Research Article

Spatial Interaction Effect of Nonpoint Source Pollution and Economic Growth on Agriculture Using Kuznets Curve and Grey Correlation Analysis

Jilin Tian¹ and Yinong Liu²

¹China Institute for WTO Studies, University of International Business and Economics, Beijing 100029, China
²School of Business Administration, Zhongnan University of Economics and Law, Wuhan Hubei 430073, China

Correspondence should be addressed to Yinong Liu; 202001080016@stu.zuel.edu.cn

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This study used the environmental Kuznets curve to assess the link between regional growth in the economy and several types of agricultural nonpoint source pollution. To protect the environment in China, prevention of nonpoint source pollution and agricultural control are essential. In agriculture, nonpoint source pollution is mostly produced by improper usage of agricultural production components such as chemical fertilizers and plastic films. This paper aims to investigate the interacting effects of agricultural nonpoint source pollution and the economics of agricultural growth space to achieve synchronized growth of environmental atmosphere and agricultural economy. To evaluate agricultural nonpoint source pollution completely, the production coefficient technique and the equal standard pollution load approach are utilized. The Kuznets curve is used to verify the interaction impact between agricultural nonpoint sources and each person’s agricultural gross production value. Grey correlation analysis was utilized for further verification to increase the efficacy of verification of interaction effect between the two parameters. Experiments show that the proposed method has a good fitting effect and is easily implementable. It serves as an effective resource for future agricultural research and encourages the green development of agriculture.

1. Introduction

With the gradual development of modern agriculture, China’s agricultural economy has developed rapidly. However, there are numerous agricultural environmental problems, one of which is agricultural nonpoint source pollution, which has significantly hindered the growth of ecological environment and social economy [1]. The use of pesticides and chemical fertilizers along with excessive use of plastic film is source of agricultural nonpoint source pollution (ANPSP). The lack of scientific discharge of livestock and poultry dung, as well as pollution sources in life, is a factor in the agricultural production process. Eutrophication pollution of water bodies, a reduction in land fertility, and soil degradation are all identified as nonsource pollution. China has issued various treatment specifications in recent years, proposing to gradually reduce the use of chemical fertilizers and pesticides [2]. In rural areas, the ecological environment has improved, as have the important requirements for nonpoint source pollution prevention and control. Pollution control and the relationship between increased agricultural performance and improved agricultural revenue have both been successfully managed [3]. Agricultural nonpoint source pollution treatment can improve not only agricultural productivity but also the agricultural ecological environment. This is more conducive to environmental protection, the development of the beautiful countryside, and a rural revitalization strategy. The relationship between agricultural pollution sources and how to improve the maintainable growth of China agriculture is particularly important. Therefore, this paper uses the Kuznets curve and grey correlation analysis to analyze the effect of economic growth and agricultural nonpoint source pollution [4].
The relationship between economic conditions and the resulting environmental pollution has been studied and debated by a vast number of academics and research institutes. The economist who first raised the topic of economics and environment was a graduate of one of the key American universities. He primarily presented a measurable correlation study of sites and the economic environmental variables that corresponded. The findings of the investigation reveal a reversed U-shaped association among the corresponding economy and environmental pollution. However, the economist cautioned that the associated inverted connection should be used with caution because the underlying connection is dependent on the type of environmental contaminants implicated [5, 6]. The pertinent researchers then presented the current Kuznets curve concerns and investigated its consistent variety. They found that only when the comparable contaminants are described as sulfuric acid and other stimulants, it is deemed to satisfy the Kuznets curve, but some governmental authorities do not agree this due to the control of related political elements [7]. Carbon dioxide is the assessment directory of conservation contaminants in the consistent developing nations, according to relevant researchers. The corresponding research findings indicate that now the corresponding turning point occurs when the country’s each personal GDP reaches approximately 5000 United States dollars and also that the corresponding prediction important milestone occurs around 2040; however, the commensurate forecast cannot verify this point perfectly, and as such the corresponding Kuznets quotient is used instead. It looks like the line is broken down [8]. Notwithstanding the becoming influence by potential determinants, the associated connection among both economy and environment needs to meet this same inverse U-shaped pattern of the Kuznets curve inside the commensurate industrialized economies when the corresponding performance measurements are described as industrial effluents, manufacturing effluent gas, and commensurate industrial waste products [9, 10].

