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A critical review of the current research mainstreams and the influencing factors of green total factor productivity

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Abstract

The current world economy needs to undergo a green transformation. Green total factor productivity provides the basis for judging whether a country or region can attain long-term sustainable development. However, there is little research into the factors that influence green total factor productivity and this has become an obstacle in the transition to a greener economy. On filtering relevant articles and interviews data collected from 2009 to 2019, open, spindle, and selective decoding are carried out to classify research conducted into green total factor productivity. From this analysis, cutting-edge research and knowledge gaps in green total factor productivity are identified. Also, an influencing factors model of green total factor productivity is built. Findings suggest that technical, economic, and government are the three main research streams involved in this transformation process. In particular, technology plays a decisive role, economy plays a guaranteeing role, and government plays a regulatory

role. Moreover, the impact of these factors cannot be isolated, as each influence and mediate the other two. Results from this study will help further popularize green total factor productivity and provide a new starting point for reducing energy consumption and environmental pollution.

Keywords Green total factor productivity; Green transformation; Grounded theory; Qualitative research

Introduction

While the global economy has made great strides since the Industrial Revolution, it has also created some serious challenges. The problem of energy and the ecological environment is becoming increasingly serious at the expense of resource consumption and environmental degradation. Despite the world's average 1971-2012 annual GDP growth rate of just 3%, total primary energy consumption doubled and CO_2 emissions from fuel combustion increased by almost 20 billion tons (World Bank, 2015). At the same time, according to the report of the first World Health Organization (WHO) Global Conference on Air Pollution and Health in 2018, an estimated 7 million people die every year from air pollution caused by excessive ambient fine particulate matter, $PM_{2.5}$ (WHO, 2018). Around 90% of urban air has particle concentrations that exceed the WHO air quality guidelines. As a result, the world has an urgent need to adopt energy conservation and emission reduction measures, carry out a green transformation, and eventually achieve sustainable development.

Many studies have shown that the adoption of sustainable development practices improve resources utilization and emissions reduction without damaging economic growth (Paramati et al., 2017; Apergis and Gangopadhyay, 2020; Murshed, 2021). The United Nations officially adopted the "Changing Our World: The 2030 Agenda for Sustainable Development," which sets out 17 global sustainable development goals (SDG) (Murshed, 2019). For the first time, different countries share specific, measurable indicators and completion deadlines. This action will hopefully lead to achieving global sustainable development in multiple dimensions such as resources utilization, environment protection, and economy development (Murshed and Tanha, 2020). There is no doubt that sustainable development is here to stay. And in the foreseeable future, sustainable development may lead to a new pattern of global development (Liu et al., 2021).

A path to sustainable economic development is to improve Green Total Factor Productivity (GTFP) (Chen et al., 2018). GTFP is a new definition of energy and environmental constraints based on the traditional total factor productivity accounting framework (Feng and Serletis, 2014). GTFP attaches great importance to energy consumption and environmental pollution (Lin and Chen, 2018; Zhu et al., 2018). Namely, GTFP is aligned with the original intention of finding a balance between man and nature. This, by properly handling the relationship between economic development, resource utilization and environmental protection, and constantly seeking for clean energies (Murshed, 2020). Hence, GTFP can be used to assess whether a country or region can achieve long-term sustainable development (Song et al., 2018; Ben Jebli et al., 2019). However, there are many influencing factors in GTFP that mainstream research has yet to clarify. A better understanding of these factors can lead to understanding GTFP more holistically, which in turn can be helpful to achieve green economic development.

However, most studies only focus on the impact on GTFP from a single perspective. They do not consider other aspects comprehensively enough to develop a productivity impact factor model that can accelerate a country’s green transformation. Cao et al. (2020), for example, studied the impact of environmental regulations on China's manufacturing sector to further promote the green development in manufacturing. Zhang et al. (2019) analyzed the impact of market misallocations on GTFP by combining data from countries along the Belt and Road. Similarly, Li and Lin (2017) explored how industrial structure and economic development patterns affect green productivity.

In response, the present study aims to systematically study the influencing factors of GTFP by a regression analysis combined with grounded theory. Based on the GTFP-related literature with large impact factors and high citations, a qualitative analysis approach is adopted. First, the literature and interview materials are reviewed to extract and code the GTFP influencing factors. Then, a subordinate relationship between these factors is established for spindle decoding an initial contour. The relationship between the main axis decoding is then further explored with more representative words for selective decoding. Finally, all current encodings are checked and a new GTFP factor model is proposed.

This study overcomes some limitations of previous research into GTFP by adopting a qualitative bibliometric study method, analyzing the factors affecting GTFP, and building a holistic model. This model has the potential to improve the green productivity of domestic companies and accelerate a country's green performance. The findings will also provide a scientific basis for policy-makers to develop measures for promoting competition between organizations and improving their overall efficiency.

The next section introduces the research methods used, as well as the data collection and filtering process. Section 3 elaborates on the research findings, including current GTFP research trends, statistical results from research journals, and retrospective findings. Section 4 discusses these findings before finally drawing the main conclusions in Section 5.

