Happiness, economic growth and air pollution: an empirical investigation

Zahra Fotourehchi* and Habib Ebrahimpour

Department of Management and Economics,
Faculty of Humanities,
University of Mohaghegh Ardabili,
P.O. Box 56199-11367, Ardabil, Iran
Email: z.faturechi@yahoo.com
Email: ebrahimpour@yahoo.com
*Corresponding author

Abstract: Previous studies on the effect of economic growth on happiness have produced mixed results. In an attempt to explain these ambiguous results, this study investigates the effect of gross domestic product (GDP) per capita on happiness by taking into account the role of air pollution in each country using annual unbalanced panel data of 59 countries between 2005 and 2015. The results indicated that an increase in GDP per capita can lead to a decrease in happiness if air pollution level is sufficiently high and, in contrast, can lead to an increase in happiness if air pollution level is too low. Moreover, our results revealed monotonic and non-monotonic relationships between air pollution and happiness. We also found that leaving air pollution out of the analysis led to about 15–27% underestimation of the income effect. These results provide some important implications for policymakers seeking to increase economic growth without aggravating happiness.

Keywords: economic growth; happiness; air pollution.

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Biographical notes: Zahra Fotourehchi is an Assistant Professor in the Department of Management and Economics at the University of Mohaghegh Ardabili, Iran. Her research has concerned agricultural, environmental, health and international economics. Her major fields of specialisation are the health and environmental Kuznets curves, sustainable development and pollution heaven hypothesis.

Habib Ebrahimpour is an Associate Professor in the Department of Management and Economics at the University of Mohaghegh Ardabili, Iran. His research areas include sustainable development, public administration and human resource management.

1 Introduction

Are wealthier countries happier than poorer ones? The first pioneering economist attempting to provide a response to this question was Easterlin (1974, p.118). His paper concluded: "…in a one-time series study, for the United States since 1946, higher income was not systematically accompanied by greater happiness." This result may mean that economic growth does not bring well-being (better known as Easterlin paradox or Easterlin hypothesis) and after basic needs are met by individuals, their personal aspirations will have a larger effect on happiness than income gains. However, there are a lot of studies that have an emerging consensus on a positive and significant link between economic growth and happiness, but the coefficients are rather small quantitatively (for example Luttmer, 2005; Clark et al., 2008). The income effect obtained from regressions of such studies reflects the sum of the proper positive income effect and ignores the cost side of income such as air pollution. In other words, air pollution increases until economic growth/income reaches a certain point, and then decreases while the growth continues. This relationship describes environmental Kuznets curve (Grossman and Krueger, 1991). There are a lot of studies in the literature confirming an inverse U-shaped relationship between economic growth and air pollution (for example Diao et al., 2009; Fotourehchi, 2016). In fact, until reaching a certain point of economic growth, earning more income leads to more air pollution. Moreover, air pollution has negative effects on happiness in both aggregate and individual data levels of air pollution and happiness proxy variables (Levinson, 2012; Zhang et al., 2017). In other words, along with an increase in income, both happiness and air pollution increase, and the negative effect of air pollution on income leads to a decrease in the impact of income on happiness and an underestimation of this effect. The negative effect of air pollution on income could be considered as an important contributor to the Easterlin paradox suggesting that economic growth may not bring more happiness and over time, happiness does not display a strong correlation with income growth. To isolate the true effect of income on happiness, however, it is necessary to control any negative impacts associated with the process of economic growth and run regressions to control the cost side of income.

In our analysis, as we expect that air pollution has more negative effects on happiness, we use a more flexible analysis for the cost side of income; quadratic specification. Therefore, it is expected that happiness first increases until reaching a certain point of air pollution accompanying income and then declines due to the cost side effect of air pollution such as diseases related to pollution, e.g., respiratory diseases (Beatty and Shimshack, 2014), cardiovascular diseases (Gallagher et al., 2010), mortality (Tanaka, 2015), hospitalisation (Lleras-Muney, 2010), mental health (Zhang et al., 2017) or detrimental effects on residential property values (Foell and Green, 1990), and agricultural production (Unsworth and Ormrod, 1982). In fact, by delinking the positive-monotonic relationship between pollution and happiness, a nonlinear relationship is created between the two variables. Moreover, it is expected that controlling for air pollution can increase the impact of income on happiness.

