Mining area ecological protection: knowledge production from the perspective of planned behavior theory

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ABSTRACT
To assess residents’ knowledge of ecological protection in mining areas, an analytical model following the planned behavior theory was developed. Data from China’s Huainan mining area were collected through a questionnaire survey and statistically analyzed through a structural equation model and a resistance diagnosis. Results showed that the relative importance of behavior perception (0.457), behavior attitude (0.332), and behavior norms (0.231) to the mining area ecological protection decreases successively for mining area residents. Further, the dominant influencing factors of economic benefits and neighborhood ethic pressure are identical, except for the observed variables of behavior perception, and there is a difference between the second and the third observed variables in relation to behavior attitude. Finally, it was also found that the causal chain path coefficient of groups with no willingness to pay was greater than that of the others. The findings of this study can help understand the impacts between the behavior cognition of mining area ecological protection and ecological protection, as well as the impact of mining area resident behavior willingness on the causal chain. Further, ecological protection knowledge production based on these are beneficial to achieve ecological security and sustainable development of mining areas. To improve knowledge productions, it is recommended to introduce the concept of ‘co-construction, co-governance, and sharing’ into the production system, devising new means of precise data gathering interventions, and optimizing a new path of value realization.

1. Introduction
Coal is one of the most efficient mineral resources, and its exploitation is increasing. However, coal exploitation destroys and degrades the ecological environment service system where it is mined. This restricts the social and economic development of the mining area and endangers its ecological security. The report of the 19th National Congress of the Chinese Communist Party (CCP), in 2017, points out that building
an ecological civilization is a millennium project for sustainable development in China. As an important part of an ecological civilization, mining area ecology also poses several challenges. In light of the current situation of mining area ecology, the Chinese government, at all levels, has issued several policies, along with effort from academics, who also launched numerous studies into ecological protection (Bai et al. 1999, 2008; Li and Guo 2012; Cheng et al. 2013; Wang and Bai 2015; Chen et al. 2018).

From the perspective of knowledge production, mining area ecological protection means introducing a ‘new combination’ of elements and conditions into the production system that never existed before (Schumpeter 1990), such as creating, introducing, communicating, and applying a new idea, as well as commercializing the new idea. This should lead to the transformation of the mining area ecological environment management system and management ability (Rogers 1993) and promote the construction of an ecological civilization. Further, the mining area ecological protection will be improved by self-knowledge creation and knowledge transfer from new fields and perspectives based on deepening the understanding of the operational mechanism and development regularity (Deng and Qian 2009). Finally, mining area ecological protection means realizing knowledge commercialization based on scientific discovery and technological invention, using explicit and implicit knowledge (Zou and Wang 2016).

Given that the knowledge production of mining area ecological protection always takes place in a certain social environment, it involves not only economic behavior but also social and political behavior. Therefore, planned behavior theory (PBT) in Figure 1 is drawn to analyze the inner mechanism of mining area ecological protection. The PBT is one of the most influential behavior prediction theories in the field of social psychology. It is devoted to the study of how individual behavior attitude, behavior norms, and behavior perception affect the behavior of the subject (Duan and Jiang 2008; Yan 2014). Therefore, it is widely used in the field of behavioral science to explain the behavior motivation and behavior intention of people and to predict the behavior of the subject (Wang and Zhu 2016; Zeng and Wei 2017). Based on the PBT, this study will analyze the current situation and survival situation of ecological protection knowledge production in mining areas and clarify the preconditions and knowledge production space of mining area ecological behavior protection and behavior compensation. This study can help understand ecological protection knowledge production in mining areas and is beneficial to achieve ecological security and sustainable development of mining areas.
2. Experimental procedures

2.1. Study area

Huainan, one of the larger cities in Anhui Province, is located along the middle reaches of the Huai river in China. As a mineral resource-based city, it is one of the 44 resource-exhausted cities in China. The mining area is approximately 180 km long from east to west and 15 to 25 km wide from north to south, covering an area of about 3,200 km². It is roughly equivalent to the geographical scope of Huainan City.

