sustainability

MDPI

Article

The Relationship between High-Tech Industrial Agglomeration and Regional Innovation: A Meta-Analysis Investigation in China

Lanqing Ge [1,†], Chunyan Li [1,*], Lei Sun [2,*], Weina Hu [3,†] and Qi Ban [4]

[1] Shanghai International College of Intellectual Property, Tongji University, Shanghai 200092, China; 2110983@tongji.edu.cn
[2] School of Economics, Anhui University, Hefei 230601, China
[3] School of Foreign Languages for Business, Guangxi University of Finance and Economics, Nanning 530007, China; verna880510@163.com
[4] School of Finance, Nankai University, Tianjin 300350, China; 1120190900@mail.nankai.edu.cn
* Correspondence: tjlcy0101@163.com (C.L.); i21201021@stu.ahu.edu.cn (L.S.)
† These authors contributed equally to this work.

Abstract: High-tech industrial agglomeration enhances the technological level and value of regional industries. It is considered to be a new and effective way to drive China's regional innovation and development at present. Numerous studies indicate that high-tech industrial agglomeration contributes positively to regional innovation, but the current academic discussion on this issue has not yet reached a unified opinion. In various research contexts, it has also been pointed out that there may be a negative correlation or non-linear relationship between the two. This contradictory relationship makes it difficult to generalize the current research findings to realistic application scenarios. Therefore, to clarify the relationship between the two scientifically, this study employs meta-analysis, reanalyzing 833 effect values derived from 69 independent research samples based on Chinese data. The findings reveal a moderately positive correlation (r = 0.204) between the agglomeration of high-tech industries and regional innovation in China. In particular, high-tech industrial agglomeration significantly contributes to regional innovation under the paths of diversified agglomeration and competitive agglomeration. We further found that sampling region, measurement approach, measurement perspective, research methodology, and year of publication all exhibit significant moderating effects on the relationship between the two variables. Based on meta-analysis, this study not only scientifically responds to the controversy of the relationship between high-tech industrial agglomeration and regional innovation but also further reveals the inner conduction mechanism between the two. It is of great significance in exploring future studies in related fields.

Keywords: high-tech industry agglomeration; regional innovation; meta-analysis; moderating effects

Citation: Ge, L.; Li, C.; Sun, L.; Hu, W.; Ban, Q. The Relationship between High-Tech Industrial Agglomeration and Regional Innovation: A Meta-Analysis Investigation in China. *Sustainability* **2023**, *15*, 16545. https://doi.org/10.3390/su152316545

Academic Editors: Marzia Traverso, Luigi Mundula and Maria Paradiso

Received: 15 October 2023
Revised: 27 November 2023
Accepted: 2 December 2023
Published: 4 December 2023

1. Introduction

Due to long-term high-intensity development and inefficient operation, various regions are facing problems such as weak economic growth, disorganization of the social structure, depletion of resources, and damage to the ecological environment. As a result, they seriously impede the sustainable development process [1]. In contrast, innovation drives high-quality economic development and enhances sustainable competitiveness [2]. The capacity and effectiveness of regional sustainable development are constrained and influenced by numerous factors. Among them, the technological factor is recognized as one of the vital engines and forces for sustainable development [3]. Innovation, as a significant modality and outcome of technological progress, takes on great significance for realizing sustainable development. According to the World Health Organization (WHO), sustainable development refers to the evolution of urban economies towards greater efficiency,

stability, and innovation with minimal use of resources [4]. While high-tech industries are characterized by low environmental pollution and low resource consumption, their production processes and products are often highly intelligent [5]. As a result, they are likely to decrease dependence on natural resources and energy as well as increase the efficiency of resource utilization. As the leading and strategic industries to enhance the competitiveness of regional innovation, high-tech industries serve not only as a fundamental means to optimize regional industrial structure but also as the backbone driving high-quality regional development and promoting China's high-quality economic development and transformation [6]. Therefore, as a crucial organizational form of industrial development, high-tech industrial agglomeration is considered a new and effective way to drive China's regional innovation development. It is also essential to further shape sustainable competitive advantage and realize sustainable strategic goals. In comparison with traditional industries, high-tech industries are characterized by knowledge-intensive, advanced technology, high value-added products and strong industrial relevance. As a result, firms can more easily adapt to the pace of market changes and technological advances and have the advantage of quickly adjusting their strategies and organizational structures than other industrial sectors. In particular, the agglomeration of high-tech industries exhibits evident technology diffusion and synergistic effects, significantly driving the production and employment of related industries in the region. The subsequent large-scale agglomeration effect can further stimulate regional endogenous dynamics and enhance regional industrial technology level and technology value, thus realizing optimal allocation and regeneration of regional innovation resources [7]. For example, the cluster of pharmaceutical companies in the Raleigh-Durham Research Triangle in North Carolina, United States, has attracted a large number of biotechnology companies, which has developed into one of the world's top biotechnology clusters. This cluster has driven a quantum leap in North Carolina's economy and technology [8]. Similarly, Silicon Valley has taken the lead in establishing an integrated industry-university-research system based on close interaction among local universities, research institutions, and enterprises. The vast innovation network allows Silicon Valley to become a "magnetic field", attracting talents, technologies, and capitals from all over the world and eventually confirming its status as a world innovation center and a global high-tech industry highland [9]. It can be seen that the knowledge spillover and the advantages of scale economy generated by the agglomeration of high-tech industries will inevitably contribute to the development of regional innovation. With the accelerating efficiency of scientific and technological change recently, the relationship between high-tech industrial agglomeration and regional innovation has become a hot topic in the realm of innovation and development. In particular, for developing countries with economies in transition, the development road based on the advantages of cheap labor and energy is unlikely to lead to sustainable prosperity. It is necessary to seek new dynamics of competitiveness and to find new solutions for sustainable development. Therefore, it is of great significance to clarify the relationship between the two so as to help China cultivate new dynamics of economic development and strengthen sustainable competitive advantage in the future. Thus, this study centers around three questions. Firstly, has China's high-tech industry agglomeration promoted regional innovation? Secondly, how strong is the relationship between the two? Thirdly, why are there differences in existing empirical research conclusions?

It is worth noting that although scholars have discussed the impact of high-tech industrial agglomeration on regional innovation from various perspectives, current academia has not yet reached a consensus on the relationship between the two. With different research backgrounds and data, studies show that the relationship between the agglomeration of high-tech industries and regional innovation may be linearly positive, linearly negative, or non-linear [10–12]. On the one hand, most of the studies indicate that high-tech industrial agglomeration has a positive impact on regional innovation. For example, Liu and Wu found that high-tech industries effectively promote green innovation under different agglomeration patterns [13]. Similarly, Zhang et al. pointed out from the perspective of development trends and regional heterogeneity that industrial agglomeration could

improve innovation performance through means of knowledge spillover, reducing innovation costs for enterprises, and optimizing reward and punishment incentive systems [14]. Yin and Guo discovered that the scale and technology effects brought about by the agglomeration of high-tech industries help improve local industries' technological level [15]. However, several studies also noted that the agglomeration of high-tech industries may exert a negative impact on regional innovation from specific perspectives. For example, Xie and Bu analyzed the relationship between the two based on the perspective of wage incentives and realized that specialized agglomeration exacerbates labor price distortions, resulting in a negative influence on the efficiency of innovation [16]. In addition, previous studies have put forward a third viewpoint that a non-linear relationship between high-tech industry agglomeration and regional innovation exists. For example, Bao and Li performed an empirical study of the Wuhan metropolitan area and proposed a nonlinear dual-threshold effect between the two in this region, exhibiting a "U" curve [17]. Similarly, Li et al. concluded that once the spatial agglomeration of high-tech industries reaches a certain threshold, the existence of the crowding effect will gradually weaken the regional innovation performance [18].

In summary, numerous studies have explored the relationship between high-tech industrial agglomeration and regional innovation from an empirical point of view and obtained research conclusions with excellent reference value. However, in terms of research content and research perspectives, the following shortcomings remain in the existing studies: Firstly, although most studies indicated that high-tech industrial agglomeration has a positive impact on regional innovation, several studies pointed out that there might be a negative or non-linear relationship between the two under different research contexts. This contradictory relationship makes it difficult to generalize the current research findings to realistic application scenarios. In addition, most studies are discussed based on data from developed countries, so in the case of China, which is undergoing an economic transition, the conclusions of the existing studies and the underlying influential mechanisms may not be directly applicable to the current situation of China's economic development. Hence, research on the impact of high-tech industrial agglomeration on regional innovation in developing countries still requires expansion. Secondly, existing literature merely focuses on the impact of high-tech industry agglomeration on regional innovation, lacking attention to the strength of the relationship between the two. In the "new normal" stage of promoting China's economy from high-speed growth to high-quality growth, innovative development is valuating in the whole society. Regions are taking advantage of the coordination linkage of industrial agglomeration to revitalize regional innovation. Therefore, exploring the intensity of the impact between high-tech industrial agglomeration and regional innovation is of great practical significance for the formulation and implementation of relevant economic policies, as well as an urgently vital research topic. Thirdly, although previous research has conducted conceptually qualitative reviews of the literature on the relationship between high-tech industry agglomeration and regional innovation, the summary of existing quantitative research results is insufficient, resulting in limitations in current research. For example, because of the influence of subjectivity on the literature selection in qualitative research, representative bias exists in literature subjects, which is detrimental to the objectivity and accuracy of research findings [19]. Therefore, it is necessary to seek more accurate and objective research methods to break through existing research bottlenecks.

