

## Article

# Technological Innovation, Production Efficiency, and Sustainable Development: A Case Study from Shenzhen in China

Sheng Zhang <sup>1</sup>, Meng Xu <sup>2</sup>, Yifu Yang <sup>1,\*</sup> and Zeyu Song <sup>3</sup>

<sup>1</sup> School of Environment & Natural Resources, Renmin University of China, Beijing 100872, China; zhangs0531@ruc.edu.cn

<sup>2</sup> Department of Mathematics, School of Science, Beijing Jiaotong University, Beijing 100091, China; 18118021@bjtu.edu.cn

<sup>3</sup> Shanxi Urban & Rural Planning and Design Institute Co., Ltd., Taiyuan 030024, China; Szy4331@163.com

\* Correspondence: yyang1991@ruc.edu.cn

**Abstract:** Shenzhen is a national sustainable development innovation demonstration zone, with the theme of innovation leading the sustainable development of megacities. This manuscript studies technological innovation, production efficiency, and sustainable development and explores the impact of their relationship on Shenzhen. The benchmark test shows a significant negative correlation between the inefficiency of production, labor levels, investment levels, technical levels, and socioeconomic status. From 2001 to 2019, the production efficiencies of 21 prefecture-level cities in Guangdong Province were used as the research object. The Cobb–Douglas production function conducted panel stochastic frontier analysis and TOBIT regression, and the conclusion was robust. The mechanism test found that the economic growth of Guangdong Province, including Shenzhen, is still dominated by labor and investment. Its production efficiency has been dramatically impacted after 2008, and the increase in production inefficiency may be affected by the crowding-out effect of a four-trillion investment. Finally, based on the Tobit regression, we found that the rise in the labor force, capital input, technological level, and socioeconomic development level could reduce Shenzhen’s production inefficiencies by 3.6%, 20.2%, 2.5%, and 4%, respectively. There is still a long way to achieve sustainable development; however, Shenzhen’s technological innovation and mega-city reform process will provide valuable insights for other regions.

**Keywords:** national sustainable development innovation demonstration zone; innovation; production efficiency; sustainable development



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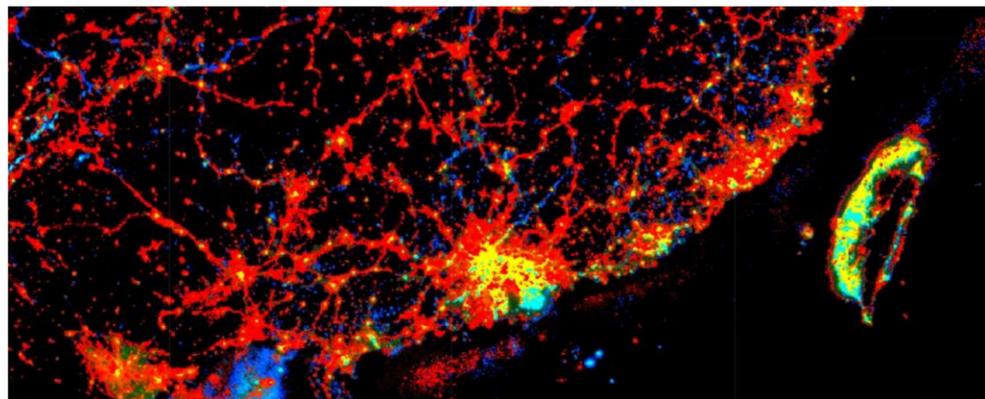
## 1. Introduction

Science and technology affect human lifestyle and play a fundamental role in the relationship between humankind and nature. The rational use of science and technology establishes the sustainability of human production methods. The three industrial revolutions brought the material living standard of humanity to an unprecedented level. However, so far, the different industrial technology systems formed by the three industrial revolutions have continuously expanded the ability and scope of humankind to conquer and transform nature, and the tendency of humanity to destroy the ecological environment and plunder natural resources.

The rapid deterioration of the ecological environment has accelerated the formation of the concept of sustainable development. In 1987, the Norwegian Prime Minister, Mrs. Brundtland, defined sustainable development as “meeting the needs of the present without satisfying the needs of future generations” in the report “Our Common Future” of the United Nations World Commission on Environment and Development under her chairmanship. The required capacity constitutes the development of a hazard [1,2]. Under

the guidance of the concept of sustainable development, we can use the side of scientific and technological progress to promote the improvement of sustainable development management, deepen man's understanding of the laws of nature, discover new available natural resources, and improve the efficiency and economy of comprehensive utilization of resources.