The Huainan mining area, as a special functional area, has benefited from the ‘resource dividend’ for a long time. However, since the 1990s, due to its characteristics, new economic forms, and economic phenomena, it has encountered several problems—economic recession, declining competitiveness, and ecological environment destruction. Therefore, the degradation of its mining area ecology has seriously threatened the area’s social and economic development and ecological civilization construction. Thus, it is necessary to analyze how awareness of the need for ecological protection can be fostered in the mining area residents and how their behavior can be changed to enable the creation of feasible strategies for the restoration of the mining area’s ecology. This would facilitate the construction of a mining area ecological civilization.

2.2. Analysis model

The knowledge production of mining area ecological protection has an important influence on the ecological environment service system. Scholars found that mining area ecological protection is not only affected by objective factors—per capita net income of families, social capital, and ecological policies (Matthew and Stephen 2000; Gao et al. 2014; Zhang et al. 2019)—but also constrained by the knowledge production (Zheng 2008; Peng et al. 2017; Chen 2019; Zhang et al. 2019; 2019). Among them, from the perspective of the PBT, ecological protection will be constrained by knowledge production in the dimensions of behavior attitude, behavior norms, and behavior perception (Liao and Zhang 2012; Hou et al. 2019; Luo et al. 2020). However, there are doubts regarding how to avoid the randomness and uncertainty of the internal correlation of these variables (Jia 2008; Jiang et al. 2018; Hu et al. 2019; Wang et al. 2019). Therefore, this study aimed to optimize the ecological protection knowledge production in mining areas from the perspective of the PBT and strengthen the value realization ability of knowledge creation and knowledge transfer through deepening its theoretical cognition.

Behavior attitude refers to the psychological tendency of individuals to present liking or disliking responses in the process of conducting a specific behavior. Mining area residents’ behavior attitude refers to their positive or negative evaluation of mining area ecological protection. Roughly, the more positive the behavior attitude of mining area residents is, the stronger the tendency toward ecological protection tends to be, and the more likely they are to respond.

The behavior attitude of mining area residents can be divided into three dimensions: economic, social, and ecological benefits. In terms of economic benefits, the measurement of ecological economic benefits and the expectation of compensation policy benefits are important factors affecting the mining area residents’ behavior.
response. Therefore, it will have a positive impact on the mining area ecological protection. From the perspective of social benefits, the behavior attitude of mining area residents is affected by the social situation. In particular, the guidance of public opinion and the likes and dislikes of the people will have significant psychological effects on their behavior response. From the perspective of ecological benefits, while pursuing the maximum economic benefits and responding to the general trend of society, the mining area residents will also consider the non-market value of the mining area ecological environment and pursue the ideal of the unity of man and nature. The purpose is to create an ecological community with a shared future. In other words, the more they agree with the principle of ecological protection, the more responsive they are. Based on the above analysis, the following hypotheses are presented:

Hypothesis 1: The behavior attitude of mining area residents has a significant positive impact on the mining area ecological protection.

Behavior norms refer to the psychological constraints formed by individuals in the process of deciding whether to conduct a particular behavior, reflecting the psychological norms formed by society, important organizations, and individuals on decision-making. Therefore, the mining area residents’ behavior norms can be understood here as the psychological norms generated by the cognition of various pressures from inside and outside in the process of mining area ecological protection, which generally come from two types of norms: mandatory and demonstrative. Among them, the psychological statute derived from mandatory norms refers to that formed by the authoritative ruling actions taken by the public authority. The psychological statute derived from demonstrative norms is the non-mandatory and benevolent psychological statute formed by friends and neighbors. Furthermore, the policy atmosphere created by the government will also have an important impact on the mining area ecological protection through their behavior attitude. Similarly, the same psychological constraints are created by the persuasion of friends and neighbors. Therefore, this study formed the following two hypotheses:

Hypothesis 2: The mining area residents’ behavior norms have a significant positive effect on their behavior attitude.

Hypothesis 3: The mining area residents’ behavior norms have a significant positive impact on the mining area ecological protection.

