Economic Research-Ekonomska Istraživanja

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rero20

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To cite this article: Ying Xin, Shuobin Yang & Muhammad Faisal Rasheed (2023) Exploring the impacts of education and unemployment on CO2 emissions, Economic Research-Ekonomska Istraživanja, 36:2, 2110139, DOI: 10.1080/1331677X.2022.2110139

To link to this article: https://doi.org/10.1080/1331677X.2022.2110139

Published online: 17 Aug 2022.

ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA
2023, VOL. 36, NO. 2, 2110139
https://doi.org/10.1080/1331677X.2022.2110139

Exploring the impacts of education and unemployment on CO2 emissions

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ABSTRACT
The role of human capital and unemployment has been debated in a limited number of empirical studies that have aimed to study the discipline of environmental sustainability. Therefore, by Employing a reliable autoregressive distributed lag (ARDL) model approach, this study examines the dynamic linkage between education, unemployment, and CO2 emissions, by using the Chinese economy's dataset from the time period pertaining to 1991–2020. The vivacious side of human capital shows that variables such as literacy rate and the average year of schooling curb CO2 emissions in the long run. Moreover, Human capital results are also based on facts in terms of their magnitude and direction. Also, empirical findings have unfolded that unemployment significantly increases CO2 emissions in the long-run. However, the short-run has estimated that the coefficients of education and unemployment provide similar results. Based on these novel findings, a wide set of economic policies are required and hence suggested for maintaining the environmental quality.

ARTICLE HISTORY
Received 13 June 2022
Accepted 1 August 2022

KEYWORDS
Education; Unemployment; CO2 emissions; ARDL; China

JEL CODES
A2; J64; E24; Z3; E2

1. Introduction

The problem of climate change has become a crucial agenda point for policymakers and authorities. Since the 1980s, many authors have emphasized upon the upsurge in human resources based on the rise in the CO2 emissions that have been observed (Bilgili et al., 2019; Shen et al., 2021; Su et al., 2021). For this reason, researchers have been undertaking a considerable amount of empirical research, based on the transmission channels of human-induced CO2 emissions (Deng et al., 2022; Shan et al., 2022). The present empirical studies offer many social and economic factors, such as economic development, globalisation, energy consumption, tourism, industrialisation, urbanisation, technology, capital movements, transportation, FDI, political regime, remittances, poverty, and trade liberalisation as the main causes of human capital-based CO2 emissions (Guo et al., 2022; Pata, 2018; Su et al., 2021; Su et al.,

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2021; Umar et al., 2020; Usman et al., 2020; Wang et al., 2020; Yuan et al., 2022). The above-mentioned social and economic factors also significantly contribute towards the existing empirical literature; and there is still more need to assess the other applicable aspects, such as human capital for sustainable development (Hmaittane et al., 2019).

In the extant literature based on this area of study, it has been shown that investment in human capital has many benefits. For instance, human capital positively contributes towards economic growth and higher productivity of labour (Becker, 1975; Romer, 1990), and it is linked with various social externalities such as greater participation in democracy, lower crime rates, and better health (Mirza et al., 2020; Sianesi & Reenen, 2003). Energy-based studies have noted that human capital negatively impacts energy consumption (Akram et al., 2019; Shahbaz et al., 2019), which in turn improves the environmental quality. A study by (Goetz et al., 1998) concluded that the USA, with its well-educated population, has good quality environmental circumstances, primarily due to the income and structural transformation that it hosts. Following the same context, (Bano et al., 2018) also examined the nexus between carbon emissions and human capital in the case of Pakistan, and found that carbon emissions reduction is a result of improvements in human capital in the long-term. However, in the short-run, there is no relationship exists between these two variables. At another instance, (Li & Ouyang, 2019) reported that a higher level of human capital increases short-term carbon emissions and also reduces long-term carbon emissions. Moreover, (Ahmed & Wang, 2019) investigated the influence of human capital on the carbon footprint in the case of India and concluded that a higher level of human capital mitigates ecological footprint by improving the outcomes of the environment in the short and long-term.