Sustainable Development Goals (SDGs) are a series of goals of the United Nations, which replace the Millennium Development Goals at the end of 2015. These goals will continue from 2016 to 2030. This series of goals has a total of 17 goals and 169 indicators attached to it. According to the "China Sustainable Development Goals (SDGs) Indicator Construction and Progress Evaluation Report: 2018", science and technology are broadly related to almost all 17-point goals and the 169 coincident indicators. Especially in SDG 9, namely "Building disaster-resistant infrastructure, promoting inclusive and sustainable industrialization, and promoting innovation." According to the "Shenzhen Sustainable Development Plan (2017–2030)", Shenzhen has built the country's first National Innovation City and National Independent Innovation Demonstration Zone. Shenzhen's emerging industries account for more than 40% of GDP, making it the most significant and vital emerging industry city in China. Shenzhen's total social research and development (R&D) investment accounts for 4.2% of GDP, twice the national average. With 80.1 effective invention patents per 10,000 people, it ranks first in large and medium-sized cities in the country. Its 5G, drones, gene sequencing technologies, and new energy vehicles rank among the top globally. There are 8037 high-tech enterprises in Shenzhen, accounting for 8% of the country. Specific major technological infrastructures are built, such as the National Supercomputing Shenzhen Center and the Shenzhen National Gene Bank. Thus, Shenzhen has a solid foundation in exploring the sustainable development of megacities [3,4]. Shenzhen should follow the national sustainable development strategy and formulate distinctive urban sustainable development strategies and decompose the national sustainable development strategy goals into local goals, with specific implementation plans and operability [5–7] (See Figure 1, charted by the Google Earth Engine).



**Figure 1.** Pearl River Delta lightmap (1990–). Green represents stable development, and red means rapid.

The concept of sustainable development has become a global consensus. It is also an inevitable choice for China to transform and upgrade its economy and achieve high-quality development in the new era. On 13 February 2018, the Chinese State Council issued the "Approval of Shenzhen City's Construction of the National Sustainable Development Agenda Innovation Demonstration Zone," agreeing that Shenzhen would take innovation to lead the sustainable development of super-large cities. The approval required Shenzhen to focus on relatively insufficient resources, environmental carrying capacity, and social governance support to explore applicable technical routes and systems. This approval had crucial, practical significance for implementing the 2030 Agenda for Sustainable Development and promoting the overall modernization of Shenzhen. Based on the Panel

Stochastic Frontier Analysis (PSFA) and panel Tobit regression methods, we discussed how Shenzhen could use technology to develop super large cities' sustainable development.

Tao maintained that China's Special Economic Zones such as Shenzhen should pursue scientific spirits and humanity and the significance of realizing a modern, international, and creative city, but lack further discussion on the production activities [8]. Jian regarded the practice and experience of Shenzhen's reform and opening -up as of great historical and practical significance, but more in an economic reform way [9]. Chen discussed the Central Business District's construction after Shenzhen had been established as a pilot demonstration zone of socialism [10]. Yu focused on effective waste management in Shenzhen city [11]. Although these documents had a specific relationship with urban construction, they inadvertently and pitifully ignored the core of Shenzhen Pilot Demonstration Zone-technological innovation.

Hao et al. maintained that in the economic field, the four Demonstration Zones, including Shenzhen, Guilin, Subei, and Taiyuan, all faced insufficient innovation to a certain extent [12]. However, Shenzhen's demand was the most urgent, and simultaneously, it had the most foundation for innovation and development. Moreover, since Shenzhen had been at the forefront of China's reform and opening up for a long time, its market economy had developed relatively well. Social construction had also achieved remarkable results. Therefore, under the conditions of sufficient development of the market and society, it can give full play to the systematic reform. This was Shenzhen's unique advantage in constructing a differentiated and diversified governance model.

Lauer et al. found that a city could play a decisive role in implementing innovation policy by discussing Shenzhen's New Energy Vehicles policy [13]. Chinese cities, in particular, make use of a broad set of innovation support measures ranging from binding quotas, public procurement and incentives, to bans and orders. Lauer et al. underlined the importance of solid regulatory instruments that did not conform to the Western notion of market-compliant policy but worked effectively in China. Moreover, the results highlighted how successful policy support for innovation could be implemented.