Behavior perception refers to the psychological perception of feasibility formed by individuals during the implementation of a specific behavior; the mining area residents’ behavior perception refers to the perceived space in the process of mining area ecological protection. Generally speaking, it is constrained by factors over which they have no control—time, resources, and environment—and can be divided into internal and external levels. Among them, the internal space refers to the behavior ability to respond to the mining area ecological protection (such as physical conditions, knowledge, and technology); the external space refers to external opportunities and resources, which are more represented by the government’s support and promotion efforts. Furthermore, whether the interior or exterior space is involved, they will have an important impact on the mining area ecological protection through their behavior attitude. Based on this, the study formed the following two hypotheses:
Hypothesis 4: The mining area residents’ behavior perception has a significant positive effect on their behavior attitude.

Hypothesis 5: The mining area residents’ behavior perception has a significant positive impact on the mining area ecological protection.

Based on the above analysis, the causal chain is formed between the ecological protection knowledge production in the mining area and its ecological protection from the perspective of the PBT. Consequently, the analysis model and hypotheses are formed.

2.3. Analytical methods

The explanatory and explained variables in the study contain many factors, which make the research content complex and dynamic. To avoid the influence of randomness and uncertainty, a structural equation model (SEM) and a resistance diagnosis were selected to achieve the research objectives.

Compared with the common regression model, the SEM model has the advantage that it can deal with multiple explained variables simultaneously. Therefore, the following model is constructed:

\[
\eta = \mathbf{B}\eta + \Gamma\xi + \zeta
\]  

Equation (1) is a structural equation, which is used to define the constraint relationship between independent and dependent variables.

\[
Y = \Lambda y\eta + \varepsilon
\]  

\[
X = \Lambda x\xi + \delta
\]

Equations (2) and (3) are measurement equations, which are used to define the constraint relationship between potential and observed variables. \( \eta \) is the endogenous potential variable and represents the mining area ecological protection behavior. \( \xi \) refers to the mining area residents’ ecological cognition; \( B \) and \( \Gamma \) are, respectively, two kinds of the potential variable coefficient matrix; \( \zeta \) is the unexplained part; \( Y \) and \( X \) are the observed parameters of two types of potential variables. \( \Lambda_y \) and \( \Lambda_y \) are, respectively, two kinds of potential variables associated to the coefficient matrix of each observation variable; \( \delta \) and \( \varepsilon \) are both residual terms.

\[
F_j = W_r \cdot W_j
\]

\[
I_{ij} = 1 - Z_{ij}
\]

\[
Y_{ij} = \left( \frac{F_j \cdot I_{ij}}{\sum_{j=1}^{n} F_j \cdot I_{ij}} \right) \cdot 100\%
\]
Yr = \sum Y_{ij} \quad (7)

Subsequently, the following resistance diagnostic model is presented (Equations 4–7), where $F_j$ is the contribution degree, $I_{ij}$ is the deviation degree, $Z_{ij}$ is the standardized value of the index, $W_j$ is the weight of single index, $W_r$ is the dimension weight of the index, and $Y_{ij}$ and $Y_r$ are the resistance values of the single observation index and the criterion layer, respectively.

2.4. Data collection

Data used in the study are from field surveys conducted in four coal mining areas of Huainan City from August to December 2019. Considering the study area, its economy and population distribution, as well as the difficulty of the investigation, the study selected a set of ordinary residents, miners (local miners and foreign miners), and some of the managers of mining enterprises as study participants. We used a Likert scale to measure the responses of the participants, where 1 means that the participants does not agree with the statement, 3 means little agreement, 5 means some agreement, 7 means much agreement, and 9 means total agreement.

According to the principles of stratified sampling and simple random sampling, Panji Town, Qiji Town, Pingwei Town, and Luji Town were selected as the sample units. Four sample villages were selected from each sample town, and 10–20 residents were selected from each sample village for one-to-one questionnaire interviews. Second, 180 miners were selected from Pan Mine 1, Pan Mine 2, and the east of Pan Mine 3. Finally, 120 managers were selected in the four regions of Huainan Mining Group. A total of 513 questionnaires were issued in the field survey. After the validity test and the elimination of invalid responses, 512 questionnaires were used for the analysis, with an effective rate of 99.9%.

2.5. Variable optimization analysis

During the investigation, it was found that the descriptive and explanatory power of the causal chain was inconsistent with the actual situation. Therefore, the variables were further defined and optimized as follows.