Research methods

Research framework

This study comprises a qualitative analysis of the factors influencing GTFP based on grounded theory. Originally proposed by Glaser and Strauss (1967), grounded theory is based on the collection and analysis of data. In particular, it roots around the data to construct a bottom-up theory that reflects social phenomena observations. Three processes embody grounded theory: open decoding, main axis decoding, and selective decoding. It carries these out without resorting to any preestablished assumptions, and finally draws conclusions. Grounded theory is suitable here as it allows conclusions to be drawn from qualitative data. Figure 1 illustrates the research framework adopted.

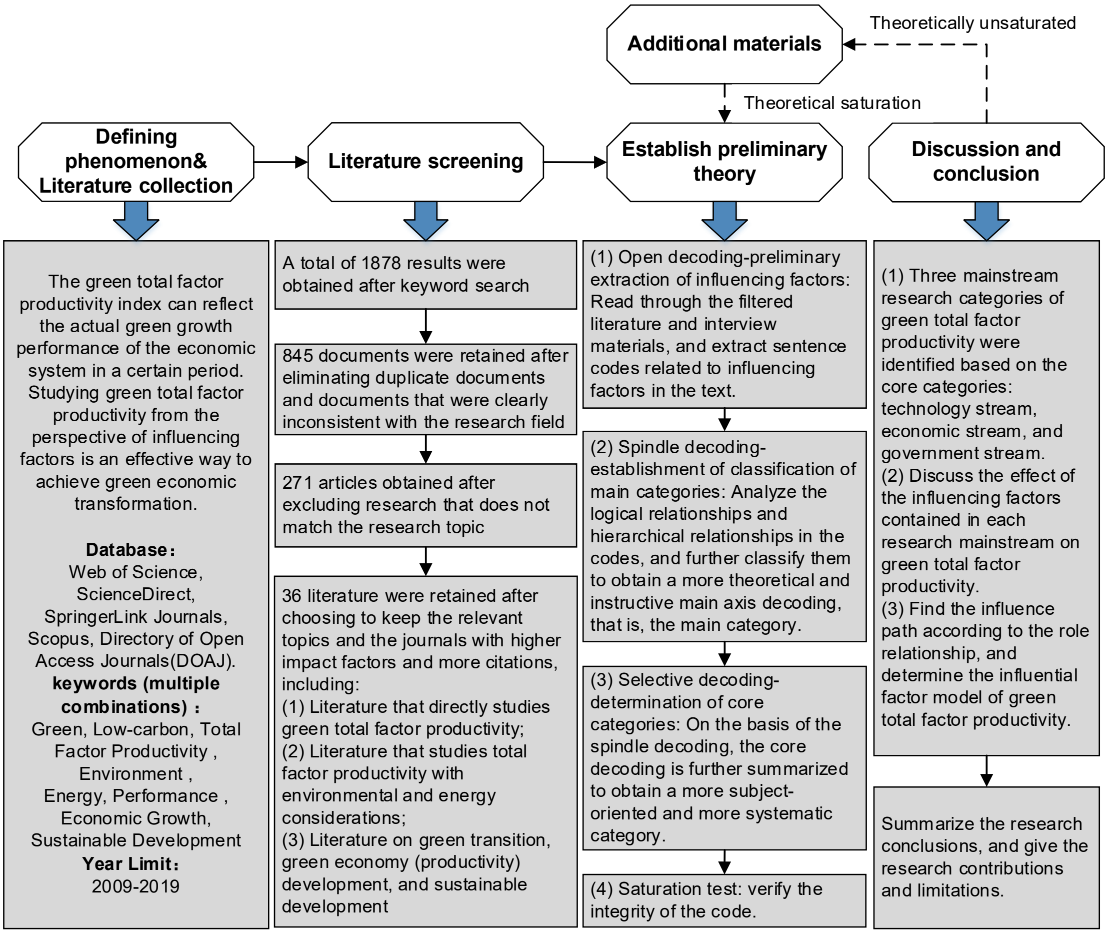

Fig. 1 Research framework

Data collection

The research involves information collected from a wide literature search and interviews. Grounded theory needs to describe the original data in depth. In order to uncover the hidden laws in the data better and present them systematically, it is necessary to make this information more representative. Hence, data relevant to GTFP is collected from researchers, corporate executives, and government personnel first. The following subsections describe this process.

Data from the literature

The published research results were gathered by a literature search. To help ensure comprehensiveness, the keywords (multiple combinations) of "Green", "Low-carbon", "Carbon Emission Total Factor Productivity", "Environment", "Energy", "Performance", "Economic Growth", and "Sustainable Development" were used as search expressions in several databases (Web of Science, ScienceDirect, SpringerLink Journals, Scopus, and the Directory of Open Access Journals). The time-span window is the 2009-2019 period, as it was from 2009 when GTFP caught the researchers' attention. When screening manuscripts, it was necessary to eliminate documents unrelated to this study while retaining those most relevant (particularly those with a large number of citations and published in journals with high impact factors). In the process of contribution screening, it was also necessary to eliminate repeated pieces of research. In this way, a total of 1878 articles were initially retrieved, and reduced to 36 after the screening process. Figure 1 summarizes this process.

