enthusiasm (Zheng et al., 2022; Wang et al., 2022).

In the macroeconomic context of China's commitment to achieving its "dual carbon" objectives and advancing green development, an in-depth exploration of the influence mechanisms of government subsidies on the green innovation performance of high-pollution enterprises holds profound theoretical implications and immense practical value. From a theoretical perspective, this comprehensive literature review addresses significant gaps in the current understanding of the relationship between government incentive policies and enterprise green innovation, particularly in high-pollution industries. By synthesizing existing research, this study aims to highlight three critical limitations in the current body of knowledge: The oversimplification of the relationship between government R&D subsidies and green innovation performance, often neglecting non-linear and complex interactions. The insufficient classification of green innovation behavioral motivations, particularly the distinction between strategic and substantive green innovation. The imbalanced focus on internal corporate governance factors at the expense of external factors, especially the critical role of government environmental regulations. From a practical standpoint, by comprehensively reviewing and analyzing these limitations, this study will provide valuable insights for both researchers and policymakers. It will contribute substantially to refining future research directions and enhancing the effectiveness of subsidy policies in promoting green innovation. This research thus makes a meaningful contribution to the development of more nuanced and effective approaches to drive the green transformation of China's economic development model and the construction of ecological civilization.

This paper aims to systematically review domestic and international literature on government subsidies and enterprise green innovation, analyzing the mechanisms through which government subsidies influence the green innovation performance of high-pollution enterprises. The paper is structured in five sections:

The first section serves as an introduction, presenting the research background, significance, content, and framework. The second section critically examines relevant domestic and international research literature, synthesizing the primary perspectives and limitations of existing studies. Building upon this literature review, the third section constructs a theoretical framework for analyzing the impact of government subsidies on the green innovation performance of high-pollution enterprises. The fourth section concludes the paper and proposes future research directions. The fifth section comprises the references.

This study employs a methodical literature review approach, utilizing key terms such as "government subsidies" and "enterprise green innovation performance" to systematically search for relevant literature in prominent databases including Web of Science, Scopus, and CNKI. The selection criteria encompass: 1) research focusing on high-pollution enterprises; 2) theoretical or empirical studies addressing the influence of government subsidies on enterprise green innovation; 3) literature types limited to academic journal articles or doctoral dissertations.

Through meticulous reading and analysis of the literature, the paper elucidates the current state of research, primary viewpoints, and controversies surrounding the impact of

government subsidies on green innovation in high-pollution enterprises. It identifies research gaps, thereby formulating the study's research questions and theoretical analytical framework, striving to demonstrate both systematicity and cutting-edge perspectives in the research.

2. The Impact of Government Subsidies on Enterprise Green Innovation Performance

2.1. Motivations for Government Subsidies

Government subsidies are a key policy tool to stimulate enterprise innovation, addressing market failures caused by positive externalities in research and development (Marshall, 1964; Pigou, 1920). These externalities occur when the benefits of innovation spill over to other firms or society, leading to underinvestment in innovation activities by private enterprises.

Externalities are particularly pronounced in the field of technological innovation. Innovation is the fundamental driver of capitalist economic growth (Schumpeter, 1990). Comparing innovation performance in monopolistic and perfectly competitive markets reveals that government intervention is especially necessary during market failures (Arrow, 1962). Consequently, research suggests that governments should subsidize enterprise innovation and human capital accumulation (Romer, 1990; Roper et al., 2017), as government subsidies can effectively stimulate technological innovation (Grossman & Helpman, 1991; Roper et al., 2013). However, some scholars argue that the externalities of innovation activities lead to insufficient enterprise investment in technological innovation (Solow, 1956; Magri, 2005; Davidson et al., 2018).

The core motivation for government subsidies lies in correcting the externalities of innovation activities. On one hand, technological innovation can generate spillover effects, resulting in social benefits that exceed the innovator's private returns, leading to insufficient motivation for innovation investment. On the other hand, innovation outcomes are easily imitated, making it difficult for innovators to fully enjoy the benefits of their innovations. Faced with situations where "marginal social benefits exceed marginal private costs" (Pigou, 1920), enterprises often struggle to independently bear all the costs and risks of innovation. Government subsidies thus become an important lever for mobilizing innovation enthusiasm.