The mining area ecological protection refers to a series of behavior measures taken by the mining area residents in the process of modern ecological protection, which can be divided into two dimensions: behavior protection and behavior compensation. Among these, behavior protection refers to the process in which the ecological environment service system is strengthened and optimized to provide flexibility and sustainability for economic and social development. Behavior compensation refers to the process of realizing the restoration of the mining area’s ecological environment system, avoiding the uncertainty caused by ecological protection interventions, and achieving the internalization of negative externalities.

The behavior attitude of mining area residents refers to the tendentious psychological judgment formed in the process of conducting some specific behaviors, and it
is assessed through economic, social, and ecological benefits. Among them, economic benefits refer to the overall evaluation of the ecological environment service system to help sustainable economic development. The social benefits refer to the general evaluation of mining area residents of stable mining, industrial structure optimization, and social response status. Ecological benefits refer to the comprehensive assessment of the improvement of ecological environment service system.

The behavior perception of mining area residents can be formed by the following two dimensions: policy scenario (national protection and support for the mining area ecological protection) and the scientific and technological (S&T) support (ecological monitoring by using big data and remote sensing technology). The purpose of replacing the ‘external constraint space’ with the ‘policy scenario’ is to strengthen the operability of the concept and highlight the objective reality of the environment and the subjective initiative of mining area residents. The purpose of changing the ‘internal constraint space’ to ‘S&T support’ is to clarify the influence of modern information technology on the improvement of behavior perception ability while strengthening the operability of concepts.

The behavior norms of mining residents are reduced to the psychological norms with two dimensions of pressure from neighbors and institutional regulatory environment, which are more limited than the previous generalization. Among them, ethical pressure from neighbors has the nature of persuasion and inducement and has an obvious psychological constraint on individuals and organizations. The institutional regulatory environment tends to highlight the psychological regulation of institutional regulation and is devoted to guiding the mining area residents to participate actively in its ecological protection.

Based on the previous statement, the descriptive statistical analysis of the variables, indicators, and measurement items are shown in Table 1.

Table 1. Main measurement items and descriptive statistics.

| Latent and dependent variables | Indicators | Measurement item (item) |
|-------------------------------|------------|-------------------------|
| Mining area ecological protection ($Y_0$) | Behavior protection | The strengthening and optimization of ecological environment service system ($Y_1$) |
| Mining area residents behavior attitude ($X_1$) | Economic benefits | Development of ecological industry, Sustainable development of mining area economy ($X_{11}$) |
| Mining area residents behavior norms ($X_2$) | Social benefits | Stable coal mining, industrial structure optimization, good social evaluation ($X_{12}$) |
| Mining area residents behavior perception ($X_3$) | Ecological benefits | The improvement of ecological environment ($X_{13}$) |

Q. XING AND G. HE
3. Method

3.1. Reliability and validity test

To ensure the accuracy of the SEM, the software SPSS20.0 was used to check the reliability and validity of the questionnaire data. The reliability of the questionnaire was tested by Cronbach coefficient $\alpha$, and the validity of the questionnaire was tested by an exploratory factor analysis. The specific results are shown in Table 2.

According to the results in Table 2, the average value of all observed variables fluctuated around 4.3, and the standard deviation fluctuated around 0.8, indicating that the data obtained by the questionnaire are relatively stable. The factor load of each observation variable is greater than 0.76, indicating that the questionnaire has high validity. The Cronbach coefficient of each variable is greater than 0.73, indicating that the reliability of the questionnaire is acceptable. Subsequently, a fitting index was obtained through the polymerization degree test of four factors, as shown in Table 3.

According to the results in Table 3, the factor passes the significance test and shows a good fitting degree.

3.2. Model fitness test

The PBT has a strict scope of application. Whether the research problem and the theoretical model have a good fit degree needs to be tested by strict parameters. The test results are shown in Table 4.

As shown in Table 4, significance probability $p = 0.329 > 0.05$, not reaching the significance level. Therefore, the null hypothesis was accepted, indicating that the hypothesis model graph was consistent with the observed data. Furthermore, the RMSEA of the model is $0.0199 < 0.05$, and the parameter test of fit degree is statistically significant. The estimated values of each fit index are all within the acceptable range, and the fitness is good. Therefore, the above hypothesis is valid.