Liu et al. regarded that China faced enormous challenges in balancing rapid economic development with social development, sustainable resources, and environmental protection in its fast-growing urban areas [14]. Liu et al. emphasized the use of metabolic thinking and eco-cycle models derived from Industrial Ecology to support urban planners in developing more sustainable and resource-efficient urban pathways. This will require closer cooperation between academics and practitioners and better monitoring of projects. Finally, it would be essential to identify ways to scale up successful interventions in the urban area.

Xie et al. argued that the formulation and implementation of sustainable urban developments were subject to local particularities and different extra-local political-economic contexts [15]. Xie et al. highlighted how vertical administrative governance and horizontal coordination between territorial jurisdictions underlie the Chinese entrepreneurial planning system, resulting in different types of urban entrepreneurship.

They all mentioned the special status of the government plan in China's market economy, especially in the urban economy. They acknowledged that the executive-led model played an active role in the past and mentioned its unsustainability. They emphasized the stability of a diversified governance system. They hoped that the sustainable experiments conducted by the Chinese government across the country could help the sustainable transformation of the Chinese economy and society.

Based on their research, we further conducted a quantitative analysis of the megacities economy's production efficiency and sustainable transformation to recommend successful policy support for innovation better and study the path of China's large cities to achieve SDGs. At present, there are still few works of literature to conduct in-depth research on this topic.

## 2. Materials and Methods

We use PSFA to analyze the inter-period production efficiency of Shenzhen City. The economic standard for the production function  $f(x)$  is the maximum output given the input  $x$ . But manufacturers may not reach the leading edge of maximum output (see 8 for details). Suppose the production of firm  $i$  is:

$$y_i = f(x_i, \beta)\zeta_i \quad (1)$$

$\beta$  is the parameter to be estimated;  $\zeta_i$  is the efficiency level of vendor  $i$ , satisfying  $0 < \zeta_i \leq 1$ . If  $\zeta_i = 1$ , then vendor  $i$  is right at the production frontier. Considering that the production function will also be subject to random shocks, therefore, Equation (1) can be rewritten as:

$$y_i = f(x_i, \beta)\zeta_i e^{v_i} \quad (2)$$

$e^{v_i} > 0$  represents random shocks. Suppose  $f(x_i, \beta) = e^{\beta_0} x_{1i}^{\beta_1} \cdots x_{Ki}^{\beta_K}$  (Cobb-Douglas production function form), take the logarithm of both sides of Equation (2) to get:

$$\ln y_i = \beta_0 + \sum_{k=1}^K \beta_k \ln x_{ki} + \ln \zeta_i + v_i \quad (3)$$

Owing to  $0 < \zeta_i \leq 1$ ,  $\ln \zeta_i \leq 0$ . Defining  $u_i \equiv -\ln \zeta_i \geq 0$ , Equation (3) can be rewritten as:

$$\ln y_i = \beta_0 + \sum_{k=1}^K \beta_k \ln x_{ki} + \underbrace{v_i - u_i}_{\theta_i}, u_i \geq 0 \quad (4)$$

$u_i \geq 0$  is the “inefficiency item,” reflecting the distance of vendor  $i$  by the efficiency frontier, and its estimation is the core of the SFA model. Because SFA is a parametric model, to estimate  $u_i$ , it is necessary to make assumptions about the distribution of  $u_i$  and  $v_i$ . On this basis, the maximum likelihood estimation (MLE) estimation can be carried out. First, suppose  $u_i, v_i$  are both i.i.d independent from each other, independently of the explanatory variables  $x_i$ . Second, suppose  $v_i \sim N(0, \sigma_v^2)$ , So its density function is  $\frac{1}{\sqrt{2\pi}\sigma_v} \exp(-v_i^2/2\sigma_v^2)$ . Finally, regarding the distribution of  $u_i$ , it is often assumed  $u_i \sim N^+(0, \sigma_u^2)$ , while the expected normal distribution is 0, the tail is docked on the left side of the origin. That is a truncated distribution, which is called “half-normal distribution.” This model is also called the “normal-half normal model.”