2.2. Effects of Government Subsidies on Green Innovation

2.2.1. Incentive Effects of Subsidies

The incentive effect primarily manifests as the government promoting enterprise green innovation activities through subsidies, encouraging increased investment in green innovation, thereby positively influencing enterprise green innovation performance (Huang et al., 2019; Bai et al., 2019). This incentive effect varies among different types of enterprises, with small and medium-sized enterprises (Bronzini & Piselli, 2016), state-owned enterprises, and highly indebted enterprises (Shao & Chen, 2022) benefiting more notably.

Regarding innovation types, government subsidies promote both green process innovation (Liu et al., 2020) and green product innovation (Hu et al., 2021) in enterprises,

though their impacts on financial performance differ. The application of targeted policy instruments such as environmental subsidies, R&D subsidies, and talent subsidies can effectively drive enterprises towards green technological innovation transformation (Shao & Chen, 2022).

In terms of influence mechanisms, research has found that government support can function through open innovation (Roh et al., 2021) and can also expand credit scale and fiscal support through financial technology development, thereby enhancing enterprise green innovation performance (Liu et al., 2023). However, the presence of information asymmetry may exacerbate moral hazard and reduce the efficiency of subsidy fund utilization (Liu et al., 2022).

Government subsidies, as an incentive mechanism, effectively stimulate enterprises' endogenous motivation to invest in green innovation by reducing initial costs and risks of green innovation projects, promoting green transformation and upgrading (Chen et al., 2018). However, the full realization of subsidy effects relies on complementary financial supervision and performance evaluation mechanisms to ensure funds are directed towards genuine green innovation activities (Qi et al., 2023).

Ex-ante subsidies and ex-post rewards are two common subsidy models, but they may differ in incentive mechanisms and fund utilization efficiency. Ex-ante subsidies help alleviate enterprises' financing constraints, while ex-post rewards tend to better stimulate innovation motivation (Hud & Hussinger, 2015). Some studies suggest that compared to ex-post rewards, ex-ante subsidies have a better impact on innovation performance by stimulating private R&D investment (Liu et al., 2021). However, the relative effectiveness of these two subsidy methods under different circumstances requires further empirical verification.

2.2.2. Crowding-Out Effects of Subsidies

Despite the intention of government subsidies to promote green innovation in enterprises, they may produce a "crowding-out effect," causing enterprises to shift R&D funds from green innovation to other projects, thereby weakening direct investment in green innovation. The potential reasons for this "crowding-out effect" include enterprises pursuing short-term benefits or insufficient supervision of subsidy funds (Fan et al., 2017).

Empirical studies show that government subsidies can crowd out inventive outputs of high-tech enterprises in the short term, with this effect being more significant in regions with low export intensity or low market-oriented levels (Chen et al., 2020). In the renewable energy sector, the crowding-out effect of government subsidies on enterprise R&D investment behavior is influenced by enterprise ownership attributes (Yu et al., 2016). Regarding the new energy vehicle industry, research has found that while government subsidies promote R&D investment and non-creative patent output, their impact on creative patent output is not significant. Simultaneously, the effects of subsidies differ across various stages of the industrial chain, with upstream enterprises' R&D investment and output being less affected, and patent output even showing a slight crowding-out effect (Wu et al., 2023).

The interaction between environmental regulation and government R&D funding can produce differentiated effects due to imbalanced energy-saving and emission reduction standards, promoting green product innovation but inhibiting green process innovation (Guo et al., 2018). This indicates that the role of government subsidies in promoting enterprise green innovation is not always positive, and the resulting

crowding-out effect needs to be minimized through effective policy design and strict management supervision.

When implementing subsidy policies, governments need to fully consider various influencing factors to avoid unexpected negative effects. This research highlights the complexity of government subsidy impacts and emphasizes the need for careful policy formulation and implementation to maximize the positive effects while minimizing potential drawbacks in promoting green innovation.

2.2.3. Non-Linear Relationships between Subsidies and Innovation

Recent studies have begun to examine the non-linear relationship between government subsidies and enterprise green innovation performance, challenging traditional linear assumptions. In the new energy vehicle sector, research has revealed a U-shaped relationship between the two, with multiple dimensions of board governance (such as board gender diversity, age diversity, CEO duality, and board education level) significantly enhancing this U-shaped relationship (Xia et al., 2022). This indicates that the effectiveness of government subsidies is moderated by internal corporate governance structures, with diverse and specialized boards being more conducive to leveraging the innovative incentive effects of subsidies.