3.3. Structural equation estimation

According to the research model, the standardized estimation results of the overall path coefficient of the SEM (Table 5) and the specific factor loading are illustrated in Figure 2.

According to the results in Table 5, the path coefficients of all the parameters of the model are at the significance level of 1% and pass the path test. Furthermore, the
path coefficient of $X_1$ as the mediator is significant at the significance level of 1%, and the above hypothesis is established.

According to the results in Figure 2, the potential variables have a significant impact on mining area ecological protection through the observed variables, and the relative importance of $X_3$, $X_1$, and $X_2$ to $Y_0$ decreases successively. Simultaneously, the observed variables $X_{12}$, $X_{22}$, and $X_{32}$ have a dominant position in the influence of their respective potential variables. Furthermore, $Y_1$ and $Y_2$ are the valid components of $Y_0$, and $Y_1$ is in a dominant position.

### 3.4. Resistance diagnosis analysis

To analyze the resistance situation of the indicators, the resistance values of each indicator were observed by using the resistance diagnostic model. The specific results are shown in Table 6.

From the above table, the primary and secondary relation of the resistance index will be determined as well as the strength degree of the resistance value. Among them, the resistance of $X_{12}$, $X_{22}$, $X_{31}$, and $Y_1$ in the corresponding criterion layer is relatively obvious, which should receive attention.

### 3.5. Multi-group model analysis

The mining area residents’ behavior willingness is the logical basis of ecological protection. However, in the process of modern mining area ecological protection, there is often a contradiction between the mining area residents’ behavior willingness and their actual behaviors. Therefore, as an important group characteristic, its specific status and practical influence in the process cannot be ignored. Based on this, the study further combined the multi-group SEM and took the mining area residents’ behavior willingness as a regulating variable to study the difference in the influence of willingness to pay (willingness to pay is greater than 0) and no willingness to pay (willingness to pay is 0) on the causal chain. The path coefficient estimation results of the multi-group SEM are shown in Table 7.
As shown in Table 7, the path coefficient estimation is statistically significant. Group 1 and Group 2 again verify the hypothesis of the causal chain, and they also have a significant influence on the correlation hypothesis of the mediator variable $X_1$.

### 4. Results and discussion

#### 4.1. Results

Through the above analysis, we arrived at the following results. As far as the behavior attitude of mining area residents is concerned, it is positive with the standardized path coefficient of mining area ecological protection. This means that in the process of modern mining area ecological protection, the more positive the behavior attitude is, the higher the enthusiasm for ecological protection will be. Thus, Hypothesis 1 is

"Table 5. SEM path coefficient standardized estimation results."

| Hypothesis/test | Path     | Estimate | S.E.  | p-value |
|-----------------|----------|----------|-------|---------|
| H1              | $X_1 \rightarrow Y_0$ | 0.332*** | 0.057 | 0.000   |
| H2              | $X_2 \rightarrow Y_0$ | 0.165*** | 0.061 | 0.002   |
| H3              | $X_3 \rightarrow Y_0$ | 0.231*** | 0.043 | 0.000   |
| H4              | $X_4 \rightarrow Y_0$ | 0.189*** | 0.060 | 0.001   |
| H5              | $X_5 \rightarrow Y_0$ | 0.457*** | 0.039 | 0.000   |

"Figure 2. SEM path coefficient and factor load."

Table 6. Main resistance factors and resistance values.

| Dimension | Indicator | Resistance | Indicator | Resistance | Indicator | Resistance |
|-----------|-----------|------------|-----------|------------|-----------|------------|
| 1         | $X_1$     | 21.2       | $X_{12}$  | 19.6       | $X_{13}$  | 17.3       |
|           | $X_2$     | 21.9       | $X_{22}$  | 19.5       | $X_{23}$  | —          |
|           | $X_3$     | 18.3       | $X_{32}$  | 12.9       | $X_{33}$  | —          |
|           | $Y_0$     | 19.4       | $Y_1$     | 17.8       | $Y_2$     | —          |