Based on this, this study systematically analyzes the relationship between high-tech industrial agglomeration and regional innovation in China by using meta-analysis methodology. The results revealed that China's high-tech industrial agglomeration is positively and moderately correlated with regional innovation (r = 0.204). Moreover, diversified agglomeration and competitive agglomeration exert a significantly higher impact on regional innovation than specialized agglomeration. Sampling regions, measurement means and perspectives of regional innovation, research approaches, and publication years all play a moderating role in the relationship between the two. Compared with previous studies, the marginal innovation of this study lies in the following aspects. Firstly, this

study emphasizes providing a scientific response to the controversy over the relationship between high-tech industry agglomeration and regional innovation. The meta-analysis method is employed to systematically summarize and further statistically analyze empirical studies of the impact of high-tech industry agglomeration on regional innovation, presenting a realistic relationship between the two. Secondly, based on a scientific response to the relationship between the two, this study focuses on the strength of the relationship between high-tech industry agglomeration and regional innovation and comprehensively analyzes the effects of various data, model settings, and literature types on conclusions. Thirdly, no attention has yet been paid to the reasons that lead to the contradiction between high-tech industry agglomeration and regional innovation. This study further explores the reasons for the bias in research conclusions, identifies the moderating variables that lead to diverse research conclusions from four levels, including samples, literature, methods, and variables, and probes into the scenarios in which high-tech industry agglomeration affects regional innovation differently.

The research approach is as follows: Firstly, a review and summary of the existing relevant literature is conducted, forming hypotheses and an analytical framework. Secondly, strictly adhering to the steps of meta-analysis, the literature is screened and information extracted, followed by effect size calculation and exploration of heterogeneity. Thirdly, a meta-analysis of results is conducted, which mainly consists of a publication bias test, an overall effect analysis, a moderating effect analysis, and a robustness test. Finally, the results of this study are presented and discussed.

2. Research Hypothesis and Framework

2.1. The Influence of High-Tech Industry Agglomeration on Regional Innovation and Its Various Sub-Dimensions

The research on the relationship between industry agglomeration and regional innovation dates back a long time. Industrial agglomeration theory reveals that industrial agglomeration brings about external economies of scale, leading to cost reduction and increased benefits for enterprises within the region [20]. The agglomeration of high-tech enterprises can form an effective innovation network organization along the industry chain that reduces transaction costs and uncertainties, thus facilitating the flow of knowledge resources. Externality theory shows that the externality effect generated by industrial agglomeration is reflected in the following three aspects [21]. Firstly, geographic agglomeration is conducive to expanding market size. It generates economies of scale that can provide specialized and low-cost intermediate inputs for upstream and downstream firms, thereby exerting a positive impact on innovation activities in the region [22]. Secondly, the "reservoir" effect of the labor force is an aspect. The specialized labor market formed by industrial agglomeration facilitates firms to reduce the cost of searching for human resources, which in turn accelerates technological communication [23]. Thirdly, while industrial agglomeration forms an innovation network, it can effectively boost the knowledge spillover among network subjects so as to accelerate the accumulation of technologies and enhance regional innovation efficiency [24]. With the establishment of high-tech industry agglomeration areas, various entities such as universities and research institutions within the agglomeration area have the potential to become sources and carriers of knowledge spillovers. As a result, it will provide an enhanced exchange and learning platform for high-tech enterprises. By promoting diversified knowledge spillovers within the agglomeration area, collective learning effects and sharing benefits are generated, leading to shortened innovation cycles and achieving a leapfrog development in innovation [25]. The mainstream view believes that high-tech industries are characterized by knowledge-intensive and technology-intensive qualities, which are more likely to form agglomeration effects and have greater impacts on regional innovation than other industries. For example, high-tech industrial agglomeration is of great significance to innovation activities. It enhances the level of regional innovation by promoting the incremental effect of returns to scale generated by the aggregation of innovative factors, such as specialized talents and investment [26]. While Ye et al. found

that China's high-tech industry is characterized by typical regional concentration, the accumulation of knowledge brought about by the concentration of R&D personnel drives the optimal allocation of innovation resources and contributes to regional high-quality development [27]. Hence, several studies believe that high-tech industrial agglomeration can promote the flow of technology and knowledge within clusters and positively affect regional innovation.

However, with the emergence of resource competition and declining corporate profits, the existing studies have presented contrasting views, arguing that the impact of industry agglomeration on regional innovation is not always positive. The influential effect may vary to some extent in different scenarios. For example, in agglomeration areas where high-end innovation elements are scarce, fierce competition among high-tech enterprises for innovation resources may occur, leading to potential over-competition among companies and resulting in a crowded innovation environment [28]. When the degree of agglomeration surpasses the carrying capacity in the region, issues like resource scarcity, environmental pollution, and increased transportation costs may occur. Ultimately, the increase in operating costs and the inhibition of innovation activities lead to a deterioration in the level of innovation in the region. Wei et al. pointed out that excessive agglomeration triggers crowding effects, resulting in negative impacts such as traffic congestion in excess of the positive impacts of knowledge spillovers, which ultimately leads to a reduction in total factor productivity [29]. Moreover, within agglomeration areas, the high spillover nature of innovative knowledge and technology inevitably leads to 'free-riding' behavior. Additionally, as knowledge accumulates, the marginal cost of innovation gradually decreases, which weakens the incentives of technology pioneers to innovate to a certain extent, resulting in insufficient innovation and issues of technological lock-in [30].

Furthermore, several studies also argue that the relationship between the agglomeration of high-tech industries and regional innovation is not a static and singular phenomenon. Instead, it may be affected by various factors such as economic development level, regional layout, and foreign investment. For example, Zhang et al. discovered that different levels of regional development lead to the gradual weakening of the spillover effect of industrial agglomeration due to the siphoning effect of surrounding cities, which ultimately manifests as a diminishing regional innovation effect [31], while Kekezi and Klaesson pointed out that spillover effects of knowledge-intensive industry agglomeration diminish with increasing geographical distance and may impose adverse impacts on innovation after crossing the municipal margins [32]. Wang and Wu suggested that foreign investment can enhance the competitiveness among local enterprises, promote the output of innovative achievements, and thus improve regional innovation capacity [33].

Overall, high-tech industries, characterized as knowledge-intensive and technology-intensive, have become an integral force in China's economic construction, industrial upgrading, and regional development. In the market economy with Chinese characteristics, high-tech industry agglomeration creates advantages in industry access and market expansion through economies of scale and scope. The upgrading of innovation networks within agglomeration areas can continuously attract new enterprises, thereby enhancing the overall innovation capacity. The impact of high-tech industry agglomeration on regional innovation may vary due to factors such as temporal and spatial dynamics and industry differences. However, as the most innovation-intensive sector, the high-tech industry possesses unique advantages that other industries cannot match in driving and promoting regional innovation. In summary, this study proposes the following:

H1: *High-tech industry agglomeration and regional innovation are positively correlated.*

There are several ways to quantify the level of industrial agglomeration, such as location entropy, EG index, and spatial Gini coefficient. Previous literature has examined high-tech industrial agglomeration in different dimensions and measured its level of agglomeration. Several researchers analyzed the overall impact of high-tech industry

agglomeration on regional innovation based on the theory of industrial agglomeration. In terms of the overall dimension, on the one hand, firms have free access to resources generated by interactions within the cluster based on standard management rules and organizational procedures [34]. On the other hand, high-tech industrial agglomeration can promote the maintenance of a sustainable and stable relationship between the participants, which contributes to the development of technological innovation activities and improves the efficiency of technological innovation. In addition, studies confirm that industrial agglomeration is conducive to forming regional innovation networks and interacting with regional innovation environments, thereby promoting regional innovation development [35]. Considering that high-tech industry agglomeration can drive regional innovation activities under the overall dimension, this paper proposes the following:

H1a: *High-tech industrial agglomeration can significantly promote regional innovation development in the overall dimension.*

Several studies explore the impact of the structural characteristics of high-tech industrial agglomeration on regional innovation from the perspective of industrial agglomeration externalities. From the structural dimension, industrial agglomeration can be subdivided into specialized, diversified, and competitive agglomeration. Specialized agglomeration refers to the degree of homogeneous differences in industrial structure between a region and other regions. The agglomeration of homogeneous firms helps to increase the horizontal correlation of sectors within the industry. It reduces production costs, which in turn exerts a positive impact on innovation activities in the region [36]. Diversified agglomeration represents the diversity of industry structures between regions and is often calculated using the Herfindahl–Hirschman Index (HHI) or its modified versions. Diversified agglomeration is mainly based on the vertical correlation effect of the industry chain to reduce the production cost of enterprises, which is conducive to promoting new explorations by meeting the complementary technological needs of enterprises within clusters [37]. The measurement of competitive agglomeration mostly employs the method of industry concentration. Porter believes that competition is more conducive to growth [38]. A healthy industrial competition mechanism will stimulate enterprises to improve their R&D capabilities and thus maintain competitiveness continuously [39]. However, increasing homogeneous enterprises or decreasing market entry barriers within the agglomeration area can lead to malicious competition, resulting in a decline in regional innovation capacity [40]. Considering that high-tech industry agglomeration can drive regional innovation activities under the structural dimension, this paper proposes the following:

H1b: *High-tech industrial agglomeration can significantly promote regional innovation development in the structural dimension.*

Some other scholars measure the industrial agglomeration level according to the feature dimension. The indicators of the feature dimension contain both knowledge spillover and environmental optimization. This type of research argues that high-tech industry agglomeration reflects the geographical concentration of innovation activities, while knowledge spillover and innovation environment optimization are accompanying phenomena of high-tech industry agglomeration. On the one hand, it has become a necessity for high-tech industries that enterprises rely on the layout of knowledge resources. The externalities of knowledge are not only reflected in the fact that the accumulation of knowledge can effectively promote the improvement of industrial productivity. At the same time, knowledge spillovers allow the innovation benefits of capital, labor, knowledge, and other factors of production to increase, thus contributing to the long-term development potential of high-tech industries [41]. On the other hand, the innovation environment is considered a network organization rooted in industrial agglomerations [42]. The network organization serves as an important carrier for each subject to obtain information, resources, knowledge, and experience, which can strengthen the innovation advantages within clusters and

improve the adhesion of knowledge, talents, and other factors [43]. With the growth of high-tech industrial agglomerations, optimizing the innovation environment can improve the efficiency of the allocation of innovation resources and the risk resistance of enterprises. Ultimately, it leads to the enhancement of sustained innovation capacity. Considering that high-tech industry agglomeration can drive regional innovation activities under the feature dimension, this paper proposes the following:

H1c: *High-tech industrial agglomeration can significantly promote regional innovation development in the feature dimension.*

Based on the above theoretical analysis and research hypotheses, the basic framework of this study is obtained, which is detailed in Figure 1.

