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

Jingxiao Zhang^{1,*}, Guanyang Lu², Martin Skitmore³, Pablo Ballesteros-Pérez⁴

¹ Professor, School of Economics and Management, Chang'an University, Shaanxi Xian, P. R. China, 710061, zhangjingxiao964@126.com

² Lecturer, School of Economics and Management, Chang'an University, Shaanxi Xian, P. R. China, 710061, luguanyang0926@126.com

³ University Professorial Fellow of Quantity Surveying and Construction Management, Faculty of Society & Design, 3_2_11, Bond University, University Drive, Robina Q4229, Australia

⁴ Associate Professor, Departamento de Proyectos de Ingeniería, Universitat Politècnica de València, Camino de Vera s/n, 46022, Valencia (Spain), pabbalpe@dpi.upv.es

* Correspondence: zhangjingxiao964@126.com; Tel: +86-159-2973-9877.

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

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

32 **Keywords** Green total factor productivity; Green transformation; Grounded theory;
33 Qualitative research

34 **Introduction**

35 While the global economy has made great strides since the Industrial Revolution, it has
36 also created some serious challenges. The problem of energy and the ecological
37 environment is becoming increasingly serious at the expense of resource consumption
38 and environmental degradation. Despite the world's average 1971-2012 annual GDP
39 growth rate of just 3%, total primary energy consumption doubled and CO₂ emissions
40 from fuel combustion increased by almost 20 billion tons (World Bank, 2015). At the
41 same time, according to the report of the first World Health Organization (WHO)
42 Global Conference on Air Pollution and Health in 2018, an estimated 7 million people
43 die every year from air pollution caused by excessive ambient fine particulate matter,
44 PM_{2.5} (WHO, 2018). Around 90% of urban air has particle concentrations that exceed
45 the WHO air quality guidelines. As a result, the world has an urgent need to adopt
46 energy conservation and emission reduction measures, carry out a green transformation,
47 and eventually achieve sustainable development.

48 Many studies have shown that the adoption of sustainable development practices
49 improve resources utilization and emissions reduction without damaging economic
50 growth (Paramati et al., 2017; Apergis and Gangopadhyay, 2020; Murshed, 2021). The
51 United Nations officially adopted the "Changing Our World: The 2030 Agenda for
52 Sustainable Development," which sets out 17 global sustainable development goals
53 (SDG) (Murshed, 2019). For the first time, different countries share specific,
54 measurable indicators and completion deadlines. This action will hopefully lead to

55 achieving global sustainable development in multiple dimensions such as resources
56 utilization, environment protection, and economy development (Murshed and Tanha,
57 2020). There is no doubt that sustainable development is here to stay. And in the
58 foreseeable future, sustainable development may lead to a new pattern of global
59 development (Liu et al., 2021).

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

74 However, most studies only focus on the impact on GTFP from a single
75 perspective. They do not consider other aspects comprehensively enough to develop a
76 productivity impact factor model that can accelerate a country's green transformation.
77 Cao et al. (2020), for example, studied the impact of environmental regulations on
78 China's manufacturing sector to further promote the green development in
79 manufacturing. Zhang et al. (2019) analyzed the impact of market misallocations on
80 GTFP by combining data from countries along the Belt and Road. Similarly, Li and Lin
81 (2017) explored how industrial structure and economic development patterns affect
82 green productivity.

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

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

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

103 **Research methods**

104 **Research framework**

105 This study comprises a qualitative analysis of the factors influencing GTFP based on
106 grounded theory. Originally proposed by Glaser and Strauss (1967), grounded theory
107 is based on the collection and analysis of data. In particular, it roots around the data to
108 construct a bottom-up theory that reflects social phenomena observations. Three

109 processes embody grounded theory: open decoding, main axis decoding, and selective
 110 decoding. It carries these out without resorting to any preestablished assumptions, and
 111 finally draws conclusions. Grounded theory is suitable here as it allows conclusions to
 112 be drawn from qualitative data. Figure 1 illustrates the research framework adopted.
 113