As shown in Table 7, the path coefficient estimation is statistically significant. Group 1 and Group 2 again verify the hypothesis of the causal chain, and they also have a significant influence on the correlation hypothesis of the mediator variable $X_1$. 
confirmed. Furthermore, in terms of the relative importance of the three potential variables, the total path coefficient of behavior attitude is 0.332, ranking second, which should be considered. From Figure 2, the factor loads of economic benefits, social benefits, and ecological benefits are 0.722, 0.803, and 0.536, respectively. Among them, the factor load of ecological benefits is obviously low, which means that the mining area has had unrestrained mining for a long time, and the index identification degree is obviously underestimated, which should receive more attention. Furthermore, in terms of economic benefits, only when the mining area ecological protection can promote sustainable economic development and industrial structure optimization, the mining area residents will hold a positive attitude and participate actively in it. In other words, the identification degree of mining area residents is to some extent based on the cost-benefit judgment of bounded rationality. Finally, the factor loading of social benefits is significantly higher than the other two observed variables. This shows that stable coal mining, optimization of industrial structure, and social response have been generally identified by the mining area residents.

As far as the mining area residents’ behavior norms are concerned, they are positive with the standardized path coefficient of mining area ecological protection. This means that in the process of modern mining area ecological protection, the greater the internal and external pressure (supervision or demonstration) the mining area residents feel, the higher their enthusiasm will be. Thus, Hypothesis 3 is valid. Simultaneously, the standardization path coefficient of behavior norms and behavior attitude is positive, indicating that the behavior norms indirectly affect the mining area ecological protection through the mediation effect of behavior attitude. Thus, Hypothesis 2 is valid. Furthermore, in terms of the relative importance of the three potential variables, the total path coefficient of behavior norms and mining area ecological protection is 0.231, ranking third, which should be considered as a whole. Figure 2 indicates that the factor load from the pressure from neighbors (0.712) is smaller than that from the institutional regulatory environment (0.750). Therefore, compared with the neighborhood ethical pressure, the institutional regulatory environment has a strong influence on the mining area ecological protection.

As far as the mining area residents’ behavior perception is concerned, it is positive with the standardized path coefficient of mining area ecological protection. This means that in the process of modern mining area ecological protection, the easier the mining area resident response is, the higher their enthusiasm will be. Thus, Hypothesis 5 is valid. Simultaneously, the standardization coefficient of behavior

| Path                  | Estimate | S.E. | Estimate | S.E. |
|-----------------------|----------|------|----------|------|
| $X_1 \rightarrow X_2$ | 0.260*** | 0.060| 0.152*** | 0.067|
| $X_2 \rightarrow X_3$ | 0.514*** | 0.059| 0.393*** | 0.058|
| $Y_0 \rightarrow X_1$ | 0.378*** | 0.071| 0.285*** | 0.072|
| $Y_0 \rightarrow X_2$ | 0.248**  | 0.065| 0.193*  | 0.082|
| $Y_0 \rightarrow X_3$ | 0.321*** | 0.067| 0.257*** | 0.067|
perception and behavior attitude is positive, indicating that the behavior perception indirectly affects the mining area ecological protection through the mediation effect of behavior attitude. That is, Hypothesis 4 is valid. Furthermore, in terms of the relative importance of the three potential variables, the total path coefficient of behavior perception and mine area ecological protection is 0.457, ranking first, which should receive attention. Figure 2 indicates that the factor load of S&T support (0.531) is smaller than that of the policy scenario (0.572). This means that in the process of modern mining area ecological protection, the mining area residents still rely heavily on policy guidance, and their control ability needs to be further improved.

From the analysis results of the structural equation and diagnostic models, the dominant influencing factors in other dimensions are identical, except for the behavior perception. That is, the indicators that aid self-development and hinder self-improvement are the same observed variables. Of course, for the behavior attitude, there is a difference between the second and third observed variables, which requires us to identify accurately and intervene promptly in these observed variables. In terms of behavior perception, the observed variables at the top are different in the structural equation and diagnostic models. This means that the positive effects of two observed variables need to be systematically recognized, such as S&T support and policy scenario.