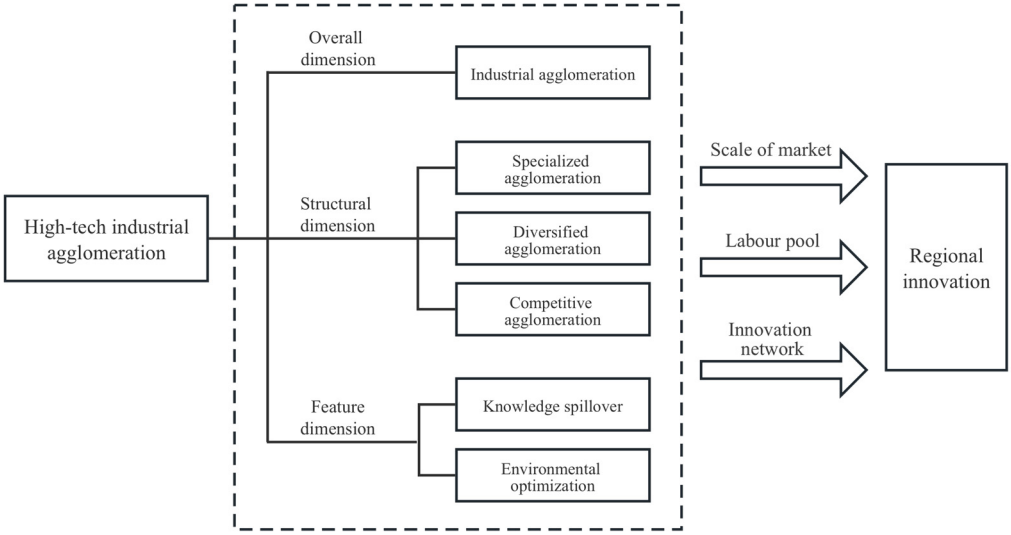

Figure 1. Meta-analysis diagram of the relationship between high-tech industrial agglomeration and regional innovation.

2.2. Factors That Moderate the Relationship between the Agglomeration of High-Tech Industries and Regional Innovation

2.2.1. The Source of Differences from the Sample

(1) The differences in the perspective of the sample stem from variations in the regional scope and sampling areas. Considering that studies conducted at the national level may lead to a reduction in effect sizes due to a broader sampling scope, different capabilities and macro- and micro-environments faced by firms in different regions may also result in variations in research outcomes [44]. For example, based on the national level, Zeng et al. investigated the internal logical connection between market transactions, agglomeration effects, and innovation performance. Based on this, they identified that the biopharmaceutical industry can form close and mutually beneficial partnerships by signing technology collaboration contracts under the guidance of policy and industrial planning, thereby promoting innovation efficiency [45]. While Wang and Hao, using nationwide data as their research object, discovered an inverted U-shaped relationship between the two factors, they argued that when the expansion of the agglomeration scale exceeds the carrying capacity of limited environmental resources and space, the resulting adverse competitive effects will hinder regional innovation development [46]. Pan et al. suggested that the promotion effect of high-tech industry agglomeration on export upgrading is significant in the eastern and western regions but not in the central region [47]. Xu and Zhang, using data from different regions as samples, concluded that high-tech industry agglomeration has a significant promoting effect in the eastern region, while its impact is not significant in the central and western regions [48]. Liu et al. analyzed the technology industry agglomeration in the

Yangtze River Delta city cluster. They found that it has both a direct and spillover effect on innovation efficiency [49].

(2) The differences in the perspective of the sample stem from variations in the data periods. The production capacity and innovation capability of high-tech industries vary across different periods. In recent years, with the development and increasing level of high-tech industry agglomeration, there has been enhanced information exchange and talent matching among industries, fostering a positive interaction among regional enterprises and creating a more conducive environment for innovation activities. Yang et al. analyzed the relationship between the agglomeration of high-tech industries and innovation efficiency from 2008 to 2017, and they found a positive linear relationship [50]. Using data from 2003 to 2016, Nan discovered an inverted U-shaped relationship [51]. It can be seen that research samples from different periods lead to different results.

2.2.2. The Source of Differences from the Variables

(1) The variations in measuring regional innovation arise from different approaches used. The measurement methods can be broadly categorized into two types: the single-indicator approach and the comprehensive evaluation approach. The single-indicator approach involves using specific metrics such as the number of granted patents, the number of patent applications, and the output of new products. On the other hand, the comprehensive evaluation approach considers innovation efficiency from both input and output perspectives. Numerous studies have indicated that the differences in variable-level measurement methods are a significant factor contributing to the variations in the results concerning the relationship between high-tech industry agglomeration and regional innovation [52,53]. For example, Li et al. used the sales revenue of new products as a measure of regional innovation performance and concluded that there is a non-linear relationship between the two [54]. Ji and Wang employed the Super Efficiency Model (SBM) to calculate innovation efficiency and found that industry agglomeration significantly and positively influences regional innovation [55].

(2) The variations in measuring regional innovation arise from different perspectives. Scholars mainly adopt four perspectives for assessing regional innovation: the patent perspective, product perspective, R&D perspective, and comprehensive perspective. These different perspectives imply different stages of regional innovation. The patent perspective examines the R&D efficiency of the high-tech industry and includes representative indicators such as the number of patent applications and granted patents. The product perspective emphasizes the marketization of innovative outcomes and includes indicators like the output value and sales revenue of new products. The R&D perspective solely focuses on research and development investments. The comprehensive perspective considers the entire process, from technological research to outcome commercialization. Thus, the relationship between high-tech industrial agglomeration and regional innovation may vary at different stages.

2.2.3. The Source of Differences from the Methodology

(1) The differences in research methods. Existing literature mainly employs two research methods: traditional panel regression and spatial panel regression. These methods have distinct assumptions and applicability, which can lead to varied conclusions. For instance, Yan et al. used both OLS and System-GMM and found a positive effect of high-tech industry agglomeration on regional innovation in both the R&D and the outcome conversion phase [56]. Fu et al. utilized the Spatial Durbin Model (SDM) and observed that when specialized agglomeration reaches a certain level, it may have a negative impact on the conversion of innovation outcomes in the local and neighboring regions [57].

2.2.4. The Source of Differences from the Literature

(1) The variation in publication years. In different time periods, scholars' research on whether high-tech industry agglomeration promotes regional innovation may be in-

fluenced by various factors, such as research hotspots, research foundations, and policy environments. For instance, in 2016, the Chinese State Council released the National Innovation-Driven Development Strategy Outline, which set strategic goals for technological innovation and made significant policy deployments in this area. As a result, during that period, scholars might have been more inclined to publish literature supporting a significant positive relationship between the agglomeration of high-tech industries and regional innovation.

(2) Different types of literature. The literature selected for this study includes both journal papers and dissertations. Journals with a peer-review system are more likely to publish papers with clear and significant findings, while studies with non-significant results or those contradicting the majority of literature may encounter challenges in publication. Additionally, authors of journal papers come from diverse backgrounds, including university faculty, students, and industry professionals, whereas dissertation authors are primarily graduate students. Thus, different types of journals may reveal different preferences for the research results on the relationship between high-tech industrial agglomeration and regional innovation.

(3) The quality and impact factors vary among different journals. Journals with different levels of influence may exhibit diverse research orientations. High-impact journals aiming to maintain sustained academic influence often prioritize the statistical significance of results and the novelty of research conclusions. Furthermore, with the growing interest in the curvilinear relationship between high-tech industry agglomeration and regional innovation in recent years, journals of different impact factors may also display varying preferences regarding higher-order relationships. As a result, journals with different impact factors may be one of the reasons for the differences in the relationship between high-tech industrial agglomeration and regional innovation.

To summarize, this paper explores the impact of different factors on the relationship between high-tech industrial agglomeration and regional innovation from the sample, variable, methodology, and literature levels. This study proposes the following:

H2: *Sources of variation at the sample level, the variable level, the methodological level, and the literature level can moderate the relationship between high-tech industrial agglomeration and regional innovation.*

The research framework is presented in Figure 2.

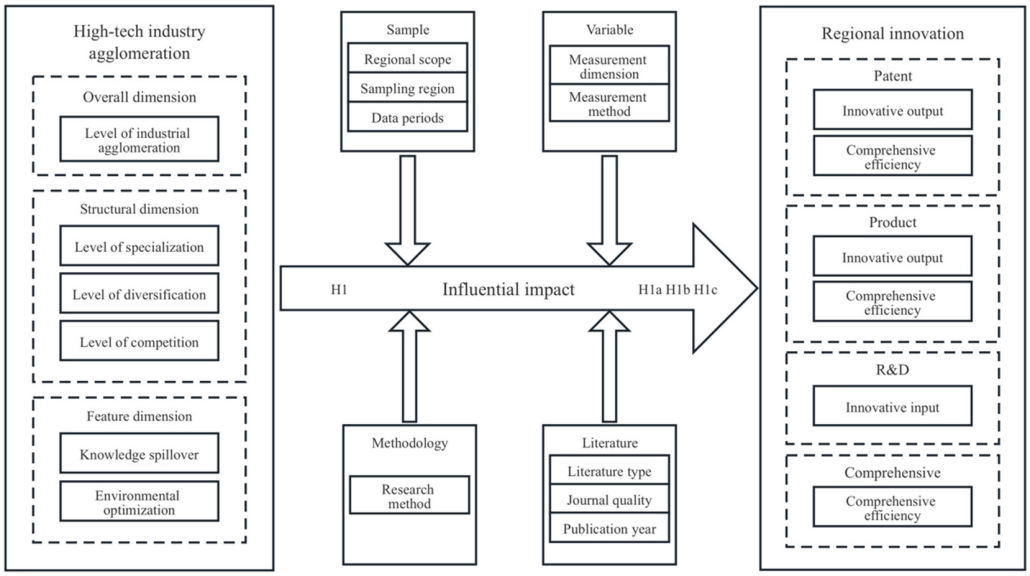

Figure 2. The meta-analysis framework of the relationship between high-tech industry agglomeration and regional innovation.