Interview data

The interviewees were proactively selected, as this helps in reducing the sample size of a study, as well as gathering information that is more likely to be insightful. The selected interviewees were mostly company managers and government personnel. As they all had wide experience in the industry and/or the government, they all had a deep understanding of GTFP − their views and opinions also being more representative and practical. The interviews were semi-structured, with question sets partially adapted to each of the two interview groups. Table 1 shows the interview protocols used.

Table 1 Interview protocols

Interview group	Basic information	Interview protocol
Government officials	Gender, age, position	1. What do you know about green total factor productivity? 2. What policies and regulations have the government currently adopted to encourage the development of green total factor productivity? 3. What measures do you think the government can take to improve green total factor productivity and how could society cooperate?
Business executives	Gender, age, management level	1. What do you know about green total factor productivity? 2. What methods do you know of to improve total factor productivity within your company. What role do you think these methods currently play? 3. As a manager, what methods do you think companies can use to improve green total factor productivity, and how do you hope the government or society can help?

Two interview methods were established – one for offline interviews and one for online interviews. Each interviewee was contacted before the interview to agree on the interview time and location, and for briefing on the interview background and topic involved. A total of 17 people was interviewed, with each interview lasting approximately 15 minutes. After ruling out incomplete and non-reference interviews, 15 effective interviews were considered valid. Of these, 73% interviewees were male, 66% were 40-50 years old, 6 were government officials (4 from environmental protection departments), and 9 were corporate management staff (3 from senior management and 4 from middle management).

Results

General trends in GTFP research

Several previous studies of GTFP focused on the relationship between GTFP and its influencing factors. Li and Liao (2020), for example, studied the heterogeneity of the impact of financial development on GTFP in 40 countries from the perspective of banking and insurance. Zhang et al. (2019) conducted a study of GTFP in 33 countries along the "Belt and Road" and concluded that inappropriate market distribution has had a severe negative impact on the GTFP of various economies. Martinez-Zarzoso et al. (2019) used data from 14 Organization for Economic Co-operation and Development countries to explore the impact of strict environmental policies on national total factor productivity (TFP), finding that stricter environmental regulations can promote cleaner production and benefit TFP.

Other studies focus on the analysis of factors affecting GTFP in an industry or region. Balezentis et al. (2020), for example, proposed a quantitative mixed method to analyze the evolution of total environmental factor productivity in the agricultural sector of European countries, finding that the changes in environmental total factor productivity were convergent in various countries and attributable to technological progress. Ghosal et al. (2019) explored the impact of environmental regulations and implementation policies on factory-level GTFP based on data from the Swedish paper industry − their results showing that environmental policies have a beneficial impact on GTFP growth and sustainable production practices in manufacturing plants. Chen et al. (2018) proposed a two-level analysis framework to assess the GTFP of the Chinese construction industry and analyze its changing trends, finding that differences in the total factor productivity of the regional construction industry increases over time, and that economic, industrial, and technological levels also have a significant effect.

Almost all studies of the factors conditioning GTFP use quantitative techniques, including parametric and non-parametric methods. However, as parametric methods require specific information concerning inputs and outputs, non-parametric methods are much more frequent. For example, Männasoo et al. (2018) used the Solow residual method, control function method, stochastic frontier analysis (SFA), and non-parametric data envelope analysis (DEA) to study the influencing factors of TFP. Feng et al. (2017) also used DEA and a green development performance index to analyze panel data from 165 countries to estimate green development performance from a global perspective. Amani et al. (2018) used a slack-based measure (SBM) model to measure the Malmquist productivity index in a variable income model and as an indicator of changes in total factor productivity over time.

The results of this preliminary literature review outline some emerging directions of GTFP research and highlight a lack of qualitative and holistic analyses. The theoretical approach used here provides an unexplored and alternative approach to study GTFP.

Journals publishing GTFP-related studies

A total of 128 journals published GTFP-related studies from 2009 to 2019. Table 2 presents those cited more frequently, together with their h- and g-index. *Applied Energy* ranks the highest. Its h-index is 17, which means that at least 17 of the 56 articles published in the journal were cited at least 17 times. The g-index is 36, which indicates that, when all the articles in the journal are sorted into descending order of number of citations, the number of citations is at least 36 squared, that is, 1296 times (the total number of citations of that journal was 1317). *Applied Energy*, *Energy Policy*, *Energy*, and *Energy Economics* all focus on energy and fuels, while the main research area of the *Journal of Cleaner Production* is green sustainable science and technology. *Renewable & Sustainable Energy Reviews* focuses on both of these areas, too. *Ecological Indicators* focuses on environmental protection and biodiversity conservation. Having accounted for around half the total number of citations, these seven journals can be considered as the decade’s mainstream journals for GTFP.

Other areas of research not included in Table 2 encompass operations research and management (e.g., *Omega-International Journal of Management Science* and *European Journal of Operational Research*), agriculture (e.g., *Journal of Agricultural Economics*), and electronic telecommunications (e.g., *IEEE Communications Magazine*).