However, some studies have reached contradictory conclusions. An analysis of new energy enterprises found an inverted U-shaped relationship between subsidy scale and enterprise innovation input, suggesting that excessive subsidy levels may crowd out corporate R&D investment (Wu et al., 2022). This implies that government subsidies have an optimal threshold, beyond which additional subsidies may prove counterproductive.

Similarly, research in the renewable energy industry has identified an inverted U-shaped relationship between government R&D subsidies and enterprise green technology innovation. This relationship varies significantly across enterprises in different life cycle stages, ownership types, sizes, and geographical locations (Lin et al., 2023). These findings underscore the heterogeneity and context-dependency of government subsidy effects.

The relationship between government subsidies and enterprise green innovation performance is not a simple linear correlation but is influenced by both internal and external factors, exhibiting complex non-linear characteristics. This poses higher demands on government subsidy policy design. Policymakers must not only determine the optimal scale and intensity of subsidies to avoid crowding-out effects caused by excessive subsidies, but also tailor policies to suit individual enterprises. Subsidy resources should be allocated judiciously based on factors such as corporate governance levels and life cycle stages to fully mobilize enterprises' green innovation drive.

While these studies provide valuable insights into the effects of subsidies on green innovation, it is important to critically analyze the limitations in the existing literature. Many previous studies have oversimplified the relationship between subsidies and innovation outcomes into linear models, failing to fully account for the complexity of green innovation processes.

This review aims to address this oversight by exploring non-linear dynamics and contextual factors that influence the effectiveness of government subsidies on green innovation. The U-shaped and inverted U-shaped relationships identified in recent studies suggest a more complex interplay between

subsidies and innovation than previously assumed. However, the contradictory findings in different sectors highlight the need for more nuanced, industry-specific analyses.

Furthermore, the heterogeneity observed across different enterprise characteristics underscores the importance of considering a wider range of moderating factors in future research. By synthesizing these critical perspectives, this review seeks to guide future research towards more sophisticated models that can better inform policy design and implementation in the pursuit of effective green innovation strategies.

2.3. Theoretical Perspectives

2.3.1. Institutional Theory in Subsidy Research

Institutional theory posits that external pressures shape organizational behavior, driving enterprises to pursue legitimacy and resources (Dacin et al., 2002). In green innovation, enterprises face challenges such as high risks and technological uncertainties. Government subsidies, as an institutional tool, can mitigate these challenges by providing financial support and policy guidance, thereby stimulating green innovation activities (Scott, 2005; Xiang et al., 2022).

According to institutional theory, enterprises' responses to government subsidies may follow two paths: one is to strategically increase the quantity and speed of green innovation to gain external recognition, potentially overlooking the substantive environmental benefits of innovation; the other is to utilize subsidies for in-depth and lasting green innovation, integrating it into core corporate strategies and operations, pursuing long-term sustainable development (Kostova, 2008; Tolbert & Zucker, 1999). The latter path requires enterprise managers to recognize the importance of green innovation for long-term development, rather than merely responding to external pressures.

In the context of this study, institutional theory helps to elucidate the interactive influence of government subsidies and environmental regulations. Subsidies provide resource support, while regulations set behavioral norms, jointly shaping the institutional environment for enterprises. Enterprises will respond to these institutional pressures in pursuit of legitimacy, utilizing subsidies to optimize green innovation strategies and enhance innovation performance (Chen et al., 2010). However, it is worth noting that mere compliance-driven innovation may not lead to genuine environmental improvements. The key lies in stimulating enterprises' endogenous motivation and mobilizing their initiative and creativity.

From the perspective of institutional theory, in the field of green innovation, external institutional pressures, especially government subsidies and environmental regulations, have a profound impact on enterprises' strategic choices and innovative behaviors. Enterprises adopt different response strategies to gain legitimacy and scarce resources. On this basis, further exploration is needed to understand the unique mechanisms of environmental information disclosure and environmental regulation in the relationship between subsidy incentives and innovation performance.

2.3.2. Principal-Agent Theory in Subsidy Research

Principal-agent theory reveals the goal misalignment and information asymmetry issues between the principal (government) and the agent (enterprise managers).