While there is a large body of literature explaining the Easterlin paradox, to the best of our knowledge, few studies have explained the puzzle from the viewpoint that worsening air condition accompanying economic growth in developing countries might reduce happiness, which is the focus of our research.

Our paper contributes to the literature by adding the air pollution effect to the Easterlin paradox in developing countries, which has been largely ignored in the literature in macro data level, as economic growth remains important amongst these countries. Another contribution of this study is to examine how air pollution level influences the effect of economic growth on happiness, which has also been ignored in the literature. This is because according to the environmental Kuznets curve, air pollution restricts economic growth.

The remainder of this paper is organised as follows: Section 2 describes the related literature. Section 3 lays out the empirical strategy and data sources. Section 4 presents our main results. Finally, Section 5 concludes and discusses implications for the Easterlin paradox.

2 The related literature

There is a large literature on the link between economic growth and happiness. Some studies have examined the cross-sectional relationship between economic growth and subjective well-being and then gone on to draw unwarranted conclusions for such a relationship over time (Guriev and Zhuravskaya, 2009). On the other hand, more recent works rely on time series data of countries and tend to find that economic growth is positively associated with happiness over time for several countries, contradicting the Easterlin hypothesis (Sacks et al., 2010, 2011; Stevenson and Wolfers, 2008). Furthermore, some recent studies have found a positive static relationship between economic growth and happiness proxy variables in both macro (Sacks et al., 2010) and micro (Diener et al., 2010; Sacks et al., 2010) data levels whereas other studies have concluded a positive dynamic relationship between them in both macro (Inglehart et al., 2008; Sacks et al., 2011) and micro (Di Tella and MacCulloch 2008; Sacks et al., 2010) data levels, but in some studies, the link between economic growth and happiness has been insignificant (Di Tella and MacCulloch, 2008; Sacks et al., 2011). However, in the happiness studies mentioned above, the cost side effect of income has been commonly neglected because an increase in gross domestic product (GDP) per capita can also give rise to negative externalities such as air pollution or erosion of social capital (Fleurbaey, 2009; Van den Bergh, 2009), which tend to reduce happiness. In fact, as the happiness approach is relatively new in environmental economics, a number of studies have been conducted to explain the difference in people's happiness as a function of ambient environmental quality (Luechinger and Raschky, 2009; Levinson, 2012). There is also some literature on the negative impact of different air pollutants on happiness (Luechinger, 2010; Levinson, 2012; Ferreira et al., 2013). Our study extend the literature by the question of how countries' happiness is affected over time by the growth of the GDP through controlling negative influences of air pollution associated with the process of economic growth as well as controlling other variables not related to the economic growth process.

3 Empirical strategy and data sources

In this section, at first, we estimate a basic individual fixed effect equation without the set of control variables so that we can isolate the impact of controlling unobserved heterogeneity. We then extend the equation by adding the set of control variables. In a further step, we first add air pollution proxy variables and expect the coefficient for the country-level GDP per capita to rise because the coefficient should now be net of a likely positive individual income effect. Second, we add the control variables not related to the GDP per capita such as population gender. The following empirical equations are used to examine the relationship between happiness and economic growth[1]:

$$H_{it} = \alpha_0 + \beta_1\ GDP_{it} + \varepsilon_{it} \tag{1}$$

$$H_{it} = \alpha_0 + \beta_1\ GDP_{it} + \beta_2 P_{it} + \beta_3 p_{it}{}^{\wedge 2} + \varepsilon_{it} \tag{2}$$

$$H_{it} = \alpha_0 + + \beta_1\ GDP_{it} + \beta_2 P_{it} + \beta_3 p_{it}{}^{\wedge 2} + \beta_4 z_{it} + \varepsilon_{it} \tag{3}$$