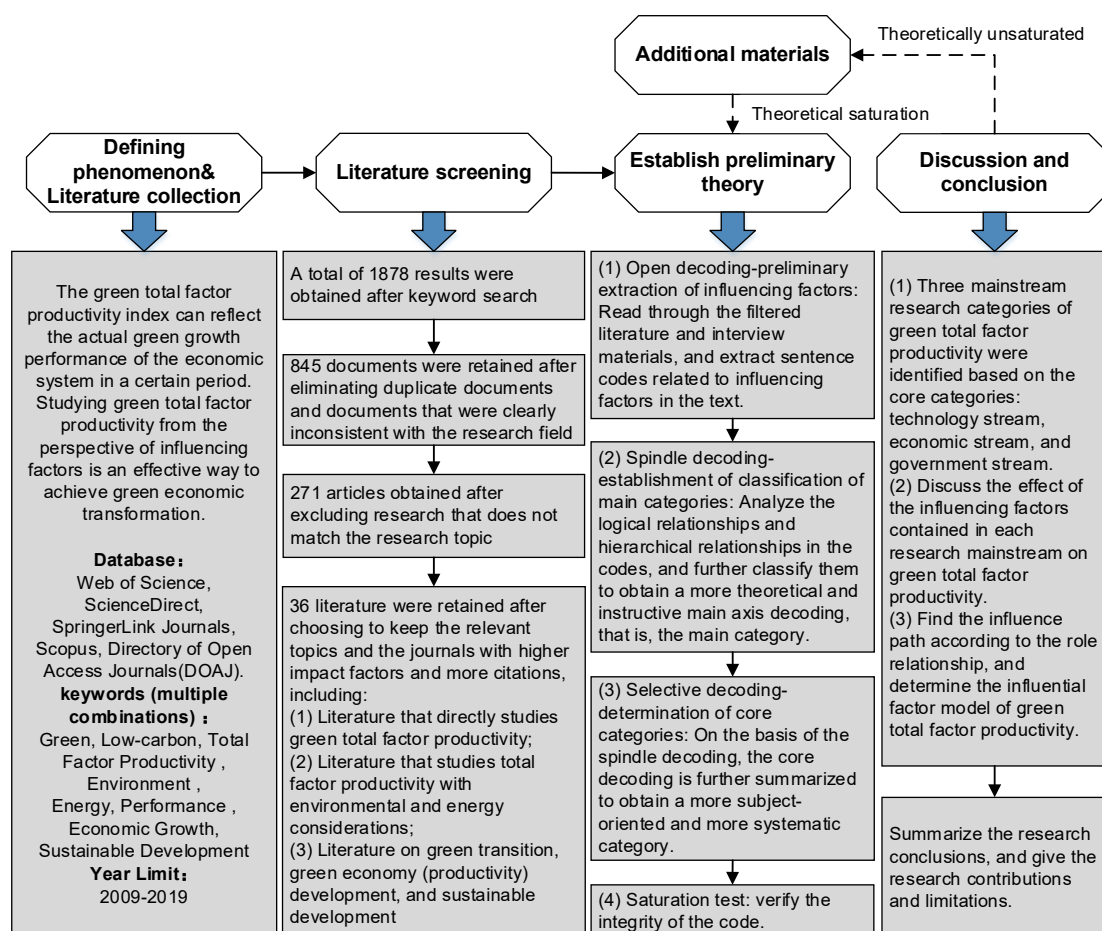


Fig. 1 Research framework

Data collection

117 The research involves information collected from a wide literature search and
 118 interviews. Grounded theory needs to describe the original data in depth. In order to
 119 uncover the hidden laws in the data better and present them systematically, it is
 120 necessary to make this information more representative. Hence, data relevant to GTFP

121 is collected from researchers, corporate executives, and government personnel first.
122 The following subsections describe this process.

123 **Data from the literature**

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

137 **Interview data**

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

145

146

Table 1 Interview protocols

Interview group	Basic information	Interview protocol
Government officials	Gender, age, position	<ol style="list-style-type: none"> 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	<ol style="list-style-type: none"> 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?

147

148 Two interview methods were established – one for offline interviews and one for
149 online interviews. Each interviewee was contacted before the interview to agree on the
150 interview time and location, and for briefing on the interview background and topic
151 involved. A total of 17 people was interviewed, with each interview lasting
152 approximately 15 minutes. After ruling out incomplete and non-reference interviews,
153 15 effective interviews were considered valid. Of these, 73% interviewees were male,
154 66% were 40-50 years old, 6 were government officials (4 from environmental
155 protection departments), and 9 were corporate management staff (3 from senior
156 management and 4 from middle management).