The methodology for agricultural nonpoint source pollution has been evaluated, and the data for agricultural nonpoint source pollution location and other data obtained utilizing remote sensing techniques, as well as the set of data for agricultural nonpoint source pollution emissions, must have been obtained by having to fill in different kinds of incomplete data. The strategy of integrating artificial neural and Kuznets matching equations was utilized to develop the emissions extraction of features framework of agricultural nonpoint source pollution and achieved the emissions segmentation method of agricultural nonpoint pollution. The actual results demonstrate that, over agriculture nonpoint source pollution emission datasets, the minimum time required is 3.6 seconds, extraction of features precision is always over 94%, and extraction of features time is something less than 0.5 seconds; the practical implementation effect is excellent [11]. The authors of the study assessed water resource input and wastewater dispersion for the agricultural experimental region between 1999 and 2019 concerning water footprints. The decoupling assessment model is constructed on this basis to explore the dissociation causal relationship between economic growth and state water environments, including its development rule. The structure of production should be modified to control and enhance economic growth by lowering water usage, developing air pollutant control technologies, and getting proper utilization of water resources to provide evidence for an acceptable water resource management strategy [12]. This study used the modified Grey relational degree (GRD) framework and the environmental Kuznets curve (EKC) to statistically and aesthetically analyze the connections between water contamination and economic expansion in the Nansi Lake Basin as part of the Shandong 5 Program. There was a correlation involving industrial effluent and economic growth, according to the data. Wastewaters discharges are also on the increase, and they are now one of the most significant causes of water pollution in the Nansi Lake Basin. The findings of this study revealed that combining the updated GRD framework with the EKC provides a unique way for assessing the water pollution, economically improved and developed in both descriptive and analytical terms [13].

According to studies on its source and manufacturing method, nonpoint source contamination is strongly linked to the crystallization process and is regulated and influenced by the hydrologic production cycle. As a result, the randomness of nonpoint source pollution creation is dictated by the variability of weather. Mostly in the case of agricultural nonpoint pollution, the environmental damage caused by agricultural chemical applications in fields is, to a large extent, highly connected to rainfall data; in other terms, pollution can only occur when rain drives it. Therefore, agricultural fertilizers may build on the ground, and contamination will only emerge during the product flow and convergence processes under wet conditions, with a significant delay [14]. A variety of variables impact pollutants, including geography, human activities, and soil conditions. Because there is no identifiable cause of pollution, the actual release point cannot be determined, and the inconsistent outflow, the source of contaminants, and the pollutants loading are all unknown, creating nonpoint source pollution control that is very difficult [15]. Climate factors including precipitation have a big impact on nonpoint source pollution, while spatial factors have a big impact on its severity. Because of its ambiguities, repeatability, and some other characteristics, monitoring nonpoint source pollutants and accurately assessing their contribution rate to water contamination is challenging. The Ningxia Yellow River’s irrigation region not only supports Ningxia’s social and economic development but also stops the Tengger and Musu deserts from growing [16]. Ecological considerations have a greater impact on the Ningxia Yellow River irrigation basin than economic reasons. Large volumes of returning water, on the other hand, have an important influence on the aquatic environment downstream in the Yellow River. There is currently insufficient education on the connection amid agricultural financial expansion and environmental changes. Eleven counties in the Ningxia Yellow River irrigation basin had their statistical data gathered, sorted, and assessed. The characteristics of animal dung and regional residential pollutants, such as human excrement and regional municipal
wastewater, were examined and studied using government standards and literature review [17]. The relevant material was utilized to discover a curve that matched the information on animal wastes and rural house contamination. In the Yellow River irrigation basin, this study does have theoretical and practical implications for agricultural nonpoint source pollution control and environmental preservation.

The following are the paper main contributions:

(i) To analyze agricultural nonpoint source pollution, the production coefficient approach and the equal standard organic pollution methods are utilized, and the Kuznets curve and grey correlation analysis are employed to evaluate the influence of the interactions between these.

(ii) The simulation outcomes demonstrate that the fitting result of interactive effect analysis is good and practical, which can provide an effective reference for subsequent agricultural-related research and play an important role in promoting agricultural development in the future.