3. Research Method

This study uses a meta-analytic approach to identify the relationship between high-tech industrial agglomeration and regional innovation and the significance of its moderating variables. As a rigorous quantitative analysis method, meta-analysis allows for systematically summarizing previous research findings. It is particularly well suited to tackle issues where research conclusions are ambiguous or subject to dispute. When there are many quantitative research results related to the same issue but showing different results, meta-analysis can be used to sort out and reanalyze the existing quantitative research results to obtain more accurate and robust research findings. It addresses the limitation of traditional descriptive literature reviews, which do not allow for quantitative analysis of research findings [58]. Because of the current abundance of empirical research results on the relationship between high-tech industrial agglomeration and regional innovation, but the studies have not reached consistent conclusions, this study applies meta-analysis to synthesize and analyze them and utilizes a more comprehensive range of samples to draw more reliable conclusions.

The flow of analysis in this study is as follows: Firstly, we search and browse the literature and then collect data from various databases by following strict literature inclusion criteria. Secondly, the correlation coefficients are categorized and coded from the obtained literature related to the research topic. The coding consists of two main parts: the study descriptors and the statistical measures. This study focuses on identifying and categorizing variables and factors in related studies. Finally, we use STATA to analyze the data and obtain objective and accurate findings. The research design of this paper is shown in Figure 3.

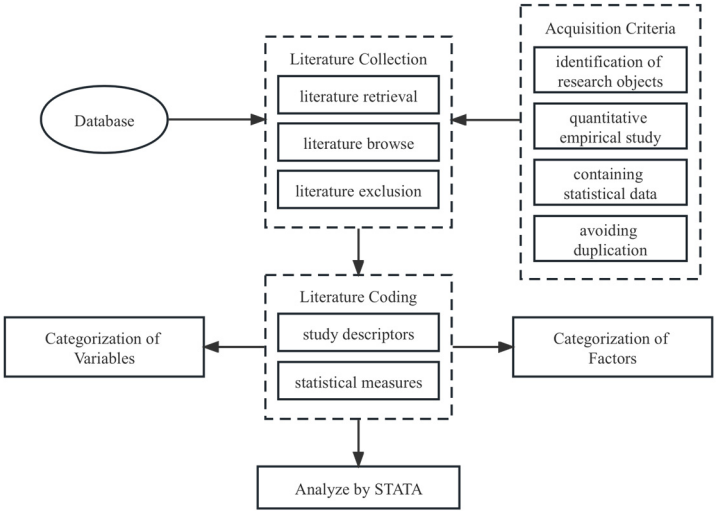

Figure 3. Research design of meta-analysis on the relationship between high-tech industrial agglomeration and regional innovation.

3.1. Data Source and Sample Selection

To ensure the comprehensiveness and accuracy of the literature included in the meta-analysis, this study follows the literature screening process proposed by Havránek et al. and strictly adheres to the following steps [59]. Firstly, a comprehensive full-text search is conducted using various combinations of keywords such as 'high-tech industry', 'agglomeration', 'industrial agglomeration', 'regional innovation', 'innovation', and 'innovation efficiency' in multiple databases, including China National Knowledge Infrastructure (CNKI), VIP, Baidu Scholar, Web of Science, Google Scholar, and others. To avoid any omissions, relevant reference lists from the reviewed literature are manually searched and supplemented. Through these steps, a total of 4418 initial literature records are obtained and imported into the EndnoteX9 reference management software. Secondly, strict screening is conducted based on several principles. Firstly, the selected literature must focus on the influence of high-tech industry agglomeration on regional innovation within

the context of China. Secondly, only empirical studies using quantitative analysis will be considered, thus excluding review articles and qualitative analysis literature, such as theoretical research and case studies. Thirdly, the literature must present regression results of high-tech industry agglomeration and regional innovation (beta coefficients, t-values, standard errors, *p*-values, etc.) to ensure the acquisition of relevant effect values. Fourthly, duplicate literature will be excluded; in cases where multiple articles with the same topic are authored by the same or collaborative authors, only the most comprehensive and representative one will be retained.

Based on the criteria mentioned above, a total of 69 original papers were finally included in this study, comprising 33 journal papers and 36 dissertations. The 36 dissertations included 7 doctoral dissertations and 29 master's theses. The time span of the literature ranged from 2011 to 2023. The detailed process of literature selection is presented in Figure 4.

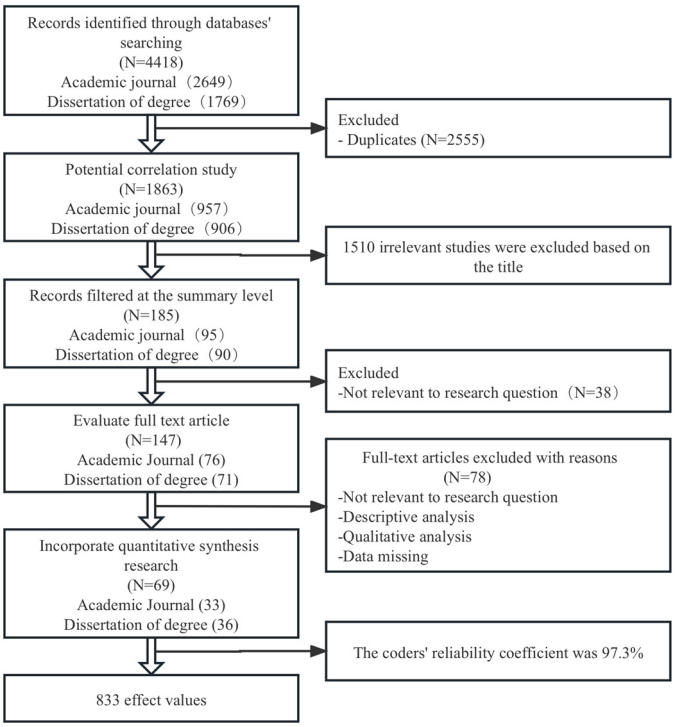

Figure 4. The process of literature retrieval, screening, and effect size coding.

3.2. Coding Rules and Effect Size Calculation

After determining the sample for analysis, relevant information and data need to be extracted from the literature. This study focuses on two aspects for coding and effect size calculation: study descriptors and statistical measures. The coding of study descriptors involves the analysis, summarization, and categorization of the extracted information. Descriptors are categorized into four levels: sample, variable, methodology, and literature. Descriptors of sample level include coding for indicators such as sample size, time span, and regional scope. Descriptors of variable level involve coding for measurement dimensions and methods related to high-tech industry agglomeration and regional innovation. Descriptors of methodology level pertain to the coding of research methods used. Descriptors of the literature level include coding for journal types, publication years, impact factors, and other relevant information. After encoding and transforming the sample information from the literature, effect size calculation is necessary. Effect size represents the standardized relationship between the independent and dependent variables. Since all included literature in this study utilizes correlation coefficients or regression techniques for analysis, this paper adopts a correlation-based (*r*-based) effect size to represent the relationship between high-tech industry agglomeration and regional innovation. The specific approach

is as follows: firstly, the parameters extracted from the original literature are converted into correlation coefficient r, and the calculation method is as follows: $r = \sqrt{t^2/(t^2 + df)}$, where t represents the result of the t-test for the regression coefficient, and df stands for degrees of freedom. Since the original studies use different sample sizes, it is necessary to convert r to the standardized effect size to correct for the small sample bias caused by the correlation coefficient r. The calculation method is as follows: $Zr = 0.5ln[(1 + r)/(1 - r)]$. Subsequently, the standardized effect size is converted back to the effect size r used in this analysis. Due to variations in variable measurements, regional scope, and model settings, the same study may generate multiple effect values. To ensure the accuracy of the encoded data, two trained coders independently coded the samples from the included literature, and the coding reliability was subsequently calculated. The computed coding reliability was 97.33%, indicating a high level of consistency in the coded data. Considering that the inconsistencies mainly resulted from operational errors and subjective judgment, the coders addressed them through error correction and discussion to reach a consensus. Ultimately, we extracted 833 effect sizes from the 69 original studies, comprising 606 effect sizes greater than 0 and 227 effect sizes less than 0.

4. Results of Meta-Analysis

Firstly, this study utilizes the meta-analysis to extract and synthesize path coefficients from the database, calculating the average effect size of the original samples and conducting tests for heterogeneity. Secondly, we examine the potential publication bias in existing research. Lastly, the meta-analysis is performed to explore the main factors influencing the heterogeneity of the relationship between high-tech industry agglomeration and regional innovation, and a discussion of the results is as follows.

4.1. Publication Bias Analysis

Meta-analysis is an observational analysis, and bias may arise at various stages of the analysis process. Publication bias can lead to erroneous conclusions about the consensus within the academic community and can also exaggerate the average effect size between correlated variables, both positively and negatively. Therefore, prior to conducting the meta-analysis, it is critical to examine the potential bias in the literature. Methods for testing publication bias include funnel plots, Egger's test, Begg's test, and the fail-safe N test, among others.

To ensure the validity and reliability of the research findings, this study employs Egger's test and the fail-safe N test to test for publication bias (see Table 1). The result of Egger's test was 0.867, and all corresponding values for other variables were also greater than 0.05, indicating the absence of significant publication bias. Moreover, the fail-safe N value was 183,256, which substantially exceeded the '5 k + 10' criterion (4070). Additionally, the fail-safe N values for other sub-dimensions also passed the test, suggesting no significant publication bias in this research. Overall, based on these analyses, this study's results are deemed stable and reliable.