Furthermore, to capture the role of air pollution in the effects of economic growth on happiness, we add the interaction term between economic growth and air pollution to the equation. This approach enables us to examine how air pollution level influences the effect of economic growth on happiness which is one of the main aims of the current study. The following equation represents our objective:

$$H_{it} = \alpha_0 + + \beta_1\ GDP_{it} + \beta_2 p_{it} + \beta_3 GDP_i * P_{it} + + \beta_4 z_{it} + \varepsilon_{it} \tag{4}$$

where *Hi* is the measured level of happiness for a country, *GDPi* represents the GDP per capita at country level, and *Pi* represents the proxy variable for the country economic growth. Moreover, in the equation, *Pi* is the control variable denoting different air pollution proxy variables related to the GDP per capita, *Z* is the other control variables not associated with the GDP per capita such as population gender, *i* and *t* stand for a country and time, respectively, and ε is an error term.

The coefficient related to the GDP per capita is expected to be positive. Moreover, it is expected that controlling the air pollution proxy variables can increase the impact of income on happiness. In our analysis, it is also expected that happiness first increases until reaching a certain point of air pollution accompanying income and then decreases due to the cost side effect of air pollution such as diseases related to air pollution, detrimental effects on residential property values and agricultural production. Based on this hypothesis, the air pollution coefficient and its square term ($\beta 2$ and $\beta 3$) should be positive and negative, respectively. Therefore, there is a quadratic relationship in an inverted U-shaped pattern indicating that high levels of air pollution are associated with decreasing levels of happiness beyond a certain level of air pollution.

In addition, in equation (4), since we examine the mediating role of air pollution in the effects of economic growth on happiness, we add the interaction term between economic growth and happiness. It is expected that the coefficient of the interaction term turns out to negative. In polluted countries, increase in economic growth can reduce happiness since pollution restricts growth, as claimed by the environmental Kuznets curve.

Furthermore, it is expected to have negative coefficient for the female control variable of the population. Since there is more gender inequality, more gender wage gap (paradox of the contented female worker)[2] and less freedom for women in developing countries due to social, cultural, and religious pressures, we expect that women are not happier than men in these countries.

3.1 Data and method

While happiness research has advanced a great deal in the last decade, shortcomings remain in measurement. As Norberg (2010) notes, measures of happiness are less scientific and more subjective than measures of output, but some analysts still favour them in place of the GDP to guide the government policy (Gropper et al., 2011). Regardless of shortcomings for happiness measures, we think it is worthwhile to examine the relationship between happiness and economic growth bearing in mind the limitations of the measures. In our analysis, we use the happiness index and life satisfaction measures of happiness. Our data sets are derived from the World Happiness Report (2017). The underlying source of the happiness scores in the world happiness report[3] is the Gallup World Poll – a set of nationally representative surveys undertaken in more than 160 countries in over 140 languages. The main life evaluation question asked in the poll is:

> "Please imagine a ladder with steps numbered from zero at the bottom to ten at the top. Suppose we say that the top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. If the top step is 10 and the bottom step is 0, on which step of the ladder do you feel you personally stand at the present time?" (also known as the 'Cantril ladder').

The data for the economic growth and other control variables for this study are obtained from the world development indicators (2017) compiled by the World Bank. Data for air pollution proxy variables are derived from the international energy agency. There are a total of 59 countries[4] included in the analysis, of which 56% are extracted from the upper middle-income and 44% from the lower middle-income for the years ranging from 2005 to 2015. In this paper, for achieving consistent and robust results, we use different proxy variables for air pollution. There are two different air pollution proxy variables whose data are available for the analysis:

1 Carbon dioxide (CO_2) emissions (metric tons per capita) that mostly stem from burning fossil fuels and manufacturing cements through releasing toxic substances into the environment leading to negative health effects.

2 PM2.5 air pollution, mean annual exposure (micrograms per cubic metre) is defined as the average level of exposure of a nation's population to concentrations of suspended particles measured less than 2.5 microns in aerodynamic diameter, which are capable of penetrating deep into the respiratory tract and causing severe health damage.