Furthermore, in their study (Piaggio et al., 2017) argued that energy transitions are one of the structural facts, and thus they should be examined with a long-term perspective, hence altering the CO2 emissions. In another study, (Stokey, 2015) reported that human capital accumulation is a slow process towards transitioning to a green economy, but it has a significant long-term impact on the environment. Other than that, in a study, (Yao et al., 2019) stated that OECD countries are not the only contributors to carbon emissions, although they are the pioneers in evolving towards cleaner alternatives. At another time (Madsen et al., 2018) reported that the OECD countries and the wealthiest economies of the world have immensely invested in accumulating human capital over time. In developing economies, maintaining economic development along with pollution reduction emissions is a significant challenge (Yarovaya et al., 2021; Zhang et al., 2021). Studies show that Pollution emissions are connected with economic based-activities that are executed by human beings (Šlaus & Jacobs, 2011; Umar et al., 2022). Economic growth, directly and indirectly, responds to human capital. The educated and skilled labour force is used as an input factor in the production process that is highly accepted in the human capital framework (Ali et al., 2017; Tao et al., 2022). Most of the advanced nations have transformed their economies from labour-based economic structures to knowledge-based ones (Dorfleitner & Grebler, 2022). Various studies have elaborated upon the significance of human capital in diverse perspectives such as human capital that leads to economic development (Asghar et al., 2012; Bottone & Sena, 2011). In the same context, (Benos & Zotou, 2014) have inferred that human capital affects the environment via the green growth process.

Similary, (Qadri & Waheed, 2014) also investigated upon the influence of human capital on economic development, primarily by utilising labour force and capital stock, and reported of significant and positive impacts of human capital on economic development. Also, Kumar noted that human capital benefits from improving techniques and promoting innovations. Secondary education also contributes towards increasing economic growth and poverty reduction (Ali et al., 2017; Lee & Chang, 2008). At another time, a study by (Bodman & Le, 2013; Yating et al., 2022) revealed that human capital positively affects economic development primarily because of individuals who are innovative, productive, and educated in their fields (Berger, 2022). Human capital also supports the increase in renewable energy consumption due to awareness, education, and knowledge (Desha et al., 2015; Yan et al., 2022). In a study, (Mehrara et al., 2015) noted that human capital proxied by tertiary education is a major factor in clean energy consumption. Although (Sianesi & Reenen, 2003) reported that human capital is noble for persons, it is also helpful for society in the context of economic growth and environmental quality.

Unemployment is another important determinant that influences people's health and the environment. The association between unemployment and the environment has drawn little attention in the existing literature. People with high incomes generally have more opportunities to fulfil their desires and maintain a good lifestyle that improves their environment. (Mulderij et al., 2021) documented that people with high income prefer to spend more money to maintain their health and lifestyle. However, the nexus between unemployment and the environment is found inconclusive (Mulderij et al., 2021). However, (Meyer, 2016) denotes that unemployment may change environmentally friendly behaviour due to time and income constraints. The prevailing literature on the association between environment and unemployment reveals that unemployment events deteriorate people's health and environmentally friendly behaviour due to a reduction in financial power (Duarte et al., 2016). The health of people gets affected when they become unemployed. It is argued that people become unhappy due to unemployment as unemployment raises stress levels (Blankenberg & Alhusen, 2019). Unemployment not only deteriorates the environmental quality but also increases the events of the crime, social tension, protest, and violence (Bossier & Brechet, 1995; Rafiq et al., 2018).

The complete literature is enormous that each economy now has its empirical literature. At the same time, China's literature on human capital and CO2 emissions are still limited. While previous studies such as (Yao et al., 2019) for OECD and (Ahmed & Wang, 2019) for Latin American and Caribbean countries have faced aggregation bias, as noted by (J. Li et al., 2022). Previous studies by (Bano et al., 2018) assumed the linear relationship between human capital and CO2 emissions but ignored the impact of unemployment on carbon emissions in the context of China (Karim et al., 2022). The past literature has also found three different empirical findings; human capital has a positive (Wu, 2017), negative (Yao et al., 2019), and insignificant (Dedeoğlu et al., 2021) impact on CO2 emissions, and infers that findings are inconclusive. While, unlike studies that used a few indicators to measure human capital, we used the government education expenditure, literacy rate, and average year of education to show human capital for suitable and robust analysis (Ielasi et al., 2018). We change the human capital variables in each robustness model.