4.2. Overall Effect Analysis

In this study, we conducted heterogeneity analysis to examine the differences among multiple independent samples. The results of the heterogeneity analysis are presented in the left side of Table 2. Heterogeneity is commonly assessed using the Q-statistic and I^2. If $Q > df(Q)$, $p < 0.05$, and $I^2 > 0.75$, it indicates that the effect sizes follow a heterogeneous distribution, and a random-effects model is adopted. On the other hand, if the Q-statistic is not significant and I^2 is below 0.75, it suggests that the effect sizes follow a homogeneous distribution, and a fixed-effects model is used. As shown in Table 2, the significant Q-test results and I^2 values greater than 0.75 indicate a high level of heterogeneity among the sample literature, thus leading us to use the random-effects model in this study.

Table 1. Egger's test and fail-safe N test.

Category	*N*	Egger's Test			Fail-Safe Number
	K	*p*-Value	Interval Estimation		*N*
H1	814	0.867	−0.527	0.444	183,256
H1a	381	0.669	−0.570	0.888	
H1b	415	0.464	−0.908	0.415	39,510
Specialized agglomeration	192	0.668	−1.143	0.734	
Diversified agglomeration	165	0.836	−0.930	1.148	
Competitive agglomeration	58	0.178	−3.614	0.684	
H1c	18	0.321	−2.917	8.378	211
Knowledge spillover	3	0.104	−145.370	412.047	
Environmental optimization	15	0.381	−3.576	8.744	159

Table 2. Overall effect.

Variable	Heterogeneity Test				Random-Effects Model					Effect Magnitude
	Df	*p*-Value	I^2	*Q*	*z*	σ	Point Estimation	Lower Limit	Upper Limit	
H1	813	0.000	75.57	3327.73	12.21	0.164	0.204	0.172	0.236	Moderate
H1a	380	0.000	77.86	1716.45	8.57	0.184	0.218	0.169	0.265	Moderate
H1b	414	0.000	73.36	1553.95	8.26	0.151	0.188	0.144	0.231	Low
Specialized agglomeration	191	0.000	72.85	703.40	4.32	0.151	0.147	0.080	0.211	Low
Diversified agglomeration	164	0.000	72.07	587.13	6.40	0.140	0.224	0.157	0.289	Moderate
Competitive agglomeration	57	0.000	77.24	250.43	3.43	0.177	0.218	0.095	0.335	Moderate
H1c	18	0.000	68.71	54.33	3.25	0.088	0.270	0.109	0.417	Moderate
Knowledge spillover	2	0.000	51.58	4.00	1.26	0.067	0.193	−0.108	0.462	Low
Environmental optimization	14	0.000	71.91	49.84	2.96	0.105	0.288	0.100	0.456	Moderate

Table 2 presents the effects of high-tech industry agglomeration on regional innovation across different dimensions. The results show that the overall average effect size of high-tech industry agglomeration on regional innovation is 0.204, with a significant level at the 95% confidence interval [0.172, 0.236]. In this case, the criteria for the interpretation of the size of the correlation coefficient refer to the study of Gignac and Szodorai, where $0.2 > r > 0.1$, $0.3 > r > 0.2$, and $r > 0.3$ are considered low, moderate, and high correlations, respectively. Based on this criterion, this study suggests that the agglomeration of high-tech industries has a moderate and positive impact on regional innovation. Specifically, when examining the overall dimension, the average effect size of high-tech industry agglomeration is 0.218, with a significant level at the 95% confidence interval [0.169, 0.265], indicating a moderate and positive correlation between high-tech industry agglomeration and regional innovation. It shows that high-tech industry agglomeration significantly contributes to regional innovation in the overall dimension. When considering the structural dimension, the average effect size of high-tech industry agglomeration on regional innovation is 0.188, with a significant level at the 95% confidence interval [0.144, 0.231], indicating a low and positive correlation between the two. Among them, the average effect sizes for specialized agglomeration, diversified agglomeration, and competitive agglomeration are 0.147, 0.224, and 0.218, respectively. It suggests that a difference exists in the role of high-tech industrial

agglomeration on regional innovation under different structural dimensions, in which diversified agglomeration exerts a more significant impact on the relationship between the two, followed by competitive agglomeration, and specialization agglomeration exerts the slightest effect. When examining the feature dimension, the average effect size of high-tech industry agglomeration is 0.27, with a confidence interval [0.109, 0.417] at 95% significant level, suggesting a moderate and positive correlation between high-tech industry agglomeration and regional innovation. Specifically, the average effect sizes for knowledge spillover and environmental optimization are 0.193 and 0.288, respectively, representing a low and positive correlation and a moderate and positive correlation. That is, different features of high-tech industrial agglomeration positively affect regional innovation, with environmental optimization playing a more significant role in knowledge spillovers. Based on these results, hypotheses 1, 1a, 1b, and 1c are all supported.

4.3. Moderating Effect Analysis

The overall effect test of the meta-analysis indicates a high heterogeneity between high-tech industry agglomeration and regional innovation, suggesting that the relationship between them is influenced by potential moderating variables. To examine this effect, we encoded and conducted subgroup analysis on the collected information and data, and the results are shown in Table 3. (1) From the perspective of the sample, there is no significant difference in the relationship between the agglomeration of high-tech industries and regional innovation when using the nationwide sample or regional sample. The subgroup analysis shows a Q value of 4078.25, $p > 0.05$. However, when further subdividing the regions, the results indicate a significant moderating effect on the relationship between the two ($Q = 834.57$, $p < 0.05$). Among them, the correlation coefficient between them in the central region ($r = 0.238$) is greater than that in the eastern and western regions, with the eastern region showing the smallest correlation coefficient ($r = 0.133$). Additionally, the research results show that the data period does not moderate the relationship between the two ($Q = 3327.73$, $p > 0.05$). (2) From the perspective of the variables, there is a significant difference in the results between studies that measure the impact of high-tech industry agglomeration on regional innovation using a single indicator and those using a comprehensive indicator. Subgroup analysis shows a Q value of 4078.25, $p < 0.05$, indicating that the different measurement methods for regional innovation have a certain moderating effect on the relationship between the two. Studies using a single indicator to measure regional innovation have a higher average effect size ($r = 0.232$) compared to studies using a comprehensive indicator ($r = 0.173$). Furthermore, the perspective of measuring regional innovation has a significant moderating effect on the relationship between the two variables ($Q = 4078.25$, $p < 0.05$). Studies that measure regional innovation from a patent perspective have a higher average effect size ($r = 0.243$) than those using other perspectives. (3) From the perspective of methodology, the research methods have a significant moderating effect on the relationship between the agglomeration of high-tech industries and regional innovation ($Q = 6.41$, $p < 0.05$). Studies using traditional panel regression ($r = 0.236$) show a stronger positive correlation compared to studies using spatial panel regression ($r = 0.204$). (4) From the perspective of the literature, both journal type ($Q = 3327.73$, $p > 0.05$) and journal quality ($Q = 3327.73$, $p > 0.05$) fail to moderate the relationship between the agglomeration of high-tech industries and regional innovation. However, the publication year has a significant moderating effect on the relationship between the two ($Q = 4078.25$, $p < 0.05$). More recent publications tend to report stronger correlation conclusions ($r = 0.214$).

In summary, the sampling region, the measurement of regional innovation, the assessment of regional innovation, the research method, and the publication year all exhibit significant moderating effects on the relationship between the two variables ($p < 0.05$). Hence, H2 is partially supported.

Table 3. Moderating effect test.

	Variable	Category	*k*	95% CI			Heterogeneity Test			
				Estimate	Lower Limit	Upper Limit	*Q*	*Df*	*p*-Value	I^2
Sample	Sampling region	Nationwide	421	0.175	0.13	0.22	4078.25	894	0.873	0.781
		Region	412	0.173	0.14	0.205				
		Eastern	232	0.133	0.079	0.186	834.57	392	0.005	0.53
		Central	84	0.238	0.118	0.351				
		Western	96	0.193	0.148	0.238				
	Data periods	2010 and after	493	0.191	0.153	0.228	3327.73	813	0.379	0.756
		Before 2010	340	0.204	0.172	0.236				
Variable	Assessment of regional innovation	Patent	256	0.243	0.171	0.311	4078.25	894	0.005	0.781
		New product	305	0.197	0.152	0.241				
		R&D	18	0.123	0.000	0.242				
		Comprehensive	254	0.173	0.140	0.205				
	Measurement of regional innovation	Single indicator	399	0.232	0.182	0.282	4078.25	894	0.001	0.781
		Comprehensive indicator	434	0.173	0.140	0.205				
Methodology	Research method	Panel regression	528	0.236	0.197	0.273	6.41	813	0.011	0.756
		Spatial regression	305	0.204	0.172	0.236				
Literature	Journal type	Journal	249	0.193	0.128	0.257	3327.73	813	0.671	0.756
		Dissertation	584	0.204	0.172	0.236				
		Quality (journal)	213	0.193	0.128	0.257	3327.73	813	0.671	0.756
		Regular (journal)	36	0.204	0.172	0.236				
	Publication year	2018 and after	632	0.214	0.180	0.248	4078.25	894	0.001	0.781
		Before 2018	201	0.173	0.140	0.205				

4.4. Robustness Test

This paper uses meta-regression analysis to examine the robustness of the results for the above moderating effects by drawing on the study of Tilley et al. [60]. It is advantageous to check whether a continuous-type variable affects the effect size by regarding that variable as a predictor variable. The results of the robustness test are shown in Table 4. At the sample level, the sampling region positively moderates the relationship between high-tech industrial agglomeration and regional innovation ($p < 0.05$). At the variable level, both measurement method and perspective positively moderate the relationship between the two ($p < 0.05$). At the method level, the research method positively moderates the relationship between the two ($p < 0.05$). At the literature level, publication year exhibits a positive and moderating effect on the relationship between the two ($p < 0.05$). This finding is consistent with the results obtained from subgroup analysis, affirming the stability of the conclusions drawn in this study.