Exposure is calculated by weighting mean annual concentrations of PM2.5 by population in both urban and rural areas. Economic growth is represented for the estimation through the GDP per capita (constant 2010 dollar). Population gender is a binary variable with $D = 1$ if more than 60% of the total population is women, otherwise $D = 0$.

Before choosing the method for estimation, we are concerned with the fact that there are significant differences in many aspects (including geographical, social, and economic factors) among the developing countries; hence, it is not appropriate to assume parameter homogeneity, i.e., all the slope coefficients are the same. The results of fixed effects tests (F and χ^2 tests) also strongly reject the null hypothesis that individual effects are redundant. In this case, we estimate two versions of equations (1)–(4): fixed and random effects. The fixed effects version treats differences in the intercepts due to deterministic factors. The random effects version treats those differences as being due to stochastic factors. Using the Hausman test, we determine the preferred version by testing the null hypothesis that the random effects are uncorrelated with the year and region. The random effects equation is preferred unless the null hypothesis is rejected at a significance level of five percent. The test statistics are reported in the following tables. While Tables 1 and 2 favour the use of the fixed effects estimation, Tables 3 and 4 (when we use PM2.5 instead of CO_2 air pollution proxy variable) confirm the use of the random effects estimation.

4 Results

Tables 1 to 4 present the regression results. According to column 1 of all the regressions, we realise that the results are consistent in showing a positive association between the GDP per capita (constant 2010 dollar) and happiness (the life satisfaction and happiness index proxy variables). However, the coefficients are rather small quantitatively. These results appear to be consistent with those of Luttmer (2005) and Clark et al. (2008). The results also indicate that there are nonlinear and linear relationships between the air pollution and happiness proxy variables. When we use CO_2 emission as a proxy variable for the air pollution, both happiness proxy variables first increase and then decrease after the turning point of 11.5–11.6 CO_2 emission (metric tons per capita). On the other hand, there is an inverse U-shaped relationship between the CO_2 emission and happiness proxy variables. Furthermore, the results of Tables 3 and 4 indicate that PM2.5 has an inverse effect on happiness. In other words, there is a monotonically decreasing linear relationship between the $PM_{2.5}$ and happiness proxy variables. According to our results, the forms of the curve (pollution-happiness) change based on the type of the air pollution proxy variables and there is no specific curve for the air pollution-happiness relationship. In fact, happiness increases until reaching a certain point of CO_2 emission (11.5–11.6 metric ton per capita) accompanying income, but it decreases due to the cost side effects of air pollution such as diseases related to pollution, detrimental effects on residential property values and agricultural production. However, since the cost side effect related to $PM_{2,5}$ is more than CO_2 emission, it creates a monotonically decreasing linear relationship between the $PM_{2.5}$ and happiness proxy variables.

Moreover, when we compare the basic equation (column 1) with the extended equations (columns 2, 3 and 4) in all the tables, we observe that the basic equation tends to underestimate the income effect on happiness, but magnitude differences among the GDP per capita coefficients (income effect) are substantially significant. The income effect increases only between 15–27% (see columns 2–5 in all the tables and compare the GDP coefficients among them). The findings in all the tables provide supportive evidence that the GDP per capita coefficient is indeed affected by including the air pollution proxy variables. These results are consistent with those of Pouwels et al. (2008). Andreas and Steffen (2009) found that controlling working hours (the other cost side of income) would increase the impact of income on subjective well-being.

In addition, if the interaction term is not included in the estimations, consequently, the level of economic growth in a country can be considered a main factor in increasing happiness in that country as shown by some previous studies. Accordingly, to more precisely address the effect of air pollution on happiness, we take into account the interaction effect between the GDP per capita and air pollution proxy variables. This interaction term allows us to evaluate how different air pollution levels in a country influence the effect of the GDP per capita on happiness. Column 5 provides the results. In column 5, where we conduct the fixed effect and random effect estimations by considering the interaction term[5] between the GDP per capita and air pollution different proxy variables, the coefficients of interaction term are significantly negative implying that the partial effect of economic growth on happiness decreases with different levels of air pollution. Therefore, our empirical results indicate that in polluted countries, an increase in economic growth can reduce happiness since according to the environmental Kuznets curve, pollution restricts growth.