(iii) A simulation experiment was carried out using SPSS19 software and then implemented on the simulation environment to test the performance of analyzing the relationship between agricultural nonpoint source pollution and agricultural economic expansion based on the Kuznets curve and grey correlation analysis.

(iv) To effectively adjust the structure of agricultural planting to encourage the effective enhancement of the quality of agricultural products and realize the supportable growth of agriculture.

The rest of this paper will be arranged in the following logical order: Section 2 shows related work, Section 3 shows the research methods of agricultural nonpoint source pollution and agricultural economics, Section 4 shows the agriculture nonpoint source pollution and agricultural economic growth have a spatial interaction effect, and Section 5 shows analysis of experimental results. Finally, Section 6 illustrates the research to a conclusion.

2. Related Work

The general public has grown increasing conscious of the relevance of agricultural nonpoint source pollution as civilization has progressed recognizing. That modern agriculture not only delivers great productivity and a variety of material items but also poses major environmental concerns. As a result, scholars have conducted extensive research on agricultural nonpoint source pollution and agricultural economic growth. Agricultural nonpoint source pollution, according to the author, has steadily become the most serious problem influencing social and economic growth, in which the agricultural structure is a key regulatory factor, on the assumption that the entire quantity of excess nitrogen in agriculture is the source of nonpoint source pollution. Using the corresponding function and variance decomposition approach based on the pulse of the VECM model, the link between agricultural economic growth, agricultural nonpoint source pollution, and agricultural structure is explored. The findings suggest that agricultural economic growth, agricultural nonpoint source pollution, and agricultural structure have a balanced connection. The variance decomposition structure reveals that agricultural economic growth and agricultural structure have relatively little influence on agricultural nonpoint source pollution. Agricultural nonpoint source pollution contributes a little amount to the forecast variance. However, agricultural nonpoint source pollution has a significant influence on agricultural economic growth [18].

In recent years, gradually promote complete treatment of agricultural nonpoint source pollution and seek a balanced connection between the environment and agricultural growth. Select the appropriate data of four essential agricultural nonpoint source pollution indicators to better understand the link between agricultural nonpoint source pollution and agricultural economic growth. The following results may be drawn using the environmental Kuznets curve theory and the software of Statal 6.0 version. The four-variable indicators in agricultural nonpoint sources and per-capita agricultural production value have a typical curve connection, and the inflection point in the study time series has occurred. The quality of chemical fertilizer pollution and livestock manure pollution must be the emphasis of agricultural nonpoint source pollution control, as can be observed from the pollution sources. This technique, however, does not result in long-term economic progress [19]. Understanding the present geographical link between agricultural nonpoint source pollution and economic growth, as well as the stage of agricultural nonpoint source pollution in a way that is beneficial to China’s relevant departments, to take appropriate actions to avoid and manage pollution, as well as to choose pollution indicators and economic growth statistics in a reasonable manner, the relationship between agricultural nonpoint source pollution and agricultural economic growth was studied using the EKC curve. The findings reveal that the usage of the four agricultural nonpoint source pollution indicators and economic growth resembles a curve, with various pollution types being used and emitted at different phases of the curve. The use of insecticides steadily dropped, the use of chemical fertilizer and plastic film increased, and animal and poultry dung emissions fell. Even though the method for this technology is more sophisticated, it provides acceptable answers when combined with the right treatment of agricultural nonpoint source pollution in China [20]. The authors found relevant data on agricultural economic development and agricultural nonpoint source pollution based on the EKC hypothesis. Build the best model using a linear function model fitting to investigate the association between agricultural economic growth and nonpoint source pollution in agriculture. According to the findings, there is a clear relationship between the amount of chemical fertilizer and pesticide used and the overall agricultural production value per capita. The usage of plastic film and the overall agricultural production value per capita then form a U-shaped curve.
The EKC curve’s inflection point is crossed by both pesticide application intensity and film application quantity, whereas chemical fertilizer application intensity is on the left side of the curve. However, chemical pollution does not reach the inflection point, suggesting that chemical fertilizer contamination is quite substantial, making this strategy impractical [21,22].