Based on the above results, high-tech industrial agglomeration in China plays an outstanding role in promoting regional innovation. At the same time, multiple factors (sampling region, measurement method, measurement perspective, research methodology, and publication year) moderate the relationship between the two. For the sampling region, the positive correlation between high-tech industrial agglomeration and regional innovation is most remarkable in the central region. For the measurement method, using a single indicator to measure regional innovation yields stronger positive correlation conclusions. In terms of measurement perspectives, high-tech industrial agglomeration exerts the most substantial driving effect on regional innovation as measured by the patent perspective. Regarding the research methodology, ordinary panel regression is more likely to obtain positive correlation conclusions than spatial panel regression. In addition, the correlation coefficients are more significant for recently published literature than for earlier publications. The summary of research results is indicated below (Table 5).

Table 4. Robustness test.

	Moderating Variable	*N*	*B*	*SE*	*T*	*P*	σ	I^2
Sample	Regional scope	421/412	−0.007	0.035	−0.19	0.853	0.192	0.776
	Sampling region	232/84/96	0.068	0.029	2.36	0.019	0.135	0.537
	Data periods	493/340	−0.044	0.035	−1.26	0.206	0.192	0.776
Variable	Assessment of regional innovation	256/305/18/254	0.052	0.014	−3.77	0.000	0.188	0.773
	Measurement of regional innovation	399/434	0.052	0.014	−3.77	0.000	0.188	0.773
Methodology	Research method	528/305	0.112	0.034	−3.24	0.001	0.189	0.773
Literature	Journal type	249/584	−0.098	0.092	1.06	0.289	0.215	0.809
	Journal quality	213/36	−0.029	0.038	−0.77	0.442	0.192	0.776
	Publication year	632/201	0.148	0.038	−3.92	0.000	0.187	0.773

Table 5. Meta-results of various variables.

Variable	Category	Sub-Dimension	Hypothesis	Significance	The Magnitude of Correlation
				Yes/No	
Core variables and sub-dimensions	Core variables	/	H1	Yes	Moderate
	/	Overall dimension	H1a	Yes	Moderate
	/	Structural dimension	H1b	Yes	Low
	/	Feature dimension	H1c	Yes	Low
Moderating variables and sub-dimensions	Sampling region	Nationwide	H2	No	/
		Region			/
		Eastern		Yes	Low
		Central			Moderate
		Western			Low
	Data periods	2010 and after		No	/
		Before 2010			/
	Measurement of regional innovation	Assessment of regional innovation		Yes	Moderate
		Patent			Moderate
		New product			Low
		R&D			Low
		Comprehensive			Low
		Single indicator			Moderate
		Comprehensive indicator			Low
	Research method	Panel regression		Yes	Moderate
		Spatial regression			Moderate
	Journal type	Journal		No	/
		Dissertation			/
	Publication year	Quality (journal)		No	/
		Regular (journal)			/
		2018 and after		Yes	Moderate
		Before 2018			Low

5. Discussion

This study applies meta-analysis to integrate the relationship between high-tech industrial agglomeration and regional innovation in China, based on 69 empirical literature publications from worldwide data sources. The conclusion agrees with most existing literature that there is a significant positive correlation between high-tech industrial agglomeration and regional innovation, and the strength of the relationship between the two is moderate. In addition, this study explores five potential moderating variables regarding sampling area, measurement method, measurement perspective, research method, and publication year.

Specifically, high-tech industrial agglomeration promotes regional innovation development through the three paths of economies of scale, the "reservoir" effect of labor, and the formation of innovation networks. There is a positive and moderate correlation between high-tech industrial agglomeration and regional innovation in China. It indicates that the continuous growth of high-tech industries and the strengthening of industry agglomeration positively influence regional innovation. Whether based on the overall, structural, or feature dimensions, high-tech industrial agglomeration shapes regional innovation advantages and promotes the enhancement of regional innovation capacity. Therefore, policy makers have to consider and pay attention to this development approach as an essential means to enhance regional innovation capacity and realize sustainable development strategies. From the structural dimension, the impact of diversified agglomeration and competitive agglomeration on regional innovation takes precedence over that of specialized agglomeration. It implies that the abundance of factors such as capital, talents, and energy resources among industries as well as healthy competition among enterprises are more conducive to the enhancement of regional innovation capacity. The advantage of diversified agglomeration lies in its ability to promote knowledge sharing, technology exchange and the collision of innovative thinking, thus providing more inspiration and ideas for innovation. At the same time, it offers a broader range of markets and resources to provide more support and security for innovation. As for competitive agglomeration, it provides enterprises with more market opportunities and resources to help them better realize innovation and development. In contrast, while specialized agglomeration enhances the productivity and competitiveness of firms, it may also lead to over-reliance on specific technologies and markets, thus limiting the innovative capacity and development space of firms. From the feature dimension, the environment optimization brought by high-tech industry agglomeration has a more substantial positive effect on regional innovation. It shows that a favorable innovation environment offers significant support for the innovation activities of enterprises, research institutions, and other organizations. The innovation environment is the summary of the relationship formed by the combination of various elements within the spatial scope of the innovation subject, which reflects the cluster's level of openness to the outside world, creative vitality, and other aspects of the situation. A favorable innovation environment not only improves the quality and effectiveness of innovation achievements, but also fosters more innovative talents and provides a constant impetus for the progress and development of society. Therefore, all sectors of society have to join efforts to create a favorable environment for innovation and to promote the sustainable development and growth of innovative activities. In general, broad innovation space and rich innovation resources represent high priorities for the development of high-tech industry clusters. Policy makers have to focus on cooperation and coordination among cluster subjects so as to achieve resource sharing and complementary advantages.

It is important to note that the overall conclusions drawn from the meta-analysis do not invalidate specific studies that have not been supported. The analysis conducted here focuses on the simple correlation between two variables, and the closeness of their relationship may be influenced or interfered with by other variables. Therefore, this study performed subgroup analysis from four perspectives: sample characteristics, variable characteristics, methodology characteristics, and literature characteristics, to systematically examine potential moderating factors that could influence the relationship between the agglomeration of high-tech industries and regional innovation. The findings revealed the following:

Sample characteristics can lead to significant differences in the relationship between high-tech industry agglomeration and regional innovation. On the one hand, the regional scope does not have a significant moderating effect on the relationship between high-tech industry agglomeration and regional innovation. However, different sampling regions can result in variations in the positive impact of industry agglomeration, as different regions in China have unique characteristics in terms of resource distribution, geographical location, innovation environment, and economic development [61]. The results indicate that in

the central region, the correlation between the agglomeration of high-tech industries and regional innovation is positive and the strongest. In recent years, policy makers from China have implemented various targeted policies, including industrial transfer, urban cluster development, and opening-up, to encourage the rise of the central region. Specific plans have been formulated and implemented to facilitate the advance of the central region. Therefore, the central region should further capitalize on its strengths and accelerate the absorption of industrial transfers from the eastern region to enhance regional economic and innovation capabilities. The eastern region possesses an advantageous geographical location and an open technological innovation environment, contributing to diverse and competitive agglomeration due to its advanced economic development. However, excessive agglomeration may lead to crowding-out effects, which can lock the cognitive distance of technological innovation for enterprises, creating barriers to knowledge absorption and hindering further improvements in innovation capabilities. On the other hand, the western region faces relative technological backwardness due to talent scarcity, and the advantages brought by high-tech industry agglomeration have not been fully realized yet. It is worth noting that the large sample size from the eastern region in this study (k = 232) may have led to a reduction in its effect size. In conclusion, considering the development status of each region, China should devise more flexible and targeted policies to address the current situation. Adopting and applying differentiated industrial agglomeration guidance policies may provide better development conditions for regional entrepreneurial innovation.

On the other hand, the moderating effect of the data period on the relationship between high-tech industry agglomeration and regional innovation is not significant, indicating that their relationship may exhibit stability over different time periods. Although the development patterns of the high-tech industry may have varied in different eras, overall, China's progress in the high-tech industry has been relatively steady. Since 1956, when China introduced the *1956–1967 Vision Plan for Scientific and Technological Development*, it has initiated a series of measures to promote high-tech advancements and fostered the growth of the first generation of high-tech research capabilities, laying a solid foundation for the progress of China's high-tech industry. Subsequent to the opening-up and reform, the gradual establishment of favorable policy environments and service systems led to the creation of a large number of high-tech enterprises, showcasing robust developmental vitality. Over the last few years, the continual expansion of the high-tech industry has infused the economy with more momentum to achieve high-quality growth.

Furthermore, the measurement and assessment of regional innovation significantly moderate the relationship between high-tech industry agglomeration and regional innovation. Firstly, compared to using comprehensive efficiency as a measure of regional innovation, using a single indicator is more likely to yield positive correlations and a stronger effect magnitude. Innovation efficiency tends to show more neutral and robust estimation results as it is influenced by both input and output. On the other hand, studies that only consider a single index for analysis, such as using metrics like patent applications or sales revenue from new products to represent regional innovation, can highlight the advantages brought about by high-tech industry agglomeration, thus obtaining more significant research results. Additionally, measuring regional innovation from the perspective of patent is more likely to yield significant and positive correlations, indicating that the agglomeration of high-tech industries has a greater impact on promoting technological R&D. This is because technological R&D heavily relies on the rational allocation of research resources. Regions with high-tech industry agglomeration often attract advanced enterprises and talents, creating an environment conducive to information exchange and knowledge spillover, thereby enhancing R&D efficiency. Compared with the patent indicator, the impact of high-tech industrial agglomeration on new products is even lower, which indicates that China's innovation activities are still facing a serious situation of "large quantity" but "low quality". The benefits of high-tech industrial agglomeration are more reflected in the number of patents, while the question of how it can be transformed into new products and become a new driving force for China's sustained economic growth is

still an issue that deserves to be explored. Therefore, according to their own development situations, local policy makers should adjust their R&D inputs to enhance the quality of innovation as well as the quantity of innovation outputs so as to avoid the waste of social resources caused by low-quality innovations.