To obtain a consistent estimate, it was previously assumed that  $u_i$  and  $x_i$  are not correlated. However, this assumption may not be accurate in the intertemporal conditions because the production unit is likely to know its inefficiency term  $u_i$  and adjust its optimal input level  $x_i$  accordingly. In the panel data,  $u_i$  can be allowed to correlate with  $x_i$  and using panel data, a consistent estimate can be obtained under the condition of  $T \rightarrow \infty$  [16–22]. Depending on whether the inefficiency term  $u_i$  changes with time, the panel stochastic frontier model (PSFA) can be divided into when the technical efficiency does not change with time and when the technological efficiency changes with time. After testing, this article mainly uses technical efficiency to change with time. Because the time dimension of data is longer, the assumption that technical efficiency does not change with time is unrealistic.

Based on the above stochastic model, Battese and Coel [16,23–25] assume that the inefficiency term  $u_{it}$  varies with the enterprise and time simultaneously:

$$u_{it} = e^{-\eta(t-T_i)} u_i \quad (5)$$

$T_i$  is the time dimension of enterprise  $i$  (unbalanced panel allowed).  $\eta$  is the parameter to be estimated, and  $u_i \sim N^+(\mu, \sigma_u^2)$ . The above formula shows,  $u_{it}$  decrease over time, Until the last period  $T_i$ ,  $u_{it} = u_i$ . When the inefficiency term  $u_{it}$  (representing the distance from the production frontier) changes, the production frontier itself may also change. This effect of technological progress can be captured by adding time dummy variables.

The SFA method obtains the production frontier by constructing a frontier production function and decomposes the error term into statistical and management error terms (i.e., technical and economic inefficiency, etc.). SFA considers the technical inefficiency term and the random error term that directly affects the technical efficiency. SFA can decompose total productivity growth into technological progress and technical efficiency changes, reflecting economic facts more reasonably. SFA is a parameter estimation method. Compared with nonparametric estimation methods, it can directly perform post-statistical testing after model estimation to reduce extra inspection work. The disadvantage is that a specific production function form and a specific distribution of disturbance items (usually normal distribution) are necessary.

A comparison between SFA and commonly used nonparametric data envelopment analysis (DEA) could be contentious [26–29]. Most of the literature believes that the appropriate model should be selected according to specific occasions and needs. Because DEA has long been criticized for lack of statistical tests, SFA can easily check the significance of the results. The dispersion of efficiency estimates is also smaller than the DEA. We still choose the SFA model.

Guangdong Province is the superior administrative unit of Shenzhen. We collected relevant macro data of 21 prefecture-level cities (N), including Shenzhen in Guangdong Province from 2001 to 2019 (T) from the “Guangdong Statistical Yearbook” and “China City Statistical Yearbook.” The regional Gross Domestic Product, the number of employees in each city at the end of the year, the total investment in fixed assets in each city, the internal expenditure of large and medium-sized industrial enterprises in science and technology, and the total amount of wastewater used. Data on wastewater in 2019 are lost. We calculated it according to the ratio of GDP in 2018 to the total amount of sewage, then converted it from GDP in 2019. The relevant variables were logarithmically processed and then analyzed by PSFA. We decided not to evaluate the eventual stationarity of the panel data based on the following three reasons:

- (1) Considering N is 21, and T is 19, N is slightly larger than T. According to Kao (1999), although non-stationary panel data may lead to biased standard errors, the point estimations of the value of parameters are consistent [30]. In addition, according to Baltagi (2008), where “large N large T,” unlike the single time series spurious regression literature, the panel data spurious regression estimates give a consistent estimate of the parameter’s actual value [31]. This is because the panel estimator averages across individuals, and the information in the independent cross-section data in the panel lead to a stronger overall signal than the pure time series case. Or, in short, T contains insufficient information content than N.
- (2) Non-stationarity can be reduced by the logarithmic processing of data.
- (3) Differentiating or standardizing the data may lose more helpful information in statistics.

After management error terms of Shenzhen have been calculated, the pooled Tobit method is used to decomposition error terms. Suppose  $y_i^* = x_i'\beta + \varepsilon_i$  ( $y_i^*$  is unobservable), and disturbance term  $\varepsilon_i|x_i \sim N(0, \sigma^2)$ . For simplicity, assume that the merge point is  $c = 0$ .