157 **Results**

158 **General trends in GTFP research**

159 Several previous studies of GTFP focused on the relationship between GTFP and its
160 influencing factors. Li and Liao (2020), for example, studied the heterogeneity of the
161 impact of financial development on GTFP in 40 countries from the perspective of

162 banking and insurance. Zhang et al. (2019) conducted a study of GTFP in 33 countries
163 along the “Belt and Road” and concluded that inappropriate market distribution has had
164 a severe negative impact on the GTFP of various economies. Martinez-Zarzoso et al.
165 (2019) used data from 14 Organization for Economic Co-operation and Development
166 countries to explore the impact of strict environmental policies on national total factor
167 productivity (TFP), finding that stricter environmental regulations can promote cleaner
168 production and benefit TFP.

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

182 Almost all studies of the factors conditioning GTFP use quantitative techniques,
183 including parametric and non-parametric methods. However, as parametric methods
184 require specific information concerning inputs and outputs, non-parametric methods
185 are much more frequent. For example, Männasoo et al. (2018) used the Solow residual
186 method, control function method, stochastic frontier analysis (SFA), and non-
187 parametric data envelope analysis (DEA) to study the influencing factors of TFP. Feng
188 et al. (2017) also used DEA and a green development performance index to analyze
189 panel data from 165 countries to estimate green development performance from a

190 global perspective. Amani et al. (2018) used a slack-based measure (SBM) model to
191 measure the Malmquist productivity index in a variable income model and as an
192 indicator of changes in total factor productivity over time.

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

197 **Journals publishing GTFP-related studies**

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

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

216 **Table 2** Representative journals related to GTFP

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

217 **Category determination**

218 **Extraction of initial categories**

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

230

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

Representative sentences	Open decoding (Child node)
--------------------------	-------------------------------

Interviews:

<p>“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.”</p>	Technological innovation
<p>“Talent matters. Professional teams in all aspects are the basis for enterprises to produce excellent products and earn customer satisfaction.”</p>	Human capital
<p>“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.”</p>	Market potential
<p>“The environmental protection policy announced by the government makes enterprises pay more attention to ecology and environmental protection.”</p>	Environmental regulation policy
<p>“Increasing the number of transportation facilities can speed up the flow of production factors, but it cannot be increased blindly.”</p>	Infrastructure level
Literature:	
<p>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.</p>	Degree of marketization
<p>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.</p>	Technological efficiency
<p>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.</p>	Intellectual property protection
<p>In terms of FDI, foreign direct investment has a significant negative effect on the growth of GTFP.</p>	Foreign direct investment

232

233

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

234 **Classification of main categories**

235 The second stage is named *spindle decoding* or *main axis decoding*. This step involves
 236 conducting a deeper level of cluster analysis from the initial categories obtained in the
 237 first stage. This is done to reveal the logical relationships that the initial categories may
 238 have and obtain a more theoretically informed and explanatory main categories
 239 description (in this case GTFP). In the present study, the 13 initial categories obtained
 240 by open decoding were analyzed in detail and combined into a tree-like diagram. Table
 241 5 gives the results.

242

243

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

244

245 **Identification of core categories**

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

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

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

268

269

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

270

271 **Saturation test**

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

279 **Discussion: classification of the major research streams**

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

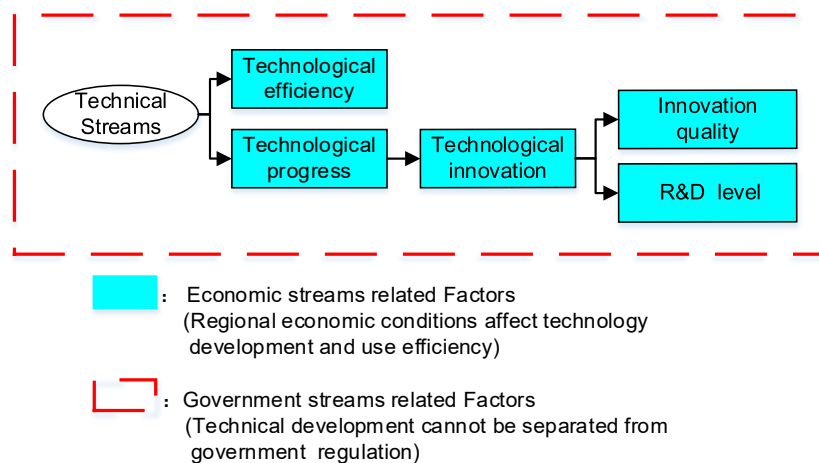
283 **Impact of technology streams (TS)**