Table 2 Representative journals related to GTFP

Name	h-Index	g-Index	Total citations	Total papers
Applied Energy	17	36	1317	56
Journal of Cleaner Production	16	33	1113	37
Energy Policy	15	26	789	26
Renewable & Sustainable Energy Reviews	13	22	521	22
Energy	11	20	429	20
Ecological Indicators	10	19	369	21
Energy Economics	9	17	317	17
Top 10% journals (n = 7)			4855	199
Others (121 journals)			4647	646
Total (128 journals)			9502	845

Category determination

Extraction of initial categories

The first stage in the grounded theory approach is *open decoding*. This mainly involves breaking up the 20 collected documents, finding the sentences relating to the change in GTFP, and extracting the corresponding influencing factors for encoding (Table 3). A total of 376 original sentences were extracted. By analyzing and combining these with coded intersecting nodes, we completed a preliminary classification, containing the following 13 initial categories: Intellectual property protection, Market potential, Financial development, Environmental regulatory tools, Physical capital, Transport infrastructure, Technological innovation, Technological efficiency, Intra-industry competition, Human capital, Degree of pollution control, Degree of marketization, and Environmental regulatory policies. The results are shown in Table 4 (only part of the coding system is shown due to space limitations).

Table 3 Example of the open decoding results of the preliminary GTFP influencing factors

Representative sentences	Open decoding (Child node)
Interviews:	

"If the technological breakthrough is not difficult and profitable, we are willing to carry out some scientific and technological research and development projects to enhance the company's strength as much as possible."	Technological innovation
"Talent matters. Professional teams in all aspects are the basis for enterprises to produce excellent products and earn customer satisfaction."	Human capital
"Our company's products are novel, the audience is wide, and the demand is large in the user and intermediate markets, which gives us a lot of room for development."	Market potential
"The environmental protection policy announced by the government makes enterprises pay more attention to ecology and environmental protection."	Environmental regulation policy
"Increasing the number of transportation facilities can speed up the flow of production factors, but it cannot be increased blindly."	Infrastructure level
Literature:	
The market process will speed up the flow of factors, which is conducive to industrial upgrading and green transformation, and the level of green economic development will gradually increase.	Degree of marketization
Technical efficiency is basically in a negative growth state, which means that improving the utilization efficiency of green technologies is the main breakthrough point to improve the green total factor productivity.	Technological efficiency
Because green technology's R&D costs are much higher than non-green technologies, strict intellectual property protection can easily make non-green technology R&D occupy green technology R&D, which is not conducive to green technology progress.	Intellectual property protection
In terms of FDI, foreign direct investment has a significant negative effect on the growth of GTFP.	Foreign direct investment

Table 4 Initial GTFP categories

Serial number	Initial category	Open decoding
1	Intellectual property protection	Intellectual property protection
2	Market potential	Market potential
3	Financial development	Outward foreign direct investment, Foreign direct investment

4	Environmental regulatory tools	Command-controlled environmental regulation, Market-inspired environmental regulation, Voluntary agreement environmental regulation
5	Physical capital	Energy factor
6	Transport infrastructure	Transport infrastructure
7	Technological innovation	Innovation quality, R&D level
8	Technological efficiency	Technological efficiency
9	Intra-industry competition	Intra-industry competition
10	Human capital	Urbanization level
11	Degree of pollution control	Degree of pollution control
12	Degree of marketization	Degree of marketization
13	Environmental regulation policy	Two-control area policy, Government emission reduction policy

Classification of main categories

The second stage is named *spindle decoding* or *main axis decoding*. This step involves conducting a deeper level of cluster analysis from the initial categories obtained in the first stage. This is done to reveal the logical relationships that the initial categories may have and obtain a more theoretically informed and explanatory main categories description (in this case GTFP). In the present study, the 13 initial categories obtained by open decoding were analyzed in detail and combined into a tree-like diagram. Table 5 gives the results.

Table 5 Main GTFP categories

Serial number	Main category	Initial category
1	Industrial structure	Intra-industry competition
2	Production factors	Physical capital, Human capital
3	Market factors	Degree of marketization, Market potential
4	Technical efficiency	Technical efficiency
5	Environmental regulation	Environmental regulatory tools, Environmental regulation policy
6	Technological progress	Technological innovation
7	Infrastructure level	Transport infrastructure

8	Intellectual property protection	Intellectual property protection
9	Economic development level	Financial development
10	Fiscal decentralization	Degree of pollution control

Identification of core categories

The third stage of grounded theory is *selective decoding*. This is based on the main axis decoding from the previous step and further summarizes into a core category. These correspond more clearly with the theme and usually exert some systematic influence on it. From this analysis we established that both technological progress and technological efficiency were related to GTFP and, of course, technology. For this reason, they were unified under the concept of *technical streams* (TS).

Analogously, the *economic streams* (ES) gathered: the industrial structure, which is an important part of the social and economic system; the level of economic development, which reflects the scale and speed of a country's economic development; production factors, which are the basic factors of production and operation; and market factors, which are related to the current economic system and reflect the economic variable of demand.

Finally, the following factors constituted *government streams* (GS): fiscal decentralization; environmental regulation and intellectual property protection; and infrastructure. Fiscal decentralization involves the fiscal power given to the local government by the central government so that local governments can enjoy corresponding autonomy; the environmental regulation and intellectual property protection are related to policy decisions issued by the government; while infrastructure, as a public item, has a non-competitive and non-exclusive nature that determines the main role of the government in the construction process. These technical, economic, and government streams denoted the three core categories of GTFP's most influencing factors (Table 6).