Assuming it can be observed  $y_i = \begin{cases} y_i^*, & \text{if } y_i^* > 0 \\ 0, & \text{if } y_i^* \leq 0 \end{cases}$ , The following is to calculate the conditional expectations of the sub-samples  $E(y_i|x_i; y_i > 0)$ . and the conditional expectations of the entire sample  $E(y_i|x_i)$

For sub-samples that meet the condition  $y_i > 0$ ,  $E(y_i|x_i; y_i > 0) = E(y_i^*|x_i; y_i > 0)$  (Given  $y_i > 0$ ,  $y_i = y_i^*$ )

$$\begin{aligned} &= E(x_i'\beta + \varepsilon_i|x_i; y_i^* > 0) \\ &= x_i'\beta + E(\varepsilon_i|x_i; x_i'\beta + \varepsilon_i > 0) \\ &= x_i'\beta + E(\varepsilon_i|x_i; \varepsilon_i) - x_i'\beta \\ &= x_i'\beta + \sigma \cdot \lambda(-x_i'\beta/\sigma) \end{aligned}$$

Therefore, when using sub-samples for regression, the nonlinear term  $\sigma \cdot \lambda(-x'_i\beta/\sigma)$  is ignored. It is included in the disturbance term, which causes the disturbance term to be related to the explanatory variable  $x_i$ , so the OLS estimation is inconsistent. For the entire sample,

$$E(y_i|x_i) = 0 \cdot P(y_i = 0|x_i) + E(y_i|x_i; y_i > 0) \cdot P(y_i > 0|x_i) = E(y_i|x_i; y_i > 0) \cdot P(y_i > 0|x_i)$$

As

$$P(y_i > 0|x_i) = P(y_i^* > 0|x_i) = P(x'_i\beta + \varepsilon_i > 0|x_i) = P(\varepsilon_i > -x'_i\beta|x_i) = P\left(\frac{\varepsilon_i}{\sigma} > \frac{-x'_i\beta}{\sigma} \middle| x_i\right) = 1 - \Phi(-x'_i\beta/\sigma) = \Phi(x'_i\beta/\sigma)$$

Therefore,  $E(y_i|x_i) = E(y_i|x_i; y_i > 0) \cdot P(y_i > 0|x_i) = \Phi(x'_i\beta/\sigma) [x'_i\beta + \sigma \cdot \lambda(-x'_i\beta/\sigma)]$  is a nonlinear function of the explanatory variable  $x_i$ . If OLS is used to perform linear regression on the entire sample, its nonlinear term will be included in the disturbance term, resulting in inconsistent estimates.

Tobin (1958) proposed using MLE to estimate this model, called the Tobit method [16,32–34]. When  $y_i > 0$  the probability density at a time does not change, still  $\frac{1}{\sigma}\phi[(y_i - x'_i\beta)/\sigma], \forall y_i > 0$ . But when  $y_i \leq 0$  distribution is squeezed to a point  $y_i = 0$ , namely  $P(y_i = 0|x) = 1 - P(y_i > 0|x) = 1 - \Phi(x'_i\beta/\sigma)$ . Therefore, the probability density function of the mixed distribution can be written as:

$$f(y_i|x) = [1 - \Phi(x'_i\beta/\sigma)]^{I(y_i=0)} \left[ \frac{1}{\sigma}\phi((y_i - x'_i\beta)/\sigma) \right]^{1(y_i>0)}$$

Therefore, the likelihood function of the entire sample can be written and then estimated using MLE.

### 3. Results

#### 3.1. Random-Effects Model Selected

Firstly, we use the fixed-effect least squares dummy variable (LSDV) method to estimate. As ordinary least squares (OLS) cannot use the clustering robust standard deviation, LSDV can be used. The ordinary standard deviation under OLS is less effective than the robust standard deviation of clustering, so the F-test of OLS may not be effective in this case [16]. The specific results are shown in Table 1.

Table 1. Fixed effect LSDV regression results.