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

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

307 Technological innovation also includes such other factors as innovation quality
308 and R&D level. The quality of innovation is conducive to the promotion of the green
309 factor, although its impact is being restricted by the threshold of environmental
310 regulation. This is because high-intensity environmental regulations strictly control

311 environmental pollution emissions and energy consumption, stimulate innovation
 312 activities, help innovation quality maintain a higher level, and have a positive impact
 313 on GTFP (Yang et al., 2019). The intensity of the R&D level positively affects GTFP.
 314 Clearly, a large amount of R&D investment by a firm can attract a large amount of
 315 outstanding talent, improve R&D facilities, stimulate innovation, and ultimately
 316 enhance GTFP (Shen et al., 2019).



317

318

Fig. 2 The technology streams system

319 **Impact of economic streams (ES)**

320 ES mainly comprises industrial structure, production factors, economic development
 321 level, and market factors, as shown in Figure 3. The current industrial structure
 322 negatively affects GTFP (Feng et al., 2019). Industry is the main source of energy
 323 consumption and pollution emissions. The overall level of green technology is
 324 relatively backward and development depends heavily on factor inputs, it cannot offset
 325 excessive energy consumption and pollution to make green development sustainable.
 326 Greening the industrial structure has become an important means of achieving the
 327 coordinated development of economic and environmental performance (Yang et al.,
 328 2018; Zhang et al., 2020). Upgrading industrial structure can accelerate the flow of
 329 production factors to clean industry and tertiary industry. This would make the
 330 industrial structure more inclined play a key role in promoting economic growth and
 331 pollution reduction (Zhang et al., 2014; Dong et al., 2020). On the other hand, a

332 diversified industrial structure can encourage companies to use complementary
333 industries (such as other related upstream and downstream industries) for joint
334 innovation and production (Feng et al., 2019).

335 Production factors are divided into physical capital and human capital. Physical
336 capital accumulation is beneficial to the transformation and upgrading of industrial
337 structure (Amri, 2018). Of the material factors, researchers pay more attention to the
338 influence of energy structure, which is negatively correlated with GTFP (Rath et al.,
339 2019). This is because the current energy consumption is dominated by traditional fossil
340 energy, and the excessive dependence on coal hinders the improvement of GTFP (Wang
341 et al., 2020). Some studies found that the diversification of export products to increase
342 the demand of greener and cleaner energy as well as energy innovation, can achieve the
343 purpose of upgrading the energy structure (Hao et al., 2021; Shahzad et al., 2021). This
344 is conducive to reducing the negative externalities of the environment and achieving
345 the improvement of GTFP (Shahzad et al., 2020; Murshed et al., 2021). Human capital
346 accumulation directly affects the innovation ability of a country or region and the
347 absorption of advanced technology, improving the positive impact of GTFP (Mannasoo
348 et al., 2018; Ahmed et al., 2020). This may be because the higher the education level of
349 the employees, the higher the output rate and the stronger the awareness of energy
350 saving (Ahmad and Khan, 2019).