Table 6 Core GTFP categories

Serial number	Core category	Main category
1	Economic streams	Industrial structure Economic development level Production factors Market factors
2	Technical streams	Technological progress Technological efficiency
3	Government streams	Environmental regulation Intellectual property protection Infrastructure level Fiscal decentralization

Saturation test

The saturation test involved keeping 10 papers apart during the literature analysis to test the factor-coding comprehensiveness − using these papers to check the coding consistency with the Nvivo 11 software, where the extracted influencing factors coincided with the proposed coding concept categories. As no new GTFP influencing factors occurred, it was concluded that the current influencing factor coding had reached saturation. Consequently, the proposed coding in the previous step was taken to be sufficiently rich and representative.

Discussion: classification of the major research streams

The study clearly identified three core categories of GTFP influencing factors: technical, economic, and government streams. These can also be considered to represent current mainstream GTFP research.

Impact of technology streams (TS)

TS mainly comprises technological progress and technological efficiency as shown in Figure 2. GTFP can be composed of the technological progress index and the technological efficiency index (Song and Li, 2019). Technological progress is the main force driving the improvement in GTFP (Wang, 2017; Zhang, 2015). Technological progress on behalf of innovation capacity shifts the frontier of green production outwards. This improves output efficiency or allows more advanced technologies of energy conservation and emission reduction. These promote the coordinated development of the economy and environment (Cheng et al., 2018). However, technical efficiency is generally low and has a negative impact on GTFP. This is caused by the decline in the efficiency of technology utilization and the inefficiency of environmental management (Shao et al., 2016). The optimization of technical efficiency can achieve a better combination of production factors, promote industrial upgrading, and improve economic input-output efficiency. These three outcomes will have a more long-term and profound impact on GTFP.

Technological progress depends on the continuous accumulation of technological innovation, and technological progress also represents the ability for technological innovation. Therefore, technological innovation is regarded a branch of technological progress, with technological innovation and GTFP being positively correlated (Du and Li, 2019). In particular, green technological innovation is likely to prompt companies to actively respond to green development. By developing green technologies, products, and improving organization and management methods, companies can increase their income levels and even obtain net profits that offset the high-cost investments of environmental governance (Wang et al. 2020).

Technological innovation also includes such other factors as innovation quality and R&D level. The quality of innovation is conducive to the promotion of the green factor, although its impact is being restricted by the threshold of environmental regulation. This is because high-intensity environmental regulations strictly control environmental pollution emissions and energy consumption, stimulate innovation activities, help innovation quality maintain a higher level, and have a positive impact on GTFP (Yang et al., 2019). The intensity of the R&D level positively affects GTFP. Clearly, a large amount of R&D investment by a firm can attract a large amount of outstanding talent, improve R&D facilities, stimulate innovation, and ultimately enhance GTFP (Shen et al., 2019).

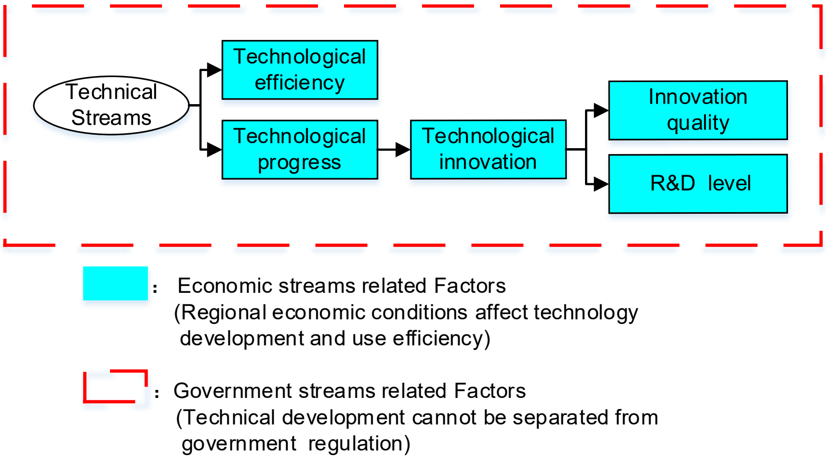

Fig. 2 The technology streams system

Impact of economic streams (ES)

ES mainly comprises industrial structure, production factors, economic development level, and market factors, as shown in Figure 3. The current industrial structure negatively affects GTFP (Feng et al., 2019). Industry is the main source of energy consumption and pollution emissions. The overall level of green technology is relatively backward and development depends heavily on factor inputs, it cannot offset excessive energy consumption and pollution to make green development sustainable. Greening the industrial structure has become an important means of achieving the coordinated development of economic and environmental performance (Yang et al., 2018; Zhang et al., 2020). Upgrading industrial structure can accelerate the flow of production factors to clean industry and tertiary industry. This would make the industrial structure more inclined play a key role in promoting economic growth and pollution reduction (Zhang et al., 2014; Dong et al., 2020). On the other hand, a diversified industrial structure can encourage companies to use complementary industries (such as other related upstream and downstream industries) for joint innovation and production (Feng et al., 2019).