Green innovation activities typically feature high input, long cycles, and high risks (Antonelli et al., 2013), while government subsidies aim to alleviate these challenges and

incentivize enterprises to intensify their green innovation efforts (Braun & Guston, 2003). However, enterprise executives, as key decision-makers, may have personal interests that diverge from organizational goals. According to principal-agent theory, as subsidy scales expand, managers might, driven by self-interest maximization motives, allocate funds to lower-risk areas less related to green innovation, resulting in diminished subsidy effectiveness (Chen et al., 2012; Waterman & Meier, 1998).

To ensure the effective utilization of subsidy funds, measures must be taken to mitigate principal-agent problems. Firstly, strengthening supervision and incentives for enterprise executives is crucial to align their decision-making with green innovation objectives and enhance their environmental responsibility awareness. Secondly, environmental information disclosure can play a unique intermediary role by increasing the transparency of green innovation activities, compelling executives to prioritize and showcase environmental achievements. Additionally, disclosure quality serves as an important basis for evaluating subsidy utilization efficiency. Moreover, the external constraints of environmental regulations can ensure that enterprises invest subsidy resources into green innovation rather than unrelated areas. The synergistic effect of information disclosure and environmental regulations helps achieve "precision irrigation" of subsidy funds.

Within the framework of principal-agent theory, focusing on the governance effects and pathways of environmental information disclosure and environmental regulations enriches the theoretical understanding and practical implications of the subsidy-performance relationship in the green innovation field. This approach provides a more nuanced perspective on how to effectively manage and optimize the impact of government subsidies on enterprise green innovation performance.

2.4. Limitations of Existing Research

Through a comprehensive review of existing research literature, the inadequacies in studying the relationship between government subsidies and corporate green innovation performance can be elucidated from the following perspectives:

Insufficient examination of the non-linear relationship between government subsidies and corporate green innovation performance. Although scholars have explored the connection between government subsidies and corporate green innovation, the existing research findings are inconsistent. On one hand, some studies suggest that government subsidies have an "incentive effect" on corporate green innovation performance (Huang et al., 2019; Bai et al., 2019). On the other hand, certain research posits that government subsidies have a "crowding-out effect" on corporate green innovation performance (Wu et al., 2023). The emergence of these diametrically opposed conclusions may be attributed to the fact that existing research primarily focuses on the simple linear relationship between government subsidies and corporate green innovation performance, lacking investigation into the more complex and dynamic relationship between the two.

Absence of classification of corporate green innovation behavior based on motivational perspectives. In research classifying corporate green innovation behavior, the majority of studies categorize based on the content of green innovation, lacking analysis from a motivational standpoint. From a

practical perspective, apart from green innovation aimed at promoting technological advancement and maintaining competitive advantage, enterprises also engage in green innovation activities for the purpose of obtaining other benefits (Xiang et al., 2022). Existing research has not adequately differentiated between the various motivations driving corporate green innovation, such as strategic and substantive green innovation, leading to an incomplete understanding of how enterprises respond to government subsidies under different motivations.

Existing studies have not considered the effects of internal and external environmental governance factors. Current research suggests that the impact of government policies on corporate green innovation performance is context-dependent (Wang et al., 2022). Due to the potential inhibitory effect of government subsidies on green innovation performance, it is particularly crucial to explore which internal and external factors influence the relationship between government subsidies and corporate green innovation performance. However, existing research primarily investigates the impact of internal factors on the relationship between government subsidies and corporate green innovation performance from the perspective of internal corporate governance (Wu, 2017). Yet, there is a lack of focus on the influence of external governance factors on the relationship between government subsidies and corporate green innovation performance.

3. Theoretical Analysis Framework

This study proposes to construct an analytical framework integrating institutional theory and principal-agent theory to systematically examine the impact of government subsidies on enterprise green innovation. Institutional theory focuses on the influence of external institutional pressures on enterprise innovation, while principal-agent theory emphasizes the impact of internal agency problems on innovation performance. Together, they form an interactive perspective of environment and management.