3. Research Methods for Agricultural Economic Growth and Pollution from Nonpoint Sources

3.1. Output Coefficient Method. The output coefficient method comprehensively considers the classification of land use and is combined with the distribution of livestock and poultry. The nonpoint source pollution emission and treatment of rural residents can accurately estimate the load. The output coefficient method is used to estimate the pollution load, which is expressed by formula (1):

$$L_i = \sum_{j=1}^{n} E_{ij} A_j + P.$$  

(1)

In formula (1), $L_i$ represents the load of agricultural pollutants, $E_{ij}$ represents the output coefficient of agricultural pollutants $i$ in $j$ and use type, or the output coefficient of pollutants $i$ produced by the $j$ livestock and poultry breeding, or the output coefficient of pollutants caused by demographic factors. $A_j$ represents the area of $j$ and use type, or the breeding quantity, or population quantity of the $j$ livestock and poultry, and $P$ represents the total amount of pollutants input by rainfall, and $n$ represents the number of agricultural pollutants [23, 24].

The total phosphorus of livestock and poultry breeding and rural life and the population of environmental protection are determined, and the values are shown in Table 1.

3.2. Pollution Load Technique of Equal Standard. The pollution levels of agricultural pollution sources can be responded to by an equal standard pollution load, which belongs to the equal standard volume of pollutants discharged per unit time. The equal standard emission of agricultural pollutant $i$ is calculated and expressed as

$$P_i = \frac{C_i}{C_0}.$$  

(2)

In formula (2), $P_i$ represents the equal standard emission of agricultural pollutant $i$, $C_i$ represents the loss of agricultural pollutant $i$, and $C_0$ represents the concentration of agricultural pollutants. The optimal model is selected through the $F$ value and determination coefficient tested by the output regression equation [25, 26].

3.3. Data Sources. These study findings are based on data from more than 30 Chinese provinces and regions. Statistical yearbook and the intensity index are used to effectively measure the data, to make it fair between regions.

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Total nitrogen</th>
<th>Total phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy field</td>
<td>16.96</td>
<td>1.21</td>
</tr>
<tr>
<td>The dry land</td>
<td>15.63</td>
<td>1.61</td>
</tr>
<tr>
<td>Woodland</td>
<td>2.35</td>
<td>0.36</td>
</tr>
<tr>
<td>The cow</td>
<td>6.10</td>
<td>1.02</td>
</tr>
<tr>
<td>The pig</td>
<td>0.46</td>
<td>0.18</td>
</tr>
<tr>
<td>The sheep</td>
<td>0.24</td>
<td>0.043</td>
</tr>
<tr>
<td>Poultry</td>
<td>0.027</td>
<td>0.011</td>
</tr>
<tr>
<td>The rural population</td>
<td>1.57</td>
<td>0.16</td>
</tr>
<tr>
<td>The urban population</td>
<td>2.47</td>
<td>0.26</td>
</tr>
</tbody>
</table>

4. Agriculture Economic Growth and Pollution from Agricultural Nonpoint Sources Have a Spatial Interaction

4.1. Analysis Based on Kuznets Curve. Combined with the above research methods, to investigate the interaction among agricultural pollution and agricultural growth, this paper comprehensively verifies the Kuznets curve by using three theoretical models: linear formula (3), quadratic curve formula (4), and cubic curve formula (5).

$$y = b_0 + b_1 x,$$  

(3)

$$y = b_0 + b_1 x + b_2 x^2,$$  

(4)

$$y = b_0 + b_1 x + b_2 x^2 + b_3 x^3.$$  

(5)

4.1.1. Simulation Analysis of Fertilizer Application Intensity. It can be shown from the regression findings between the amount of chemical fertilizer used and the overall agricultural production value per capita that the fitting effect of the cubic curve model is good, and the level of analysis of variance is 0, which is represented in Table 2. It is concluded that the optimal model between the intensity of chemical fertilizer application and the total agricultural output value per capita is represented by formula (6):

$$y = 105.749 + 0.11 x + (-8.153 x - 7) x^2 + (2.202 x - 11) x^3.$$  

(6)

With the increasing demand for grain, the application of chemical fertilizer is also increasing year by year. From the curve fitting results, it is roughly in the "N" type. The total output value of per-capita agriculture at the inflection point is 12355 yuan. As shown in Figure 1, with previous modulation opinion, the application intensity of chemical fertilizer increases with economic growth. The closer it is to the inflection point, the faster the growth rate decreases. When it exceeds 12354 yuan, the application intensity of chemical fertilizer increases gradually, but if it is not controlled, the
4.1.2. Simulation Analysis of Pesticide Application Intensity.
According to \( R^2 \) and \( F \) values in Table 3, the best model for describing the connection between pesticide application strength and the per-capita gross production value is the quadratic function, and \( \text{Sig} \) is 0.000, which indicates that the model is statistically significant.