Ingdp	Coefficient	Robust std. err.	t	P > t	[95% conf.	Interval]
lnlabor	1.884197	0.2232654	8.44	0	1.418473	2.34992
lncapital	−3.415403	0.1964353	−17.39	0	−3.82516	−3.005646
lntech	−0.0887293	0.0393135	−2.26	0.035	−0.1707357	−0.0067228
lnpollution	−0.0728982	0.3964882	−0.18	0.856	−0.8999582	0.7541617
id						
2	−1.099355	0.0891314	−12.33	0	−1.28528	−0.91343
3	−4.71644	1.03508	−4.56	0	−6.875579	−2.5573
4	−6.375027	0.9432812	−6.76	0	−8.342678	−4.407377
5	−2.358762	0.4289812	−5.5	0	−3.253601	−1.463923
6	−7.676051	1.09286	−7.02	0	−9.955717	−5.396386
7	−8.769257	1.373281	−6.39	0	−11.63387	−5.904643
8	−9.340738	1.231904	−7.58	0	−11.91044	−6.771033
9	−5.167388	0.8201045	−6.3	0	−6.878096	−3.45668
10	−7.759408	1.252987	−6.19	0	−10.37309	−5.145724

Table 1. Cont.

lngdp	Coefficient	Robust std. err.	t	P > t	[95% conf.	Interval]
11	−3.66642	0.376632	−9.73	0	−4.45206	−2.880779
12	−4.873893	0.7891717	−6.18	0	−6.520077	−3.22771
13	−5.131775	0.753666	−6.81	0	−6.703895	−3.559655
14	−8.610814	1.40466	−6.13	0	−11.54088	−5.680745
15	−7.026054	0.8912243	−7.88	0	−8.885116	−5.166993
16	−7.740174	1.036089	−7.47	0	−9.901418	−5.57893
17	−6.141635	0.9979905	−6.15	0	−8.223406	−4.059863
18	−7.323589	1.122507	−6.52	0	−9.665098	−4.982081
19	−9.395488	1.331497	−7.06	0	−12.17294	−6.618034
20	−6.980828	1.022822	−6.83	0	−9.114398	−4.847258
21	−8.706463	1.415568	−6.15	0	−11.65929	−5.753639
_cons	29.60347	5.596796	5.29	0	17.92875	41.27818

As the individual factor variables are used, one degree of freedom is missing in statistics, so the city id1 (Guangzhou) is standardized to 1. It can also be seen that the inefficiency level of the city id2 (Shenzhen) is much lower than the other Prefecture-level cities in Guangdong Province under the fixed effect. However, because the dummy variables of most individuals are very significant, and the individual effects are apparent, the random-effects model should be further adopted. Considering the long-term dimension of panel data, a time-varying attenuation model should be used.

### 3.2. Analysis of Individual Random Time-Varying Attenuation Model

Since the average period of this sample is 19 years, the probability of technological change is extremely high, and the direct use of the time-varying attenuation model of random effects will cause the model to fail to converge (See Table 2). Add the time dummy variable to estimate:

Table 2. Regression results of time-varying decay model.

lngdp	Coefficient	Std. err.	z	P > z	[95% conf.	Interval]
lnlabor	0.1808549	0.039011	4.64	0	0.1043946	0.2573151
lncapital	0.3542843	0.0316031	11.21	0	0.2923433	0.4162253
lnitech	0.070742	0.0138372	5.11	0	0.0436216	0.0978624
lnpollution	0.2072254	0.0262627	7.89	0	0.1557515	0.2586992
year						
2002	0.024745	0.0521957	0.47	0.635	−0.0775566	0.1270467
2003	0.0605332	0.0537396	1.13	0.26	−0.0447945	0.1658609
2004	0.1205836	0.056661	2.13	0.033	0.0095301	0.2316371
2005	0.1485102	0.0604527	2.46	0.014	0.0300252	0.2669953
2006	0.2362668	0.0641919	3.68	0	0.110453	0.3620805
2007	0.2930112	0.0689919	4.25	0	0.1577896	0.4282328
2008	−8.45228	0.088603	−95.39	0	−8.625939	−8.278621
2009	−8.430435	0.0909088	−92.74	0	−8.608613	−8.252257
2010	−8.582676	0.1034326	−82.98	0	−8.7854	−8.379952
2011	−8.582941	0.0889698	−96.47	0	−8.757318	−8.408563
2012	−8.57244	0.0948219	−90.41	0	−8.758288	−8.386593
2013	−8.533628	0.1013222	−84.22	0	−8.732216	−8.33504
2014	−8.491161	0.1073357	−79.11	0	−8.701535	−8.280787
2015	−8.465245	0.1134295	−74.63	0	−8.687562	−8.242927
2016	−8.408629	0.1183456	−71.05	0	−8.640582	−8.176676
2017	−7.718082	0.1712415	−45.07	0	−8.053709	−7.382455
2018	−7.676071	0.1754187	−43.76	0	−8.019885	−7.332256
2019	−7.658909	0.1795656	−42.65	0	−8.010851	−7.306967

Table 2. Cont.