As for the mining area residents’ behavior willingness, Table 6 indicates that the path coefficients of both groups with and without willingness to pay are positive; that is, the causal chain hypothesis mentioned above has been verified again. Furthermore, in the comprehensive path assessment process of behavior attitude and mine area ecological protection, the path coefficients of the groups with no willingness to pay and those with willingness to pay are 0.378 and 0.285, respectively. In the process of comprehensive path assessment of behavior norms and mine area ecological protection, the path coefficients of the two are 0.248 and 0.193, respectively. In the comprehensive path assessment process of behavior perception and mine area ecological protection, the path coefficients of the two are 0.321 and 0.257, respectively. Therefore, it was found that the causal chain path coefficient of the groups with no willingness to pay is greater than that of the others. It means that the positive effect of the group with no willingness to pay is greater.

4.2. Discussion

According to the foregoing analysis, it was found that from the perspective of PBT, the causal chain of ecological protection knowledge production in the mining area and its ecological protection has the following characteristics:

(1) There are positive, heterogeneous, and complex impacts between the behavior cognition of mining area ecological protection and its ecological protection.

The results show that the factor loads of variables in the causal chain are different. That is, although they affect the causal chain directly or indirectly, there is heterogeneity in their relative importance. Furthermore, in the causal chain, the relative importance of behavior perception, behavior attitude, and behavior norms decrease successively (the overall standardized path coefficients are 0.457, 0.332, and 0.231,
respectively). In other words, in the process of modern mining area ecological protection, the influences of the three behavior cognitions are significantly different. Moreover, compared with the specific path coefficients, behavior attitude (0.342), behavior perception (0.196), and behavior norms (0.177), they still have obvious complexity. Finally, in the process of path assessment in which the behavior attitude plays a mediating role, the overall standardized path coefficients of behavior perception and behavior norms are 0.189 and 0.165, respectively. Compared with the specific path coefficients (0.463 and 0.220) of the two behavior cognitions, their influence also has obvious complexity.

(2) There are differences, irrationality, and feasibility in the impact of mining area resident behavior willingness on the causal chain.

The results show that the path coefficients of the two groups with and without willingness to pay in the causal chain are positive; however, the loads are different. This not only retests the causal chain hypothesis but also suggests that there are differences in their effects. Furthermore, by comparing and analyzing the causal chain between the two groups, it is found that the influence of the group with no willingness to pay is greater than that of the group with willingness to pay. One possible explanation is that, compared to the mining area residents who are willing to pay, those who are not willing to pay are often residents in production and living, experiencing the mining area ecological environment directly. Therefore, they have formed a more direct and obvious ecological protection willingness. Ultimately, the group with willingness to pay has more practical significance than the others. This means that the positive response and guidance of the mining area residents to the ecological protection will help us optimize the causal chain and expand the available space for ecological protection knowledge production in the mining area.

(3) Limitation and future work

This paper mainly explores the constraint mechanism of knowledge production of mining area ecological protection from the perspective of the PBT. The research results and conclusions are significant for clarifying the feasible strategies of ecological restoration in mining areas and facilitating the construction of mining area ecological civilization. Of course, the knowledge production of mining area ecological protection proposed by this study may not be generalizable. Only the case of Huainan City is used to verify the research hypothesis. Whether it is applicable to other types of knowledge production sites of mining area ecological protection remains to be further tested. In the future, comparative research can be conducted in different types of mining areas.

Further, there are two limitations of this study: on the one hand, this study is limited by mainly considering the perspective of micro psychology. In the future, the content of this study can be further enriched from the meso level of the mining area, improving the theoretical system of ecological protection knowledge production in the mining area; on the other hand, this is a static study on the formation mechanism of knowledge production of mining area ecological protection. Longitudinal research methods can be adopted in the future to fully consider the heterogeneous effects of influencing factors of different types of mining area ecological protection in different development cycles of their knowledge production.
5. Summary and conclusions

From the perspective of the PBT, to support mining area ecological protection and enhance the realization effect of value, the focus should be on the following knowledge production:

(1) Expanding the ‘new combination’ of ecological protection knowledge production in mining areas.