Human capital, specifically education, contributes significantly to raising environmental sustainability by controlling CO2 emissions. The literature reveals that education helps achieve sustainable growth and a sustainable environment. Some of the latest studies provide such evidence, for example, (N. Liu et al., 2022) proved a negative association between education and CO2 emissions. Similarly, (X. Li & Ullah, 2022) reported that an increase in education significantly controls CO2 emissions, while a decline in educational attainment has amplified CO2 emissions in BRICS economies. (Zafar et al., 2022) reported robust findings between education and environmental deprivation. Conversely, (C. Zhang et al., 2022) reported deterioration in environmental quality as education tends to enhance emissions levels.

To reduce the bias, we estimate the effect of unemployment and education on CO2 emissions only for China's economy for robustness. The contribution of the study to the empirical literature is renewed, as China's one of the economies that faces the problem of greenhouse gas emissions (Ji et al., 2021; Umar et al., 2022; Xu et al., 2022). China's economy is ranked 1st in CO2 emitters. Carbon emissions are one of the major issues in the Chinese economy. China is confronted with pollution emissions generated from secondary and primary sources, i.e., O3, PM2.5, PM10, NOx, and CO2. The intensification of GHGs and CO2 emissions creates various health-related problems in China. This study is more significant for China because the economic growth of China is highly connected to energy consumption and CO2 emissions. China also signed the agreements of Kyoto protocol, which motivated a green economy.

The study makes the following contributions to the prevailing stock of the literature. First, our study, for the first time, examines the impact of human capital and unemployment on environmental sustainability. Second, the study adopted possible potential variables for analysing the nexus between education, unemployment, and carbon emissions, which were ignored in existing studies. This exercise will help policymakers control the increasing vulnerability created due to climatic variations. Third, instead of using causality and cointegration techniques, this study employs the ARDL technique. ARDL technique provides long-run as well as short-run coefficient estimates. This technique provides more reliable results that help design policy measures for the short-run and long-run that enhance environmental sustainability.

This study's finding is more effective than the previous, unlike empirical studies for policy-making due to the advanced econometric method. The remaining study is organised; Section 2 describes the model, method, and data. The empirical estimates are offered in Section 3, but Section 4 gives the conclusions and policy.

2. Model, Methods and Data

Theoretical research argues that human capital formation may also play an effective role in environmental quality through numerous transmission channels. (Dedeoğlu et al., 2021) noted that human capital formation, directly and indirectly, influences the environment in the long run. Similarly, unemployment has reduced saving rates, increased renewable energy poverty, and worsened technological innovation (Becker, 1975), reducing CO2 emissions. However, empirical evidence provides mixed results regarding the relationship between unemployment and the environment (Y.-Q. Liu & Feng, 2022). The literature reveals that being unemployed envisages a considerable reduction in human well-being. Therefore, in line with (X. Li & Ullah, 2022) and (Zaidi et al., 2021), we adopt the following model specification:

$$CO_{2,t} = \eta_0 + \eta_1 Education_t + \eta_2 Unemp_t + \eta_3 GDP_t + \eta_4 Trade_t + \mu_t \quad (1)$$

where t represents a country, CO2 is CO2 emissions, education is educational attainment, Unemp is unemployment. We used the GDP per capita (GDP) and trade liberalisation (trade) as control variables. If human capital formation role plays in the functioning of the green economy, η_1 will be to be negative. Regarding empirical and theoretical literature, unemployment could have positive and negative impacts on CO2 emissions, $\eta_2$will be to be positive or negative. Estimation of Equation (1) yields only long-run estimates. Thus, to include the short-term effect, an error-correction model is employed. An econometric approach that yields the long-run and the short-run effects in one step is that of (Pesaran et al., 2001) as follows:

$$\begin{aligned}\Delta CO_{2,t} = {} & \eta_0 + \sum_{p=1}^{n1} \pi_{1p} \Delta CO_{2,t-p} + \sum_{P=0}^{n2} \pi_{2p} \Delta Education_{t-p} + \sum_{p=0}^{n3} \pi_{3p} \Delta Unemp_{t-p} \\ & + \sum_{p=0}^{n4} \pi_{4p} \Delta GDP_{t-p} + \sum_{p=0}^{n5} \pi_{5p} \Delta Trade_{t-p} + \eta_1 CO_{2,t-1} \\ & + \eta_2 Education_{t-1} + \eta_3 Unemp_{t-1} + \eta_4 GDP_{t-1} + \eta_5 Trade_{t-1} \\ & + \delta.\ ECM_{t-1} + \mu_t\end{aligned} \quad (2)$$