In general, the estimates suggest that the air pollution proxy variables have stronger effects on happiness, as compared to the GDP per capita. Moreover, air pollution through its prohibitive effect on happiness reduces the positive effect of the GDP per capita on happiness.

Finally, among the signs of coefficients for population, in all the tables, female is negative. In other words, women are not happier than men in these countries, but it is insignificant. This might imply that a minimum amount of female population is necessary for increasing happiness.

Table 1 Fixed effect panel estimation: life satisfaction (happiness proxy variable)

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
GDP per capita	0.00011 (4.694)***	0.00012 (3.781)***	0.00012 (3.400)***	0.00014 (3.430)***	0.00014 (3.181)***
CO_2	-	0.0434 (1.488)	0.21 (2.91)***	0.208 (2.902)***	–0.067 (–2.4696)**
$CO_2^{\wedge 2}$	-	-	–0.009 (–2.527)**	–0.009 (–2.520)**	-
CO_2 * GDP	-	-	-	-	–4.30E-06 (–6.966)***
Population gender	-	-	-	–0.078 (–0.497)	–0.079 (–0.501)
Constant	4.634 (31.669)	4.573 (30.059)	4.251 (21.508)	4.292 (20.071)	4.515 (20.210)
R^2	0.84	0.84	0.84	0.84	0.84
N	532	530	530	530	530
Fixed effect test					
F	30.54 [0.00]	28.57 [0.00]	28.32 [0.00]	28.26 [0.00]	28.21 [0.00]
χ^2	821.16 [0.00]	793.00 [0.00]	790.37 [0.00]	790.40 [0.00]	789.57 [0.00]
Hausman test					
χ^2	6.24 [0.0622]	5.74 [0.05]	13.62 [0.003]	13.22 [0.01]	5.24 [0.026]

Notes: Figures in the parentheses indicate t-statistic. *10%, **5% and ***1% denote statistical significance levels. P-values of tests are in the brackets.

Table 2 Fixed effect panel estimation: happiness index (happiness proxy variable)

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
GDP per capita	0.00011 (4.683)***	0.00013 (3.774)***	0.00012 (3.395)***	0.00014 (3.425)***	0.00014 (3.170)***
CO_2	-	0.043 (1.47)	0.208 (2.891)***	0.207 (2.877)***	–0.067 (–2.456)**
CO_2^2	-		–0.009 (–2.505)**	–0.0090 (–2.498)**	-
CO_2 * GDP	-			-	–4.25E-06 (–2.688)***
Population gender	-	-	-	–0.078 –0.496	–0.07 (–0.50)
Constant	4.636 (31.699)	4.575 (30.091)	4.257 (21.544)	4.297 (29.108)	4.519 (20.238)
R^2	0.84	0.84	0.84	0.84	0.84
N	533	531	531	531	531
Fixed effect test					
F	30.55 [0.00]	28.57 [0.00]	28.32 [0.00]	28.26 [0.00]	28.21 [0.00]
χ^2	821.90 [0.00]	793.68 [0.00]	790.96 [0.00]	790.97 [0.00]	790.20 [0.00]
Hausman test					
χ^2	6.23 [0.063]	5.70 [0.05]	13.51 [0.003]	13.13 [0.01]	5.21 [0.026]

Notes: Figures in the parentheses indicate t-statistic. *10%, **5% and ***1% denote statistical significance levels. P-values of tests are in the brackets.