Furthermore, different research methods significantly moderate the relationship between high-tech industry agglomeration and regional innovation. Traditional panel regression yields higher correlation coefficients compared to spatial panel regression. This difference may be because spatial regression introduces the concept of the 'neighboring effect,' which focuses more on the impact of geographical distance. As a result, while analyzing the effects on the local area, it may also report effects on neighboring regions. The polarization effect of the growth pole theory reveals that regions with superior location conditions will attract the continuous concentration of production factors from surrounding areas toward the pole, creating a siphon effect that could have adverse implications for innovation in the surrounding regions. Therefore, employing spatial regression analysis might lead to more neutral results and consequently result in a decrease in effect size. Moreover, the relationship between the agglomeration of high-tech industries and regional innovation is also influenced by the characteristics of the published literature. The type of literature and the quality of journals do not significantly impact the above conclusions, meaning that whether it is a journal paper or a dissertation, regardless of the impact factor, there is no intentional selection of specific relationships or results that may cause publication bias. However, the publication year moderates the relationship between high-tech industry agglomeration and regional innovation. It is likely because the rapid development of high-tech industries over the past few years and the continuous introduction of favorable policies have made scholars more inclined to publish conclusions that show a positive correlation between the two. Additionally, the number of journal papers published after 2017 (24 papers) far exceeds those published before (9 papers), indicating a significant increase in academic attention to this topic in recent years.

6. Conclusions

China has a vast population, but it is relatively poor in resources and fragile in ecology. In the previous process of economic development, China has adopted a crude growth pattern of high input and low efficiency, thus placing the carrying capacity of the ecological environment in a critical state of overload. This development pattern is hardly sustainable without timely adjustments to the concepts and ways of promoting economic and social development. Under such circumstances, the real question of whether the agglomeration of high-tech industries promotes regional innovation in China matches the economic pattern and respects the objective reality. It is essential for promoting upgrading industrial structure and realizing sustainable regional development. The results of this study show a significant and positive correlation between high-tech industrial agglomeration and regional innovation. The findings support H1 and align with the majority of existing research. Additionally, this study elucidates the moderate strength of their correlation, signifying that the relationship between high-tech industry agglomeration and regional innovation is statistically significant, underscoring the importance of not disregarding or overstating their interconnection in practical endeavors. Policy makers have to rationally control the scale of high-tech industry agglomeration by adjusting tax or other preferential policies. Moreover, the results show that the correlation coefficients between diversified agglomeration, competitive agglomeration, and regional innovation are higher than the correlation coefficient between specialized agglomeration and regional innovation. This indicates that complementary industries and appropriate competition have a greater influence on regional innovation. Therefore, policy makers have to encourage the progress of high-tech industry agglomerations with shared knowledge foundations and forward–backward linkages. It should actively leverage the knowledge spillover and radiation effects of high-tech industry agglomerations to drive overall regional innovation levels and improve efficiency. Additionally, this study applies the moderating effect test to further explore the relationship

between high-tech industrial agglomeration and regional innovation. We identify that the sampling region, the measurement method, the measurement perspective, the research methodology, and publication year play a moderating role in the relationship between the two.

This study is based on controversies and substantial accumulated original research on high-tech industry agglomeration and regional innovation. It employs meta-analysis to investigate the relationship between the two factors in the context of China, utilizing data from a wide-ranging and meticulously curated selection of journal papers and dissertations, thus obtaining comprehensive and objective research conclusions. Clarifying the relationship between high-tech industrial agglomeration and regional innovation is conducive to the healthy development of high-tech industries and the implementation of sustainable development strategies. At the same time, this study not only enriches the research content and research methodology in the field of regional innovation but also furnishes sufficient empirical evidence to facilitate the development of high-tech industries. Moreover, we accurately and objectively identify the strength of the relationship between the two, providing a practical decision-making reference for formulating reasonable and efficient regional innovation policies and enhancing China's innovation capacity.

However, this study also has some limitations. Firstly, it solely focuses on the impact of high-tech industry agglomeration on regional innovation within the context of China and does not address the relationship between the two factors in other countries. Furthermore, this study solely focused on the moderating factors that influence the overall effect of the relationship between high-tech industry agglomeration and regional innovation. It employed subgroup analysis to examine their moderating effects but did not explore the possibility of a curvilinear relationship and its influencing factors. In the future, it would be beneficial to employ alternative methods to further validate these aspects. Moreover, the relationship between high-tech industry agglomeration and regional innovation is influenced by various factors, some of which were not included in this study. Future meta-research in this field could explore the moderating effects of other factors, such as economic development level, human capital, and degree of openness, and investigate the stable and indirect mechanisms between high-tech industry agglomeration and regional innovation. Last but not least, in view of the critical connection between regional innovation and sustainable development, it is beneficial to further examine the impact and path of high-tech industry agglomeration on regional sustainable development.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su152316545/s1.

Author Contributions: Methodology, L.G. and C.L.; Software, C.L. and W.H.; Validation, L.G. and Q.B.; Formal analysis, L.G., C.L. and Lei Sun; Investigation, L.G., C.L. and L.S.; Resources, L.S. and Q.B.; Data curation, W.H.; Writing—original draft, L.G., W.H. and Q.B. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Social Science Foundation (The Strategic Research on China's Participation in Global Governance of Intellectual Property under the New Situation) under Grant (2A&ZD165).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available in Supplementary Materials.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Cillo, V.; Petruzzelli, A.M.; Ardito, L.; Del Giudice, M. Understanding sustainable innovation: A systematic literature review. *Corp. Soc. Responsib. Environ. Manag.* **2019**, *26*, 1012–1025. [CrossRef]
2. Ahmad, N.; Liu, Y.J.; Zikovic, S.; Belyaeva, Z. The effects of technological innovation on sustainable development and environmental degradation: Evidence from China. *Technol. Soc.* **2023**, *72*, 102184. [CrossRef]

3. Nara, E.O.B.; da Costa, M.B.; Baierle, I.C.; Schaefer, J.L.; Benitez, G.B.; do Santos, L.; Benitez, L.B. Expected impact of industry 4.0 technologies on sustainable development: A study in the context of Brazil's plastic industry. *Sustain. Prod. Consum.* **2021**, *25*, 102–122. [CrossRef]
4. Ghobakhloo, M.; Iranmanesh, M.; Mubarak, M.F.; Mubarik, M.; Rejeb, A.; Nilashi, M. Identifying industry 5.0 contributions to sustainable development: A strategy roadmap for delivering sustainability values. *Sustain. Prod. Consum.* **2022**, *33*, 716–737. [CrossRef]
5. Gupta, B.B.; Gaurav, A.; Panigrahi, P.K.; Arya, V. Analysis of artificial intelligence-based technologies and approaches on sustainable entrepreneurship. *Technol. Forecast. Soc. Change* **2023**, *186*, 122152. [CrossRef]
6. Chen, X.Q.; Liu, X.W.; Zhu, Q.Y. Comparative analysis of total factor productivity in China's high-tech industries. *Technol. Forecast. Soc. Change* **2022**, *175*, 121332. [CrossRef]
7. Presutti, M.; Boari, C.; Majocchi, A.; Molina-Morales, X. Distance to Customers, Absorptive Capacity, and Innovation in High-Tech Firms: The Dark Face of Geographical Proximity. *J. Small Bus. Manag.* **2019**, *57*, 343–361. [CrossRef]
8. Moretti, E. The Effect of High-Tech Clusters on the Productivity of Top Inventors. *Am. Econ. Rev.* **2021**, *111*, 3328–3375. [CrossRef]
9. Kerr, W.R.; Robert-Nicoud, F. Tech Clusters. *J. Econ. Perspect.* **2020**, *34*, 50–76. [CrossRef]
10. Fan, J.T.; Zhao, F.S.; Zhao, Y.H. The Potential of Industrial Agglomeration to Promote Pharmaceutical Innovation: Analysis of China's "Medicine Valley" Construction Upsurge. *China World Econ.* **2022**, *30*, 86–112. [CrossRef]
11. Tao, C.Q.; Xu, Y.; Peng, Y.Z.; Li, H. Driving mechanism and spatial effect of technological potential energy agglomeration promoting the development of high-tech industry. *Econ. Res.-Ekon. Istraz.* **2022**, *35*, 5924–5946. [CrossRef]
12. Tong, T.; Zainudin, N.B.; Yan, J.W.; Abd Rahman, A. The Impact of Industry Clusters on the Performance of High Technology Small and Middle Size Enterprises. *Sustainability* **2023**, *15*, 9333. [CrossRef]
13. Liu, S.; Wu, P. The impact of high-tech industrial agglomeration on China's green innovation efficiency: A spatial econometric analysis. *Front. Environ. Sci.* **2023**, *11*, 414. [CrossRef]
14. Zhang, R.; Sun, B.; Liu, M. Do External Technology Sourcing and Industrial Agglomeration Successfully Facilitate an Increase in the Innovation Performance of High-Tech Industries in China? *IEEE Access* **2019**, *7*, 15414–15423. [CrossRef]
15. Yin, X.B.; Guo, L.Y. Industrial efficiency analysis based on the spatial panel model. *EURASIP J. Wirel. Commun. Netw.* **2021**, *2021*, 28. [CrossRef]
16. Zhang, C.; Qin, J.; Zhou, Y. Study on Effects of Industrial Agglomeration on Regional Innovation under the Technology Diffusion: Based on the Angle of Value Chain in the Two Stages. *Sci. Sci. Manag. S. & T.* **2017**, *38*, 124–132.
17. Bao, J.H.; Li, Y. Has high-tech cluster improved regional innovation capacity? evidence from Wuhan metropolitan area in China. *Front. Environ. Sci.* **2023**, *11*, 1180781. [CrossRef]
18. Li, T.C.; Shi, Z.Y.; Han, D.R.; Zeng, J.W. Agglomeration of the new energy industry and green innovation efficiency: Does the spatial mismatch of R&D resources matter? *J. Clean. Prod.* **2023**, *383*, 135453.
19. Andrews, I.; Kasy, M. Identification of and correction for publication bias. *Am. Econ. Rev.* **2019**, *109*, 2766–2794. [CrossRef]
20. Marshall, A. Principles of Economies. Master's Thesis, Macmillan, London, UK, 1920.
21. Beaudry, C.; Schiffauerova, A. Who's right, Marshall or Jacobs? The localization versus urbanization debate. *Res. Policy* **2009**, *38*, 318–337. [CrossRef]
22. Huang, Y.; Hong, T.; Ma, T. Urban network externalities, agglomeration economies and urban economic growth. *Cities* **2020**, *107*, 102882. [CrossRef]
23. Feser, E.J. Tracing the sources of local external economies. *Urban Stud.* **2002**, *39*, 2485–2506. [CrossRef]
24. Baptista, R.; Swann, P. Do firms in clusters innovate more? *Res. Policy* **1998**, *27*, 525–540. [CrossRef]
25. Chandrashekar, D.; Subrahmanya, M.H.B. Exploring the factors of cluster linkages that influence innovation performance of firms in a cluster. *Econ. Innov. New Technol.* **2019**, *28*, 1–22. [CrossRef]
26. Yang, S.; Liu, W.; Zhang, Z. The Dynamic Value of China's High-Tech Zones: Direct and Indirect Influence on Urban Ecological Innovation. *Land* **2022**, *11*, 59. [CrossRef]
27. Ye, J.; Wan, Q.; Li, R.; Yao, Z.; Huang, D. How do R&D agglomeration and economic policy uncertainty affect the innovative performance of Chinese high-tech industry? *Technol. Soc.* **2022**, *69*, 101957.
28. Henderson, V.J. Marshall's Scale Ecnomomies. *J. Urban Econ.* **2003**, *53*, 1–28. [CrossRef]
29. Wei, W.; Zhang, W.L.; Wen, J.; Wang, J.S. TFP growth in Chinese cities: The role of factor-intensity and industrial agglomeration. *Econ. Model.* **2020**, *91*, 534–549. [CrossRef]
30. Hoffmann, V.E.; Belussi, F.; Martinez-Fernandez, M.T.; Reyes, E. United we stand, divided we fall? Clustered firms' relationships after the 2008 crisis. *Entrep. Reg. Dev.* **2017**, *29*, 735–758. [CrossRef]
31. Zhang, M.; Li, W.; Zhang, R.; Yang, X. How do manufacturing and producer service agglomerations affect urban innovation differently? Empirical evidence from China. *PLoS ONE* **2022**, *17*, e0275616. [CrossRef]
32. Kekezi, O.; Klaesson, J. Agglomeration and innovation of knowledge intensive business services. *Ind. Innov.* **2020**, *27*, 538–561. [CrossRef]
33. Wang, C.C.; Wu, A.Q. Geographical FDI knowledge spillover and innovation of indigenous firms in China. *Int. Bus. Rev.* **2016**, *25*, 895–906. [CrossRef]
34. Alberti, F.G.; Belfanti, F.; Giusti, J.D. Knowledge exchange and innovation in clusters: A dynamic social network analysis. *Ind. Innov.* **2021**, *28*, 880–901. [CrossRef]