The error-correction Equation (2) is due to (Pesaran et al., 2001), where the short-run effects reflected by the η_{1k}, η_{2k}, η_{3k}, η_{4k}, η_{5k}, and η_{6k}. Notations π_{1p}, π_{2p} ,π_{3p} , π_{4p} , and π_{5p} are the short-run coefficients of the lagged dependent variable, human capital, unemployment, GDP, and trade, respectively. The long-run coefficients are η_2, η_3, η_4, η_5 for focussed and other control variables. Lastly, δ displays the speed of adjustment. Using the error correction approach, (Pesaran et al., 2001) presented a bound testing system for cointegration known as the autoregressive distributive lag order (ARDL) model. An earlier study by (Ullah et al., 2022) recommends two tests to establish cointegration, such as diagnostic tests (e.g., F-test and ECM). The null hypothesis of the F-test among the variables is (Ho: $\eta_1=\eta_2=\eta_3=\eta_4=\eta_5=\eta_6=0$), but against the alternative hypothesis (H1: $\eta_1\neq\eta_2\neq\eta_3\neq\eta_4\neq\eta_5\neq\eta_6=0$). Previous conventional methods require that the model variables be stationary at I(0) or at I(1). However, the ARDL model considers the mixture of I(1) and I(0) variables. Another privilege of the ARDL model is that it simultaneously provides long-run and short-run estimates. Additionally, a smaller number of observations is a common problem of time-series analysis. The advantage

Table 1. Definitions and sources.

Variables	Symbol	Definition	Sources
CO2 emissions	CO2	CO2 emissions (kt)	World Bank
Education expenditure	EE	Government spending on education, total (% of GDP)	World Bank
Literacy rate	Literacy	Literacy rate, adult total (% of people ages 15 and above)	World Bank
Year of schooling	AYS	Average year of schooling	Barro-Lee
Unemployment	Unemp	Unemployment, total (% of the total labor force) (modeled ILO estimate)	World Bank
GDP per capita	GDP	GDP per capita (constant 2010 US$)	World Bank
Trade	Trade	Trade (% of GDP)	World Bank

Source: Author's Estimation.

of the ARDL model is that it deals with the issue of a small number of observations and provides unbiased and efficient results. We have to employ Dickey Fuller-Generalized Least Square (DF-GLS) for unit root testing purposes. In the last stage, we also employ some diagnostic and stability tests. To check the problems of serial correlation, functional misspecification, Heteroskedasticity, we have applied LM, Ramsy's RESET, and BP tests. The renowned CUSUM and CUSUM-sq tests are also applied to confirm short-term and long-run coefficient estimates stability.

2.1. Data

We collect a sample of China's economy and data spanning from the period 1991 to 2020. This study's range of time periods is selected based on data availability. The Chinese economy is among the world's major economies that contribute significantly to raising GHGs emissions. Chinese economy's share is almost 27% of total CO2 emissions (J. Li et al., 2022). Due to data availability, we restrict our human capital to only three variables: education expenditure, literacy rate, and average year of schooling. So, we extract our dataset from the World Development Indicator (WDI) offered by the World Bank, while the average year of schooling dataset. Unemployment is measured by total unemployment (% of the total labour force). We also employ the extrapolation method for the missing dataset of China's economy. Before estimation, we have converted the GDP and CO2 emission variables into a natural logarithm. The details of the variables are also given in Table 1.

3. Empirical results and discussion

To inspect the level of stationarity of selected variables, we have employed the traditional unit root tests, i.e., ADF and PP tests. It is necessary to investigate the integration order of variables. The null hypothesis shows the presence of unit root and confirms that the variables are stationary or non-stationary. In our analysis, most of the variables accepted the alternative hypothesis and revealed that the variables are stationary at the first difference. ADF and PP show that our model variables have mixed order integration, but none of the variables is I(2). However, ADF and PP tests highlighted similar outcomes and showed the validity of the unit root outcome. (Table 2)

Table 2. Unit root tests.