Production factors are divided into physical capital and human capital. Physical capital accumulation is beneficial to the transformation and upgrading of industrial structure (Amri, 2018). Of the material factors, researchers pay more attention to the influence of energy structure, which is negatively correlated with GTFP (Rath et al., 2019). This is because the current energy consumption is dominated by traditional fossil energy, and the excessive dependence on coal hinders the improvement of GTFP (Wang et al., 2020). Some studies found that the diversification of export products to increase the demand of greener and cleaner energy as well as energy innovation, can achieve the purpose of upgrading the energy structure (Hao et al., 2021; Shahzad et al., 2021). This is conducive to reducing the negative externalities of the environment and achieving the improvement of GTFP (Shahzad et al., 2020; Murshed et al., 2021). Human capital accumulation directly affects the innovation ability of a country or region and the absorption of advanced technology, improving the positive impact of GTFP (Mannasoo et al., 2018; Ahmed et al., 2020). This may be because the higher the education level of the employees, the higher the output rate and the stronger the awareness of energy saving (Ahmad and Khan, 2019).

The relationship between economic development level and GTFP is in the shape of a "U" (Feng et al., 2017). Hence, the "Environmental Kuznets Curve" hypothesis is valid in most countries and regions (Ali et al., 2017; Loganathan et al., 2020). Most research results show that, in the early stage of economic development, rapid economic development is often accompanied by the extensive use of resources and increased environmental pollution emissions. This eventually leads to a decline in GTFP (Song et al., 2018). When the level of economic development reaches a critical point, the country will gradually improve its efficiency of resource utilization (Li and Liao, 2020). It will also adopt innovative technologies to shift the economic model to a cleaner, more intensive and efficient development model that promotes the growth of GTFP (Xie and Zhang, 2020). Of these, outward foreign direct investment (OFDI) has played a positive role in GTFP (Xu et al., 2019). Foreign investment has enabled companies to come into contact with internationally advanced greener and cleaner technologies. Through the reverse feeding of green technologies and processes to domestic diffusion, absorption, and innovation, it has also promoted the improvement of GTFP. Conversely, foreign direct investment (FDI) is not conducive to GTFP improvement (Herzer and Donaubauer, 2018). Local governments with limited channels to introduce foreign capital may relax their environmental regulations in order to enhance their competitiveness. In addition, they may have a strong interest in investment projects with low benefits and efficiency (Naz et al., 2019). Imported FDI is concentrated in pollution-intensive industries, which increases the pressure of national environmental pollution. Loss of efficiency and increased pollution have indeed hampered GTFP growth (Lin and Chen, 2018).

From the perspective of market factors, the degree of marketization is conducive to GTFP (Li and Gao, 2016). To some extent, the degree of marketization can represent the market vitality of the economy. A high degree of marketization is conducive to the rapid flow of factor resources, which can realize the reasonable allocation of the country’s economic resources and accelerate the pace of industrial structure upgrading and green transformation to promote green economic growth (Lu et al., 2020). In addition, an improvement in the process of marketization is conducive to the promotion of foreign direct investment on GTFP (Dong et al., 2019). When the degree of marketization is relatively high, there often is an efficient product and factor market environment that can promote technical exchanges and cooperation between companies. This can accelerate the diffusion and dissemination of the technology spillover effects of foreign direct investment to improve the country’s innovation resource efficiency. Market potential is positively correlated with GTFP. This represents the regional scale of market demand. The larger the scale of demand, the more the accompanying currency externalities can be exerted, and the region can reach a higher GTFP (Wang and Feng, 2019).

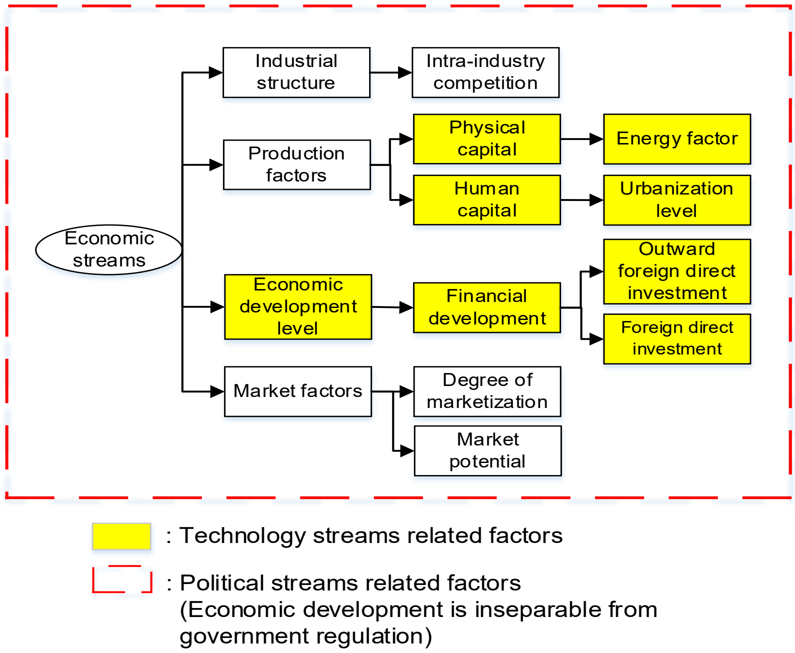

Fig. 3 The economic streams system

Impact of government streams (GS)