By introducing the parameters into formula (7), the total agricultural output value per capita at the inflection point is 15930.78 yuan. With the change in the overall planting structure, the growing field of some agricultural income crops falls, but the growing field of maize with a low pesticide usage rate grows, resulting in a large drop in chemical herbicide demand. Combined with the above reasons, the trend develops to the right side of the Kuznets curve, as shown in Figure 2.

\[
y = 1.631 + 0.001x + (-1.666E - 8). \tag{7}
\]

4.1.3. Plastic Film Application Intensity and Per-Capita Gross Agricultural Production Value Simulation.
The cubic fitting result is the best, as shown in Table 4, based on the regression findings between the amount of plastic film used and the per-capita gross agricultural target output. The coefficient is introduced into formula (8), and the fitting curve is in an "N" shape. As shown in Figure 3, the total output value of agriculture per capita at the inflection point is 1244.84 yuan and 17639.66 yuan. The plastic film has the characteristics of heat preservation and moisture retention. However, in recent years, due to the excessive use of plastic film, the cumulative amount of soil residual film increases with the year, resulting in the hardening of the land and the reduction of crop yield.
To decrease the harm produced using plastic film, relevant parts advocate the recycling of used plastic film and the introduction of degradable plastic film. Therefore, the peak use of plastic film decreases with economic growth, which is located on the right side of the Kuznets curve [29, 30].

\[
y = 74.384 - 0.001x + (4.300E - 7)x^2 + (-1517E - 11)x^3. \tag{8}
\]

4.1.4. Simulation Analysis of Excretion Density of Livestock and Poultry Feces. According to the regression results of livestock and poultry manure pollution production and per-capita gross agricultural production value, the cubic fitting effect is good, which is shown in Table 5. By introducing this coefficient, formula (9) can be obtained. There are two inflection points in the closed curve. As shown in Figure 4, the per-capita gross agricultural output value is 5630.67 yuan and 16444.17 yuan. With the continuous development of the breeding industry, the amount of livestock and poultry feces is also gradually increasing. As shown in Figure 4, before the first turning point, the amount of livestock and poultry feces is increasing with the total output value, indicating that, with the gradual growth of the economy, the amount of livestock and poultry feces is also gradually increasing [31, 32].

\[
y = 4612.085 + 1.507x + (-1.806E - 4)x^2 + (5.539E - 9)x^3. \tag{9}
\]

4.2. Grey Correlation Analysis. Compared with the above model analysis based on the Kuznets curve, grey correlation analysis is used for reverification.

4.2.1. Construct the Reference Sequence. Construct the reference sequence and subsequence of agricultural nonpoint source pollution. Using agricultural data and important
indicators of agricultural economic growth and agricultural nonpoint source pollution, the grey correlation approach was applied. This paper constructs a grey correlation analysis perfect to comprehensively investigate the correlation between agricultural pollution and economic growth [33, 34], as shown in Figure 6. A virtual environment testing was performed using SPSS19 software and then implemented on the simulation platform to verify the effectiveness of using the Kuznets curve and grey correlation analysis to explore the association between agricultural economic growth and agricultural nonpoint source pollution in agriculture $r_{0i}$. The formula may be used to calculate the degree of management between agricultural economic growth and agricultural nonpoint source pollution (12). The correlation degree between the use of chemical fertilizers, plastics, and pesticide films and the pollution production of livestock and poultry and the added value of agriculture is 0.7138, 0.7046, 0.7109, and 0.7753, and the four indexes are higher than 0.7, indicating a relatively high correlation relationship. In particular, the correlation degree between the pollution production of livestock and poultry breeding and the actual total agricultural output is above 0.75, indicating that the pollution production curve of livestock and poultry breeding is very similar to the curve of the actual total agricultural output value $r_{0i}$.

$$r_{0i}(k) = \frac{m + \xi M}{\Delta_i(k) + \xi M}$$  \hspace{1cm} (10)

In formula (10), $\xi \in (0, 1)$, $k = 1, 2, \ldots, n$, and the correlation coefficient between sequences is calculated.