Ingdp	Coefficient	Std. err.	z	P > z	[95% conf.	Interval]
_cons	10.53261	0.3687187	28.57	0	9.80993	11.25528
/mu	0.885207	0.1924876	4.6	0	0.5079383	1.262476
/eta	−0.0207798	0.0052681	−3.94	0	−0.0311051	−0.0104545
/lnsigma2	−1.764397	0.3405304	−5.18	0	−2.431825	−1.09697
/lgtgamma	1.62427	0.4195282	3.87	0	0.8020095	2.44653
sigma2	0.17129	0.0583295			0.0878763	0.3338813
gamma	0.8353831	0.0576927			0.6904042	0.9203073
sigma_u2	0.1430928	0.0584274			0.0285772	0.2576083
sigma_v2	0.0281972	0.0020693			0.0241415	0.032253

It can be seen from the above table that the time-varying coefficient (eta) and the time dummy variables after 2003 are both extremely significant. However, it was not significant before 2003 (inclusive), which may be due to China's official accession to the World Trade Organization in December 2001 and the SARS epidemic in 2003. At the same time, the relatively colossal decline in technical efficiency in Guangdong Province after 2008 may be due to the financial crisis and the crowding-out effect of the four trillion infrastructure construction on the technological level [35,36]. After the international financial crisis broke out in September 2008, China's economic growth rate dropped rapidly, and the economy faced the risk of a hard landing. To cope with this crisis, the Chinese government launched a package of measures to expand domestic demand further and promote steady and rapid economic growth in November 2008. It was initially estimated that the investment would be about four trillion yuan by the end of 2010. The relevant measures involve many major infrastructure constructions such as railways, highways, rail transit, and airports. For China, where the external economic environment was rapidly deteriorating in 2008, the most considerable significance of the four trillion-yuan plan was a positive signal sent by the central government to inspire confidence in the sluggish market. Although over time, the shortcomings of the four trillion-strong economic stimulus plan have also been criticized: it has missed the excellent window period for industrial restructuring. It allows low-end/low-efficiency industries to survive and over-scale. The over-issued currency did not enter the real economy as expected [37–41].

Guangdong's dazzling achievements are inseparable from its development history. The opening of the Maritime Silk Road has made Guangdong Province a vital link between China and Southeast Asia, Africa, and Europe. In 1978, Guangdong took the lead in implementing the reform and opening policy throughout the country and became China's most prominent economic province. It has always been one of the most developed market dynamics and attractive investment regions in China. The considerable number of enterprises and the well-developed private economy create millions of jobs every year, attracting labor from all provinces across the country to come to Guangdong to pan for gold. But as far as Guangdong Province is concerned now, its productivity is still mainly driven by investment and labor, and the pollution caused by it is also very severe. Although the technical level has also been improved to a certain extent, the effect is not significant in the entire province.

### 3.3. Tobit Analysis

We adopt the pooled Tobit model and the  $u_i$  of Shenzhen obtained in the previous period is the result variable. The number of employees in each city in Shenzhen at the end of the year, the amount of investment in fixed assets of the whole society in each city, the internal expenditure of science and technology funds of large and medium-sized industrial enterprises, and the GDP (due to Shenzhen's industrial structure is quite different from other prefecture-level cities. It is more reasonable to use GDP instead of pollution to characterize the impact of human society and economy on the ecological environment) as the response variable. The results are shown in Table 3:

**Table 3.** Shenzhen Tobit regression results.

Uhat Coefficient	Std. err.	t	P > t	[95% conf.	Interval]
lnlabor	−0.0362742	−1.88	0.061	−0.0742097	0.0016613
lncapital	−0.2018442	−12.6	0	−0.2333428	−0.1703456
lntech	−0.0253503	−6.81	0	−0.032666	−0.0180345
lngdp	−0.040579	−8.67	0	−0.0497757	−0.0313824
_cons	2.997522	30.63	0	2.805156	3.189889
var(e.uhat)	0.0601729	0.0042602		0.0523541	0.0691592