From an institutional theory perspective, enterprises facing external institutional pressures adopt conformity strategies to secure policy support and social recognition. In this context, firms respond to government subsidies by increasing the quantity and pace of green innovations, thereby enhancing strategic green innovation performance, albeit potentially lacking in substantive content. Institutional theory aids in elucidating how external pressures shape corporate behavior. Within the framework of green innovation, companies employ conformity strategies in response to government subsidies, augmenting the volume and velocity of green innovations to attain legitimacy and policy backing. Environmental regulations engender institutional pressures that influence the efficacy of R&D subsidies in promoting green innovation.

Conversely, principal-agent theory unveils the potential for substantial subsidies to induce opportunistic behavior among managers, who may allocate funds to low-risk areas with minimal correlation to green innovation, thus inhibiting substantive green innovation performance. This theory addresses the potential misalignment of interests between the government (principal) and enterprises (agents) in the subsidy process. Substantial subsidies may incentivize managerial opportunism, resulting in the allocation of funds to low-risk domains tangentially related to green innovation. This theoretical framework elucidates why subsidies occasionally impede substantive green innovation performance.

Considering the dual externalities of green innovation behavior, the external environmental institution will influence the effectiveness of government R&D subsidies. According to institutional theory, environmental regulation, as a key external institutional force, plays a crucial role in determining whether government R&D subsidy policies can achieve the expected effect of promoting enterprise green innovation. Higher levels of environmental regulation are conducive to creating a favorable external innovation environment, enhancing enterprises' initiative to engage in green innovation (Zhang et al., 2020).

By integrating institutional theory and principal-agent theory, a multi-level analytical framework is proposed to explore the impact of government R&D subsidies on enterprise green innovation performance under different environmental conditions. This framework allows for a more comprehensive understanding of the complex interplay between government subsidies, environmental regulations, information disclosure, and enterprise green innovation performance.

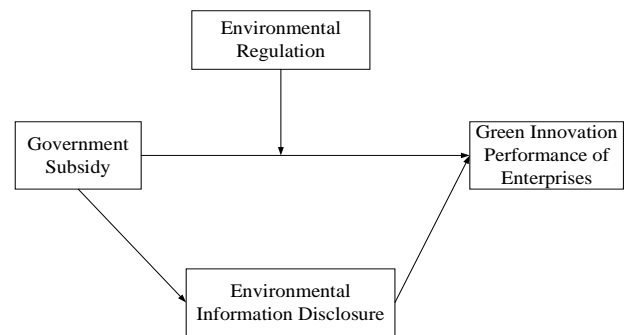


Figure 1. Theoretical Framework

4. Summary and Future Research Directions

This paper reviews the impact of government subsidies on corporate green innovation performance. Early research focused on subsidy motivations and their "incentive" and "crowding-out" effects, while recent studies explore non-linear effects and contextual factors influencing subsidy efficacy. By integrating institutional and principal-agent theories, this study proposes a unified analytical framework to examine how subsidies affect green innovation in heavily polluting enterprises, considering environmental regulation and information disclosure.

The findings of this study have significant policy implications. Policymakers should recognize the complex, non-linear relationship between subsidy intensity and innovation outcomes, and design subsidy programs that avoid potential crowding-out effects at high subsidy levels. The effectiveness of R&D subsidies can be enhanced by strengthening environmental regulations, creating a supportive institutional environment for green innovation. Implementing robust environmental information disclosure mechanisms is crucial for improving the efficiency of subsidy allocation and utilization. Moreover, subsidy policies should be differentiated based on enterprise characteristics such as ownership structure, size, and industry sector, acknowledging the heterogeneous responses of firms to government support. By considering these factors, policymakers can craft more targeted and effective subsidy programs that maximize the impact on green innovation performance.

Future research should focus on three key areas: Firstly, develop comprehensive econometric models that integrate firm-level data with institutional indicators, employing sophisticated statistical techniques to capture the non-linear dynamics between subsidy intensity and innovation performance. Secondly, conduct comparative studies across diverse governance contexts, particularly between state-owned and private enterprises, to elucidate how ownership structures and institutional environments shape innovation strategies and resource allocation in response to subsidies. Thirdly, explore the synergistic effects between R&D subsidies and other policy instruments, such as environmental regulations, green taxation, and information disclosure mechanisms. This holistic approach will facilitate the identification of optimal policy combinations, leveraging the complementary effects of various tools to maximize impact on green innovation performance.

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