GS includes environmental regulations, fiscal decentralization, infrastructure level, and intellectual property protection. All these are shown in Figure 4. Environmental regulations in terms of regulation intensity and GTFP has an inverted "U"-shaped relationship (Lei and Wu, 2019). Low-intensity and moderate environmental regulations can give full play to the government's leading role, prompting firms towards technological innovation and upgrading green technologies, thereby obtaining higher returns and innovation compensation. However, high-intensity environmental regulations cause the price of production factors and environmental cost to increase. Excessive governance costs crowd out R&D investment in technological innovation, which is harmful to GTFP (Song et al., 2018). Therefore, the government needs to adopt a "properly designed" environmental regulation intensity to achieve the coordinated development of the economy and environmental protection. These regulations must actively induce the economy to make innovations in systems, technology, and management to make their operations more effective.

Fiscal decentralization has an inhibitory effect on GTFP at the national level – giving local governments a certain degree of fiscal autonomy, which can allocate resources more rationally and stimulate local economic development. However, substantial expansion of local-scale reduction of expenditures of the central government's macroeconomic regulation and control capabilities, can easily lead to the duplication and waste of resources (Wu et al., 2020). GDP-based incentives can lead local governments to blindly pursue economic growth and ignore such sustainable development goals as energy conservation and environmental protection. This results in large negative environmental externalities (You et al., 2019). It also indicates that there are unaccounted mediating effects between fiscal decentralization, environmental regulation, and GTFP (Ge et al., 2020). However, fiscal decentralization achieves the purpose of reducing the adverse impact on GTFP through the intermediary effect of environmental regulation (Song et al., 2020).

The impact of infrastructure on GTFP is moderate. When the infrastructure stock is moderate, the infrastructure level is positively correlated with GTFP. As the carrier of technology and knowledge diffusion, infrastructure plays a significant role in linking the exchanges between regions (Farhadi, 2015). Infrastructure can improve the level of GTFP by increasing the marginal productivity of labor, capital, and energy. However, excessive infrastructure has adverse effects on GTFP. According to the laws of diminishing marginal investment returns, with the increase of capital stock, the marginal rate of return of capital will decline, resulting in lower production efficiency (Jiang et al., 2020). An excessive amount of infrastructure is also accompanied by the large consumption of steel, coal, and other raw materials that will cause huge energy consumption and pollution.

Intellectual property protection inhibits GTFP growth at the national level and its "tragic anti-commons" effect hinders the use of green technology. At the same time, the complexity of green certification hinders the green transformation of companies and limits the role of green consumption orientation (Deng et al., 2019). In addition, the intellectual property rights protection system in the process of green technology innovation fails to play a proper role. Companies competing for the industry monopoly advantage of a green technology or avoiding the use of certain green technologies reduces companies' interests. In this scenario, both green technology and its patent inventors often become the victims (Saito, 2018).

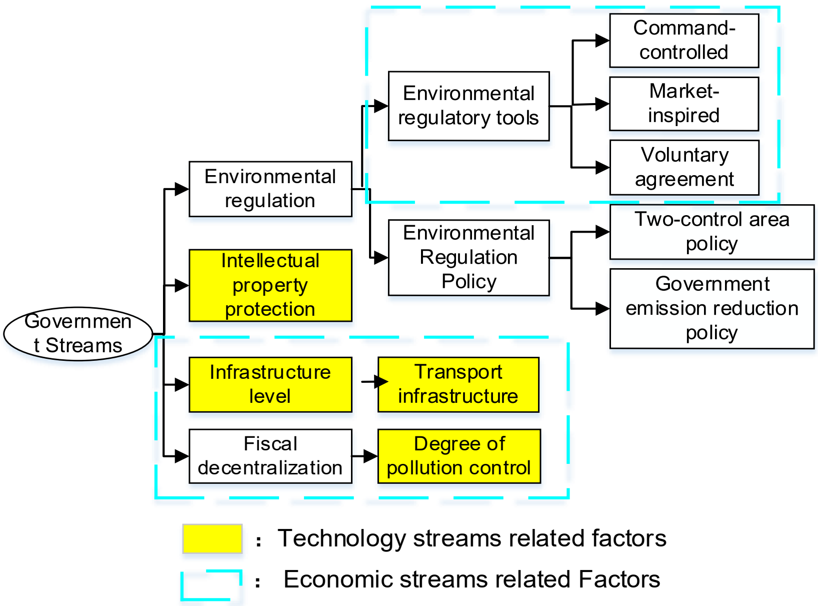

Fig. 4 The government streams system

Model of GTFP influencing factors

When considering the impact of GTFP, we found the government has issued various policies and subsidies to guide technological innovation in several industries. It has also actively made foreign direct investments to introduce advanced foreign technologies. This technology can accelerate, and make more efficient, the necessary technological progress that promotes GTFP. As we discussed, TS links ES and GS. An excellent technology level economy enables firms to obtain higher profits. The government can better maintain economic development and stability by adjusting an upgraded market and industrial structure. Similarly, ES links TS with GS. The green development of the economy needs reasonable regulation by the government through policy means, and the regulation of environmental and energy policies should be realized through green technology. GS then links TS with ES. Therefore, it can be concluded that the technical, economic, and government streams are not separate sources affecting GTFP; any mainstream will jointly affect other mainstreams and the GTFP.