	ADF I(0)	I(1)	PP I(0)	I(1)	Decision ADF	PP
CO2	−3.442***		−4.748***		I(0)	I(0)
EE	−2.151	−4.381***	−2.489	−4.334***	I(1)	I(1)
Literacy	−1.016	−12.73***	−1.393	−11.43***	I(1)	I(1)
AYS	−0.277	−3.522***	−0.338	−3.552***	I(1)	I(1)
GDP	−1.127	−3.926***	−1.016	−3.888***	I(1)	I(1)
Unemp	−1.321	−5.148***	−1.633	−5.159***	I(1)	I(1)
Trade	−2.684*		−2.731*		I(0)	I(0)

Source: Author's Estimation.

The key aim of the current study is to examine the influence of human capital and unemployment on CO2 emissions for the China economy. For this purpose, we used three indicators of human capital, i.e., education expenditures as a proxy of human capital in model 1 and literacy rate as a proxy of human capital in model 2. In the last model, we take mean years of schooling as a proxy of human capital. Since investigating the level of a unit root in the next phase, the study used the ARDL approach to find out the short-run and long-run elasticities of coefficients in Tables 3, respectively. Table 3 Panel A revealed the short-run dynamics for all the models such as M1-FF, M2-literacy, and M3-AYS. The results showed that EE and literacy in models 1 and 2 have an insignificant impact on pollution emissions in the short-term. While AYS in model 3 shows a significant negative effect on carbon emissions in China in the short run. Further, the empirical results depict that unemployment is positively linked with carbon emissions in all the models for China. The outcome explored that increased output growth contributes to carbon emissions in all the models. On the other hand, the turns out indicate that trade opens are statistically significant and negatively correlated with carbon emissions in China except for the M2-literacy model in the short-run.

Panel B offered the long-run dynamics for all the models. The results highlight that EE in model 1 indicates an insignificant influence on carbon emissions in the long-term. However, in model 2, literacy, and model 3, AYS negatively influences carbon emissions in the long run. Our human capital finding is backed by (Yao et al., 2019), who indicate that pollution emissions are reduced by increasing the level of human capital in the long run. The results show that the increase in education leads to a reduction in pollution emissions, but this effect is relatively small in the context of China's economy. The empirical results recommend that humans play a vital role in environmental quality, especially in the China economy. Education is deliberated the most important factor for developed countries. Human capital is also curbing Carbon emissions in China. Findings also show that human capital reduces renewable energy poverty by limiting long-term carbon emissions. Our findings infer that the educational systems of China and fiscal spending are favourable for environmental quality.

The outcome indicates that unemployment positively influences carbon emissions only in models 1 & 2 for China. Our results imply that unemployment leads to higher CO2 emissions. Due to increased financial burdens, the availability and accessibility of the range of environmentally friendly products and services also decrease, reducing environmental quality. These findings describe that due to an increase in

Table 3. ARDL estimates of human capital and CO2 emissions.

Variable	M1-EE Coefficient	t-Statistic	M2-literacy Coefficient	t-Statistic	M3-AYS Coefficient	t-Statistic
short-run						
D(EE)	−0.008	0.290				
D(EE(-1))	0.050	1.370				
D(EE(-2))	−0.051	1.604				
D(LITERACY)			−0.006	1.065		
D(AYS)					−0.152*	2.206
D(AYS(-1))					0.001	0.003
D(AYS(-2))					−0.012	0.113
D(Unemp)	0.011***	2.954	0.007**	2.323	0.008**	2.282
D(Unemp (-1))	−0.007**	2.066	−0.005*	1.695	−0.005	1.208
D(Unemp(-2))					−0.002	0.559
D(GDP)	0.955**	2.269	0.643*	1.820	0.815**	2.120
D(GDP(-1))	−0.669	1.091	−0.457	0.795	−1.198**	2.190
D(GDP(-2))	1.814***	2.987	1.266***	3.163	1.267***	3.010
D(Trade)	−0.006**	2.474	−0.003	1.380	−0.008***	3.039
D(Trade(-1))					0.000	0.109
D(Trade(-2))					−0.005*	1.668
Long-run						
EE	−0.044	0.218				
LITERACY			−0.038*	1.950		
AYS					−0.026**	2.386
Unemp	0.042*	0.052	0.031	1.110	0.033***	2.765
GDP	2.605***	5.252	1.484	1.129	2.536***	5.731
Trade	0.007	0.357	−0.007	0.488	0.006	0.931
C	−7.061**	2.199	0.235	0.029	−6.631***	2.261
Diagnostic						
F-test	7.302***		4.987***		8.678***	
ECM(-1)	−0.243**	1.989	−0.264**	2.240	−0.372**	2.533
LM	2.231		5.123**		2.264	
BP	1.189		0.996		0.932	
RESET	1.823		1.105		2.241	
CUSUM	US		S		S	
CUSUM-sq	US		S		S	