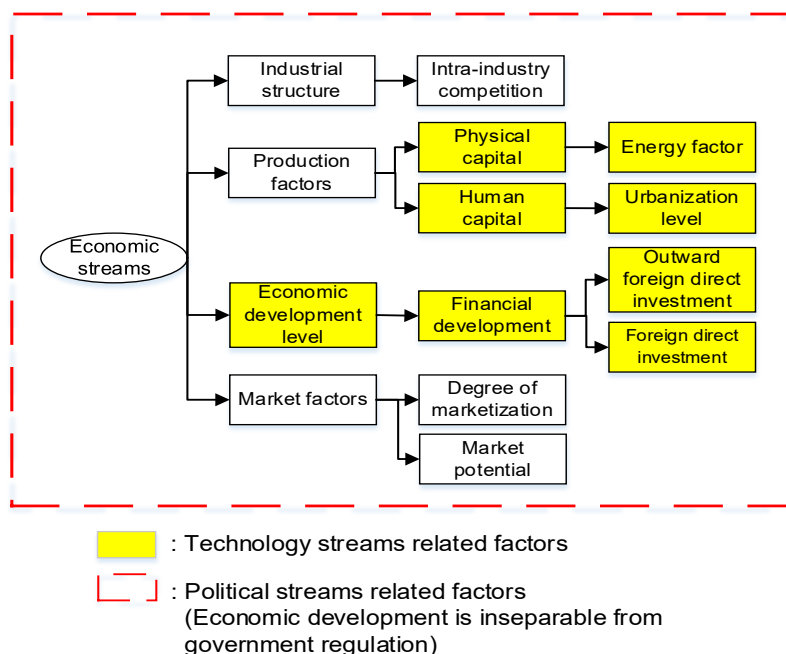
351 The relationship between economic development level and GTFP is in the shape
352 of a "U" (Feng et al., 2017). Hence, the "Environmental Kuznets Curve" hypothesis is
353 valid in most countries and regions (Ali et al., 2017; Loganathan et al., 2020). Most
354 research results show that, in the early stage of economic development, rapid economic
355 development is often accompanied by the extensive use of resources and increased
356 environmental pollution emissions. This eventually leads to a decline in GTFP (Song
357 et al., 2018). When the level of economic development reaches a critical point, the
358 country will gradually improve its efficiency of resource utilization (Li and Liao, 2020).
359 It will also adopt innovative technologies to shift the economic model to a cleaner, more

360 intensive and efficient development model that promotes the growth of GTFP (Xie and
361 Zhang, 2020). Of these, outward foreign direct investment (OFDI) has played a positive
362 role in GTFP (Xu et al., 2019). Foreign investment has enabled companies to come into
363 contact with internationally advanced greener and cleaner technologies. Through the
364 reverse feeding of green technologies and processes to domestic diffusion, absorption,
365 and innovation, it has also promoted the improvement of GTFP. Conversely, foreign
366 direct investment (FDI) is not conducive to GTFP improvement (Herzer and
367 Donaubauer, 2018). Local governments with limited channels to introduce foreign
368 capital may relax their environmental regulations in order to enhance their
369 competitiveness. In addition, they may have a strong interest in investment projects
370 with low benefits and efficiency (Naz et al., 2019). Imported FDI is concentrated in
371 pollution-intensive industries, which increases the pressure of national environmental
372 pollution. Loss of efficiency and increased pollution have indeed hampered GTFP
373 growth (Lin and Chen, 2018).

374 From the perspective of market factors, the degree of marketization is conducive
375 to GTFP (Li and Gao, 2016). To some extent, the degree of marketization can represent
376 the market vitality of the economy. A high degree of marketization is conducive to the
377 rapid flow of factor resources, which can realize the reasonable allocation of the
378 country's economic resources and accelerate the pace of industrial structure upgrading
379 and green transformation to promote green economic growth (Lu et al., 2020). In
380 addition, an improvement in the process of marketization is conducive to the promotion
381 of foreign direct investment on GTFP (Dong et al., 2019). When the degree of
382 marketization is relatively high, there often is an efficient product and factor market
383 environment that can promote technical exchanges and cooperation between companies.
384 This can accelerate the diffusion and dissemination of the technology spillover effects
385 of foreign direct investment to improve the country's innovation resource efficiency.
386 Market potential is positively correlated with GTFP. This represents the regional scale
387 of market demand. The larger the scale of demand, the more the accompanying

388 currency externalities can be exerted, and the region can reach a higher GTFP (Wang
389 and Feng, 2019).

390



391

392

Fig. 3 The economic streams system

393 **Impact of government streams (GS)**

394 GS includes environmental regulations, fiscal decentralization, infrastructure level, and
395 intellectual property protection. All these are shown in Figure 4. Environmental
396 regulations in terms of regulation intensity and GTFP has an inverted "U"-shaped
397 relationship (Lei and Wu, 2019). Low-intensity and moderate environmental
398 regulations can give full play to the government's leading role, prompting firms towards
399 technological innovation and upgrading green technologies, thereby obtaining higher
400 returns and innovation compensation. However, high-intensity environmental
401 regulations cause the price of production factors and environmental cost to increase.
402 Excessive governance costs crowd out R&D investment in technological innovation,
403 which is harmful to GTFP (Song et al., 2018). Therefore, the government needs to adopt
404 a "properly designed" environmental regulation intensity to achieve the coordinated

405 development of the economy and environmental protection. These regulations must
406 actively induce the economy to make innovations in systems, technology, and
407 management to make their operations more effective.