35. Qin, X.H.; Wang, X.L.; Kwan, M.P. The contrasting effects of interregional networks and local agglomeration on R&D productivity in Chinese provinces: Insights from an empirical spatial Durbin model. *Technol. Forecast. Soc. Change* **2023**, *193*, 122608.
36. Zhang, X.L.; Hu, X.H.; Xu, W. Spatio-temporal dynamics of technical efficiency in China's specialized markets: A stochastic frontier analysis approach. *Growth Change* **2020**, *51*, 1182–1202. [CrossRef]
37. Zhang, L.; Mu, R.Y.; Hu, S.H.; Zhang, Q.; Wang, S. Impacts of Manufacturing Specialized and Diversified Agglomeration on the Eco-Innovation Efficiency-A Nonlinear Test from Dynamic Perspective. *Sustainability* **2021**, *13*, 3809. [CrossRef]
38. Porter, M.E. Location, competition, and economic development: Local clusters in a global economy. *Econ. Dev. Q.* **2000**, *14*, 15–34. [CrossRef]
39. Wolff, G.; Wältermann, M.; Rank, O.N. The embeddedness of social relations in inter-firm competitive structures. *Soc. Netw.* **2020**, *62*, 85–98. [CrossRef]
40. Cao, S.L.; Feng, F.; Chen, W.Y.; Zhou, C.Y. Does market competition promote innovation efficiency in China's high-tech industries? *Technol. Anal. Strateg. Manag.* **2020**, *32*, 429–442. [CrossRef]
41. Lee, P.C. Investigating the Knowledge Spillover and Externality of Technology Standards Based on Patent Data. *IEEE Trans. Eng. Manag.* **2021**, *68*, 1027–1041. [CrossRef]
42. Zhao, N.; Lei, C.C.; Liu, H.; Wu, C.L. Improving the Effectiveness of Organisational Collaborative Innovation in Megaprojects: An Agent-Based Modelling Approach. *Sustainability* **2022**, *14*, 9070. [CrossRef]
43. Heaphy, L.; Wiig, A. The 21st century corporate town: The politics of planning innovation districts. *Telemat. Inform.* **2020**, *54*, 101459. [CrossRef]
44. Li, X.Y.; Tang, J.H.; Huang, J.Y. Place-based policy upgrading, business environment, and urban innovation: Evidence from high-tech zones in China. *Int. Rev. Financ. Anal.* **2023**, *86*, 102545. [CrossRef]
45. Zeng, J.J.; Liu, D.J.; Yi, H.T. Agglomeration, Structural Embeddedness, and Enterprises' Innovation Performance: An Empirical Study of Wuhan Biopharmaceutical Industrial Cluster Network. *Sustainability* **2019**, *11*, 3922. [CrossRef]
46. Wang, H.; Hao, W. Impact of high-tech industrial agglomeration on the efficiency of green innovation in China. *China Soft Sci.* **2022**, *8*, 172–183.
47. Pan, K.; He, F.; Liu, R. Does High-Tech Industry Agglomeration Promote Its Export Product Upgrading?—Based on the Perspective of Innovation and Openness. *Sustainability* **2022**, *14*, 8148. [CrossRef]
48. Xu, S.; Zhang, Y. Impact of Manufacturing Agglomeration on the Green Innovation Efficiency-Spatial Effect Based on China's Provincial Panel Data. *Int. J. Environ. Res. Public Health* **2023**, *20*, 4238. [CrossRef]
49. Liu, P.Z.; Zhao, Y.M.; Zhu, J.N.; Yang, C.Y. Technological industry agglomeration, green innovation efficiency, and development quality of city cluster. *Green Financ.* **2022**, *4*, 411–435. [CrossRef]
50. Yang, J.; Wang, S.; Sun, S.; Zhu, J. Influence Mechanism of High-Tech Industrial Agglomeration on Green Innovation Performance: Evidence from China. *Sustainability* **2022**, *14*, 3187. [CrossRef]
51. Nan, S. Research on the Influence of High-tech Industry Specialization Agglomeration on Innovation Efficiency. In *E3S Web of Conferences*; EDP Sciences: Les Ulis, France, 2021; Volume 235.
52. Li, X.; Lai, X.D.; Zhang, F.C. Research on green innovation effect of industrial agglomeration from perspective of environmental regulation: Evidence in China. *J. Clean. Prod.* **2021**, *288*, 125583. [CrossRef]
53. Xu, D.; Yu, B.; Liang, L. High-Tech Industrial Agglomeration and Urban Innovation in China's Yangtze River Delta Urban Agglomeration: From the Perspective of Industrial Structure Optimization and Industrial Attributes. *Complexity* **2022**, *2022*, 2555182. [CrossRef]
54. Li, T.; Liang, L.; Li, Y. Specialized agglomeration, human capital mismatch and innovation performance of the high-tech industry—A case study by taking the pharmaceutical manufacturing industry as an example. *Sci. Res. Manag.* **2021**, *42*, 131–137.
55. Ji, Y.; Wang, Z.L. Impact of local living environment on innovation efficiency of high-tech industries in China: A spatial analysis. *Environ. Sci. Pollut. Res.* **2022**, *29*, 73563–73576. [CrossRef]
56. Yan, J.; Wang, J.; Wang, L. Research on the Innovation Efficiency and Its Influencing Factors of Urban High-Tech Industrial Parks:a Case Study of Zhongguancun Technology Park in Beijing. *Urban Stud.* **2020**, *27*, 132–140.
57. Fu, W.F.; Luo, C.J.; He, S. Does Urban Agglomeration Promote the Development of Cities? An Empirical Analysis Based on Spatial Econometrics. *Sustainability* **2022**, *14*, 14512. [CrossRef]
58. Stanley, T.D. Wheat from chaff: Meta-analysis as quantitative literature review. *J. Econ. Perspect.* **2001**, *15*, 131–150. [CrossRef]
59. Havránek, T.; Stanley, T.D.; Doucouliagos, H.; Bom, P.; Geyer-Klingeberg, J.; Iwasaki, I.; Reed, W.R.; Rost, K.; van Aert, R.C. Reporting guidelines for meta-analysis in economics. *J. Econ. Surv.* **2020**, *34*, 469–475. [CrossRef]
60. Tilley, J.L.; Huey, S.J.; Farver, J.M.; Lai, M.H.C.; Wang, C.X. The Immigrant Paradox in the Problem Behaviors of Youth in the United States: A Meta-analysis. *Child Dev.* **2021**, *92*, 502–516. [CrossRef]
61. Xu, A.T.; Qiu, K.Y.; Jin, C.Y.; Cheng, C.J.; Zhu, Y.H. Regional innovation ability and its inequality: Measurements and dynamic decomposition. *Technol. Forecast. Soc. Change* **2022**, *180*, 121713. [CrossRef]