Note: ***$p < 0.01$; **$p < 0.05$; and *$p < 0.1$.
Source: Author's Estimation.

unemployment, the health of the environment deteriorates in the long-run. Unemployment adversely impacts human well-being and the environment, reducing life satisfaction and predicting poor mental and psychological health. Unemployment creates several economic hardships, including a reduction in human development. This finding is also in line with (Blankenberg & Alhusen, 2019; Liu & Feng, 2022; Meyer, 2016), who demonstrate that health damages could be driven by low education, unemployment, and various other economic adversities that lead to a decline in environmental quality. Unemployment generally imposes financial burdens on individuals that ultimately cause a reduction in environmental quality. Moreover, the results revealed that GDP is positively interlinked with carbon emissions except for M2-literacy.

Panel C is offered various diagnostic tests. These results show that all the models did not suffer from any statistical issues. Panel C displays the numerous statistical diagnostic tests. The ECM value is negative and significant in all models. F-test is also significant, and the results show the existence of long-term relationships between human capital, unemployment, and Co2 emissions. Also, results demonstrate that the model did not suffer from multicollinearity, heteroscedastic, and autocorrelation.

These test results indicate the stability of all the models. The CUSUM tests indicate stability, and Ramsey RESET confirms the correct functional form.

4. Conclusion and Policy Implications

Over the last few decades, many developed economies, such as China, have achieved rapid economic growth through the excessive use of human and natural resources, thus increasing the environmental pollution in the economy. In China, air and soil pollution has become a severe problem because of industrialisation, urbanisation, dirty economic growth, and deprived situation of human capital. Therefore, this study examined the impact of human capital and unemployment on CO2 emissions in China from 1998 to 2020. This empirical research reveals that China's literacy rate and average year of schooling negatively influence carbon emissions in the long run. The linear finding shows that human capital improves environmental quality by increasing environmental awareness, renewable energy poverty, and green growth. Several robust analyses and diagnostic tests confirm the human capital reliability of the findings in linear. Furthermore, unemployment negatively determines environmental quality by increasing CO2 emissions in China in the long-run. On the other hand, GDP also hurts the environmental quality in China.

Environmental education should be considered at early levels of education. The authorities and policymakers should fix energy-related issues through education. The China government should stimulate the educational sector to conduct a clean and green revolution that acts as a mechanism for a green and clean economy. Furthermore, CO2 emissions can be controlled through education in China. A highly skilled labour force can use energy sources efficiently, which can help in reducing CO2 emissions. The governments should ensure that the policies of employment are capable of complementing the welfare policies of the environment and green growth. On the other side, the policymakers should try to reduce unemployment in the economy to allow the people to afford more sophisticated, environmentally friendly services.

The study undergoes numerous limitations. CO2 emissions are used as environmental pollutant measures, while CH4, N2O, and greenhouse gas emissions are ignored. Panel analysis for China provinces can be conducted. Future research may extend the empirical analysis to China-specific to have an in-depth nexus between education, unemployment, and renewable energy consumption (wind, geothermal, solar, biofuel, and biogas). Future research can be conducted using a large sample size and up-to-date dataset. This study is done for China at the aggregate level, but in future research, there is a need to explore the impact of education and employment on CO2 emissions at a disaggregated level. Empirical studies test the green growth hypothesis by enhancing sample size and data period.

Disclosure statement

No potential conflict of interest was reported by the authors.

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