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

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

432 Intellectual property protection inhibits GTFP growth at the national level and its
 433 "tragic anti-commons" effect hinders the use of green technology. At the same time, the
 434 complexity of green certification hinders the green transformation of companies and
 435 limits the role of green consumption orientation (Deng et al., 2019). In addition, the
 436 intellectual property rights protection system in the process of green technology
 437 innovation fails to play a proper role. Companies competing for the industry monopoly
 438 advantage of a green technology or avoiding the use of certain green technologies
 439 reduces companies' interests. In this scenario, both green technology and its patent
 440 inventors often become the victims (Saito, 2018).
 441

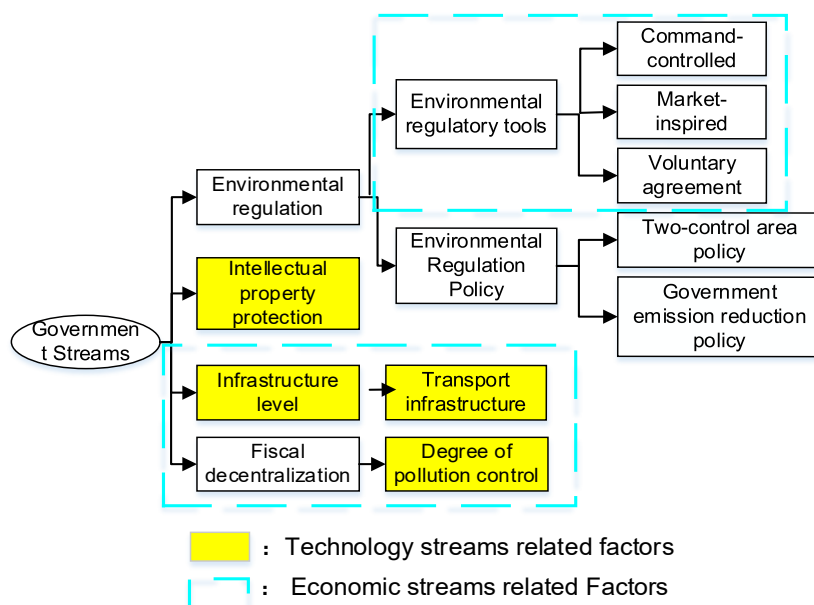


Fig. 4 The government streams system

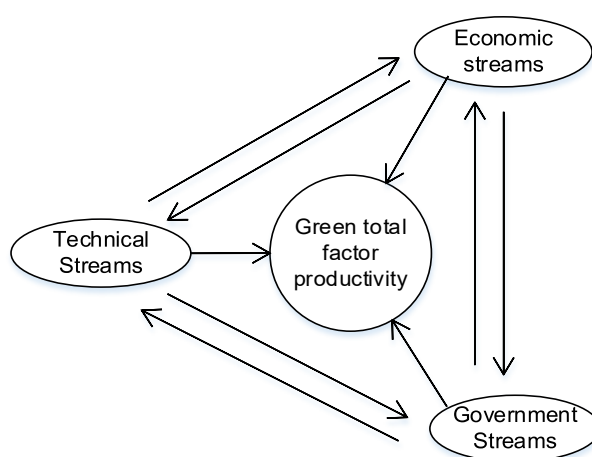
444 **Model of GTFP influencing factors**

445 When considering the impact of GTFP, we found the government has issued various
 446 policies and subsidies to guide technological innovation in several industries. It has also
 447 actively made foreign direct investments to introduce advanced foreign technologies.
 448 This technology can accelerate, and make more efficient, the necessary technological
 449 progress that promotes GTFP. As we discussed, TS links ES and GS. An excellent

450 technology level economy enables firms to obtain higher profits. The government can
 451 better maintain economic development and stability by adjusting an upgraded market
 452 and industrial structure. Similarly, ES links TS with GS. The green development of the
 453 economy needs reasonable regulation by the government through policy means, and the
 454 regulation of environmental and energy policies should be realized through green
 455 technology. GS then links TS with ES. Therefore, it can be concluded that the technical,
 456 economic, and government streams are not separate sources affecting GTFP; any
 457 mainstream will jointly affect other mainstreams and the GTFP.

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

467



468

469

Fig. 5 Model of GTFP influencing factors

470

471

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	

472 Conclusion

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

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

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

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

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

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

523

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530

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