The impacts of TS on GTFP play a particularly decisive role. The influence of the other two mainstreams is achieved by promoting technological progress or improving technological efficiency. ES is the protection factor in GTFP. Similarly, the role of the government is inseparable from economic stability and financial support. GS is the dominant factor in GTFP research, but development of the economy and technology is inseparable from the control of the government. The dominant position of the government is as an "invisible" hand. Therefore, as shown in Figure 5, the following GTFP influencing factor model is constructed according to the actual impact of these factors. Table 7 provides the list of influencing factors in the model.

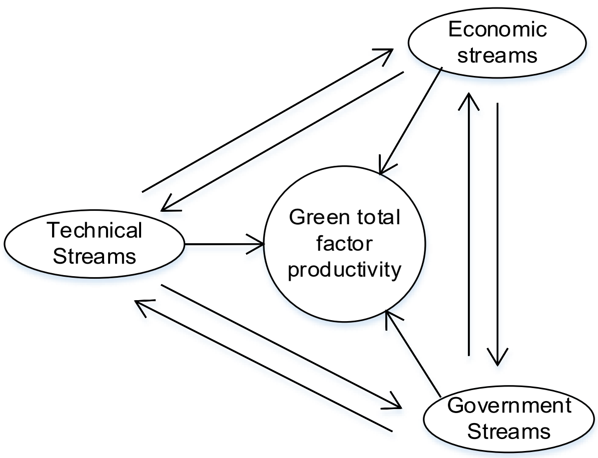

Fig. 5 Model of GTFP influencing factors

Table 7 List of GTFP influencing factors

Research mainstream	Main category	Initial category
Economic streams	Industrial structure	Intra-industry competition
	Economic development level	Financial development
	Production factors	Physical capital
		Human capital
	Market factors	Degree of marketization
		Market potential
Technical streams	Technological progress	Technological innovation
	Technological efficiency	Technological efficiency
Government streams	Environmental regulation	Environmental regulatory tools
		Environmental regulation policy
	Intellectual property protection	Intellectual property protection
	Infrastructure level	Transportation infrastructure
	Fiscal decentralization	Degree of pollution control

Conclusion

Green total factor productivity (GTFP) provides the basis for judging whether a country or region can attain long-term sustainable development. However, there are many influencing factors in GTFP that mainstream research has yet to clarify. Our analysis of 2009-2019 literature on GTFP has indeed shown that major works and journals have focused on explaining GTFP from the perspective of its influencing factors. High-impact journals, for example, have focused on energy, green technology and biodiversity conservation. These analyses have also included areas such as manufacturing, metals, and construction. Additionally, they have considered macro, micro, and meso-level factors that have made a great contribution to the GTFP practice and laid a solid foundation for further research.

However, there is a strong need for industry and policy makers to be provided with clear practical principles and policies to adopt GTFP. That is, they need feasible designs to accelerate the marketization process and industrial upgrading. This, while preventing the adverse circumstances of economic development (i.e. ecological and energy issues). The question of how to do this has not been thoroughly addressed in the academic literature.

Analyses of this article have shown the main categories of GTFP research to date. Within each category we have highlighted potential research areas that can help the academic community develop sector-based tools and use them as country-level solutions. Namely, this study has used grounded theory to conduct a qualitative analysis of the 2009-2019 GTFP literature. Upon analyzing the literature and interview results, the factors influencing the GTFP were extracted, coded, and 13 initial categories identified. These initial categories were further classified according to their affiliation and we identified further GTFP core categories. Then, these core categories were abstracted into new concepts to form three main categories. Finally, after testing their code saturation, a model representing the influencing factors of GTFP was proposed and a list of the corresponding influencing factors was obtained.

These influencing factors are divided into three main research categories of GTFP research: technical streams (TS), economic streams (ES), and government streams (GS). TS consists of technological progress and technological efficiency. ES consists of industrial structure, production factors, economic development level, and market factors. GS consists of fiscal decentralization, environmental regulation, government intervention, and intellectual property protection. There are some mediating effects between technical streams, economic streams, government streams, and GTFP. In addition to directly affecting GTFP, these research mainstreams also indirectly affect GTFP through the other two research streams. TS plays a decisive role in GTFP, ES guarantees GTFP, and GS plays a leading regulating role.

Hence, the paper develops an overview of the broader literature in the field of GTFP, analyzing the development path of GTFP from three streams of influencing factors to promote sustainable development. Results can help academia understand the missing points in the field and develop new research directions that may be useful in exploring various areas of sustainable development. This is also useful to avoid duplication and to develop sector-based applied research for environmental protection.

A limitation of the study is that the conclusions drawn exclude an analysis at region- or industry-level and therefore some influencing factors specific to an industry are not considered in the model. For example, agriculture is inherently susceptible to changes in climate and the natural environment, with farmland disasters, soil erosion, etc. In addition, although the study divides the GTFP research stream into three mainstream categories, the decisive factors for each stream cannot be fully considered. Further research is needed to address these limitations.

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