Only when the value realization concept of ‘co-construction, co-governance, and sharing’ is formed in the process of ecological protection knowledge production in mining areas, a new way of high-quality guided development will be explored, prioritizing ecological and green development. Specifically, first, the concept of ‘co-construction’ of multiple collaborations should be improved. In other words, the centralized and unified leadership of the CCP must be upheld, the leading role of the government must be strengthened, the dominant role of enterprises must be deepened, and the participation of social organizations and the public must be mobilized. Subsequently, the mining area residents can strengthen and optimize their ecological protection through group policy and group power, and a tolerance of and lasting power for socio-economic development and ecological civilization construction can be provided. Second, the concept of ‘co-governance’ needs to be strengthened with all elements. The only way to avoid the uncertain factor intervention of behavior compensation, realize the internalization of the negative externality of behavior protection, and improve the behavior identification of mining area residents is to emphasize the source control and form the working force. Third, the dividends ‘sharing’ concept of mining area residents should be highlighted. The dividends ‘sharing’ can get a powerful mechanism guarantee only by realizing the benign interaction between government governance, social regulation, and enterprise autonomy. Subsequently, a positive behavior cognition will be formed, and people will play an active part in modern mining area ecological protection.

(2) Precisely managing the intervention focus of ecological protection knowledge production in mining areas.

To promote the fundamental improvement of mining area ecological protection and the construction of ecological civilization and attractive Chinese mining areas, the space for knowledge creation and knowledge transfer must be cleared in the process of mining area ecological protection. Specifically, first, modern information technology and sensing technology should be used to gather big data on the causal chain and accurately identify the trend of each observed cognition index. Subsequently, the fit of internal correlation can be improved, and the modern mining area ecological protection ability can be enhanced. Second, the monitoring focus of the dominant observation index should be defined in the causal chain, and the logical correlation should be evaluated by using a new econometric model. Further, the scientific and effective knowledge production of mining area ecological protection can be ensured, and the effect of ecological protection behavior intervention can be improved. Third, it is necessary to clarify the working mechanism of who is in charge, who is responsible, and who implements in the causal chain. Subsequently, the intervention effect of the behavior cognition of mining area ecological protection can be improved.
effectively, and the causal chain can be strengthened by improving the identification degree of observation indicators.

(3) Optimizing the value realization of ecological protection knowledge production in mining area.

Mining area resident behavior willingness is the logical basis of ecological protection. To avoid a lack of willingness and behavior in the process of modern mining area ecological protection, the legitimate interests and demands of all parties must be dealt with in mining areas to create positive incentives. Specifically, first, the laws, regulations, and policies regarding mining area ecological protection should be completed. Subsequently, the explicit and implicit knowledge production of mining area ecological protection can be improved, and the authoritative distribution order from the perspective of interests can be clarified. The economic, social, and ecological benefits of the mining area can be improved only in this manner. Further, a positive behavior attitude of mining area residents can be formed. Second, new scientific discoveries and technological inventions should be used to upgrade the means of mining area ecological protection, improve the compensation cost accounting technology, give reasonable consideration to the legitimate interests of the target group, and safeguard the legitimate rights and interests of all parties. The behavior norms of neighborhood ethic pressure and the institutional regulatory environment can be strengthened only in this manner. Subsequently, more reasonable and effective behavior norms of mining area residents can be formed. Third, a more operational scientific and educational environment and policy scenario should be formed in mining areas. Thus, the ability of mining area resident ecological protection knowledge creation and knowledge transfer can be enhanced, and the space for their behavior perception can be expanded. This is the only way in which an intelligent guarantee for the mining area ecological protection can be provided. This will enable the construction of a community with a shared future for human ecology.

Conflict of interest

State any potential conflicts of interest here or ‘The authors declare no conflict of interest’.

Funding

This work was supported by the following programs: 1. The National Natural Science Foundation of China with the title ‘Evaluation of Coal Miners’ Safety Behavioral Ability and Its Dynamic Pre-warning under the Interaction between Individuals and Environment’ (NO. 51574010). 2. Social science innovation and development research project in Anhui with the title ‘Research on ecological compensation mechanism, path and benefit in middle and lower reaches of Huaihe River’ (2019CX110).

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