It can be found that the improvement of labor level, the improvement of investment level, the advancement of technology level, and the progress of socioeconomic status can all reduce inefficiency items. The economic growth of Shenzhen is still mainly driven by the input of increasing factors. The considerable redundancy of capital and employee input is not conducive to the further economic development of Shenzhen. The key to solving these problems still lies in technological progress. Although the coefficient of technological level is relatively small, according to the literature, it is highly correlated with the improvement of labor quality, the improvement of capital return rate, and the improvement of socioeconomic level [42–47]. Therefore, it is necessary to take scientific and technological progress as the core and combine it with the level of investment, labor level, and socioeconomic level to reduce low production efficiency and improve sustainable development. The driving forces of various demand factors in a country at different times are inherently other. China's economic growth is mainly driven by investment demand, which should still be fully utilized at this stage. Under the Covid-19 epidemic, investment demand plays a vital role in stabilizing economic growth. We believe that technological innovation and infrastructure construction will become the primary components of the investment driving force. The essence of economic growth is the continuous improvement of labor productivity, which depends on the progress of science and technology.

#### 4. Discussion

In the development process of the 21st century, Shenzhen should be the first to take the lead in building a sustainable metropolis in China.

When the economic situation is facing shocks, the government uses non-market means to encourage investment to achieve high economic growth. This method can significantly stimulate investment, but it will form many ineffective investments, most notably fixed asset investments.

##### 4.1. Improve the Distribution of Scientific Research Funds and Expand Scientific Research Expenditures

Following this, the key to controlling invalid investment is, therefore, according to Section 3.3, to establish a scientific research management mechanism based on trust and give scientific researchers greater discretionary control over humans and properties, and to pay close attention to implementing the income distribution policy-oriented to increase the value of knowledge and reasonably determine scientific research personnel's income level. On this basis, supplement funds for scientific research projects and the conversion of scientific and technological achievements should be provided [48–50].

##### 4.2. Actively Develop the Capital Market and Develop Direct Financing

Scientific research projects require significant R&D funds, long R&D cycles, and slow return of funds; scientific research activities have certain risks, and enterprises need to bear more significant responsibilities. The problem of funding bottlenecks in the development of high-tech enterprises has become prominent. Banks cannot provide strong financial support during the entrepreneurial stage of high-tech enterprises due to their risk aversion characteristics. Therefore, it is important to strengthen the construction of the capital

market financing system for high-tech enterprises. Expanding the financing channels of high-tech enterprises is the key to the survival of high-tech enterprises [51,52].

#### 4.3. Further Transform Government Functions

According to Section 3.2, it is necessary to strictly regulate government behavior and make it clear that the government's function is to create an environment for economic and social development, maintain economic and social development, and provide necessary public products and services. Through institutional changes, the budget constraints of governments, banks, and enterprises at all levels will be strengthened, and the institutional factors caused by ineffective investment will be alleviating.

### 5. Conclusions

The demonstration zone is a sample of cities that have accumulated "Chinese experience" and contributed to the world. Shenzhen is the frontier of China's reform and opening up. China's reforms were initially initiated by a small group of farmers fighting for basic welfare, and this has gradually been recognized by governments at all levels [53]. Afterward, the pilots of "opening up" were carried out in several coastal cities, including Shenzhen, and their experiences were shared nationwide. This is a bottom-up and top-down process. The tremendous success of reform lies in institutional reforms and appropriate policy reforms. Although considering the particularity of China's reform and the scale of development, very few countries could be directly compared to China. However, excitingly, China is currently making itself a living laboratory for different pathways to sustainable development by delegating power to regional units such as Shenzhen.

It is a milestone to build Shenzhen into a pioneering area for implementing the 2030 Agenda for Sustainable Development. In just forty years, starting from a small fishing village, Shenzhen's development level is now close to that of a developed country with equally high speed, which could be regarded as a splendid miracle compared to *prima facie* similar cases studied in other regions [54,55]. Shenzhen's transformation is extremely leading and referenced in major cities in China, and even in the world. In the Industry 4.0 era, the transformation of cities, especially in emerging economies, needs to be supported by science and technology. How these cities can meet the SDGs, especially the requirements of SDG 9, Shenzhen's pathway will have significant reference values and provide new insights than those from developed regions. This article has discovered the crowding-out effect of ineffective investment on production efficiency and quantitatively discussed how Shenzhen should improve production efficiency through technological innovation and institutional change. Of course, many of the points put forward in this article are only preliminary attempts, and we look forward to more quality studies in the future.

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