### 4.2.5. Correlation Degree

Ranking of correlation degree between agricultural economic growth and agricultural nonpoint source pollution: It can be seen from the calculation results of the previous step that $r_{01} > r_{03} > r_{02}$, which shows that, from the association between agricultural economic growth and agricultural nonpoint source pollution, it is the pollution production of livestock and poultry breeding that has a great influence on the relationship of agricultural economic growth, followed by the application of chemical fertilizer, plastic film, and pesticide [37].

### 5. Experiment Results and Analysis

A virtual environment testing was performed using SPSS19 software and then implemented on the simulation platform to verify the effectiveness of using the Kuznets curve and grey correlation analysis to explore the association between agricultural economic growth and agricultural nonpoint source pollution.
The fitting impact of the strategy suggested in this work is compared to that of a singular Kuznets curve of both agricultural economic growth and agricultural nonpoint source pollution. To test the applicability of the Kuznets curve and grey correlation analysis approach suggested in this study, the fitting impact of the approach described in this study and the standard Kuznets curve are compared in Figure 5.

By analyzing Figure 5, the fitting impact of the four Kuznets curve indications and grey correlation for agricultural nonpoint source pollution predicated on the analytical approach described in this research is higher than that of a single Kuznets curve, as can be observed. The fitting effect of the interactive investigation of agricultural economic growth and agricultural nonpoint source pollution, so promoting agricultural greening and
sustainability. Figures 6 and 7 show the comparison of the practicability of the proposed method and the single Kuznets curve for agricultural economic growth and agricultural nonpoint source pollution.

Through the comparative analysis of Figures 6 and 7, the method based on the Kuznets curve and grey correlation analysis proposed in this paper are relatively practical for the verification of various indicators of agricultural nonpoint source pollution [38]. The feasibility of using a single Kuznets curve to verify numerous indicators of agriculture nonpoint source contamination is substantially lower than the technique provided in this study. It shows that the practicability of verification only using a single Kuznets curve is poor. It is not effective to comprehensively analyze the interactive effect between economic growth and agricultural nonpoint source pollution. Therefore, using the method proposed in this paper can provide an important situation for follow-up agricultural research and promote the green growth of agriculture in what is upcoming.

6. Conclusions

Agricultural nonpoint source pollution in numerous nations has become increasingly significant as the social economy has developed, posing a serious threat to human health. Controlling agricultural nonpoint source pollution is vital in both theoretical and practical implications. To that aim, it is necessary to develop an analytical technique for agricultural emission characteristics and to construct an actual system for managing agricultural pollution. The significance of the connection between agricultural nonpoint source pollution and agricultural economic growth space is highlighted through an in-depth analysis. As a result, as revenue increases, the pollution burden lowers. However, the preceding results are based on environmental economics; this finding is not a good predictor of a reduction in overall pollution. In the previous 19 years, the regression relationship between farmers per income per capita and livestock-breeding pollutants has shown typical EKC features; yet, livestock-breeding emissions have been steadily growing. In the agricultural water and soil environmental area, controlling nonpoint source pollution is becoming a critical problem; as a result, river basin pollution regulators must receive more attention in the future, and more research into comprehensive agricultural nonpoint source pollution control measures should be conducted. Because current strategies for extracting agricultural nonpoint sources pollution emission characteristics have various flaws, this study suggested a technique for extracting agricultural nonpoint source emissions control features based on the Kuznets curve. Experiments were used to determine the maximum process time for agricultural nonpoint source pollutant emission data. To support the effective enhancement of agricultural product quality and achieve agriculture’s long-term growth, it is required to properly adapt the structure of agricultural planting. Paying attention to agricultural pollution is a very significant development measure in China at the current for agricultural production development, and it is important to promote China’s agricultural economic
growth and environmental optimization. As a result, it is important to investigate the connection between economic growth and agricultural nonpoint source pollution.

**Data Availability**

All the data about this research are included for the publication of this work.

**Conflicts of Interest**

The authors declare that there are no conflicts of interest for the publication of this paper.

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