Table 3 Random effect panel estimation: life satisfaction (happiness proxy variable)

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
GDP per capita	0.00013 (4.694)***	0.00014 (4.178)***	0.00014 (3.980)***	0.00013 (4.131)***	0.00014 (2.250)***
$PM_{2.5}$	-	–0.008 (–2.294)**	–0.023 (–2.056)***	–0.025 (–2.21)***	–0.008 (–2.462)**
$PM_{2.5}$^2	-	-	0.00014 (1.385)	0.00015 (1.463)	-
$PM_{2.5}$ * GDP	-	-	-	-	–3.02E-07 (–2.216)
Population gender	-	-	-	–0.189 (–1.22)	–0.174 (–1.153)
Constant	4.634 (31.669)	5.132 (24.516)	5.431 (18.058)	5.572 (17.281)	5.374 (18.34)
R^2	0.84	0.08	0.08	0.09	0.09
N		348	348	348	348

Notes: Figures in the parentheses indicate t-statistic. *10%, **5% and ***1% denote statistical significance levels. P-values of tests are in the brackets.

Table 3 Random effect panel estimation: life satisfaction (happiness proxy variable) (continued)

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Fixed effect test					
F	30.55 [0.00]	22.64 [0.00]	22.23 [0.00]	21.92 [0.00]	21.01 [0.00]
χ^2	821.90 [0.00]	592.08 [0.00]	587.89 [0.00]	584.86 [0.00]	572.97 [0.00]
Hausman test					
χ^2	0.23 [0.063]	1.23 [0.53]	0.42 [0.93]	0.50 [0.97]	6.51 [0.16]

Notes: Figures in the parentheses indicate t-statistic. *10%, **5% and ***1% denote statistical significance levels. P-values of tests are in the brackets.

Table 4 Random effect panel estimation: happiness index (happiness proxy variable)

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
GDP per capita	0.00013 (4.683)***	0.00014 (4.165)***	0.00014 (3.966)***	0.00013 (4.119)***	0.00015 (2.526)***
$PM_{2.5}$	-	–0.0008 (–2.349)**	–0.024 (–2.124)**	–0.026 (–2.282)**	–0.0008 (–2.467)**
$PM_{2.5}^{\wedge 2}$	-	-	0.00014 (1.436)	0.00015 (1.515)	-
$PM_{2.5}$ * GDP	-	-	-	-	–3.44E-07 (–2.247)**
Population gender	-	-	-	–0.189 (–1.232)	–0.174 (–1.154)
Constant	4.636 (31.699)	5.139 (24.611)	5.446 (18.213)	5.587 (17.424)	5.219 (19.208)
R^2	0.84	0.08	0.08	0.09	0.09
N	533	349	349	349	349
Fixed effect test					
F	30.55 [0.00]	22.66 [0.00]	22.27 [0.00]	21.95 [0.00]	21.01 [0.00]
χ^2	821.90 [0.00]	593.01 [0.00]	589.08 [0.00]	586.02 [0.00]	573.83 [0.00]
Hausman test					
χ^2	0.23 [0.063]	1.09 [0.57]	0.29 [0.96]	0.39 [0.98]	6.30 [0.17]

Notes: Figures in the parentheses indicate t-statistic. *10%, **5% and ***1% denote statistical significance levels. P-values of tests are in the brackets.

5 Conclusions and discussion

Previous studies have failed to examine the impact of air pollution on economic growth causing a downward bias in the economic growth-happiness relationship. We investigated the effect of economic growth on happiness taking into account the role of air pollution. Our estimation results indicated a positive relation between the GDP per capita and happiness, but the coefficients were rather small quantitatively. These results were robust even if we used a different proxy variable for happiness. However, in this study, we extended the economic growth-happiness relationship literature. Our extensions included

1 broadening the dataset to an unbalanced panel of ten years

2 controlling for individual unobserved heterogeneity by including fixed effects

3 specifying the impact of air pollution in a more flexible, quadratic form that allowed for non-monotonic influences

4 examining the mediation role of air pollution in the effects of economic growth on happiness.

With these extensions, our results suggested that the impact of air pollution on happiness depended on the type of the air pollution proxy variables and there was no specific curve for the air pollution-happiness relationship. While there was an inverse U-shaped relationship between CO_2 emission and happiness, this link changed to a monotonically decreasing linear relationship when the proxy variable for air pollution was $PM_{2.5}$ mean annual exposure. As a result, the increase of happiness need different policies for each air pollution indicator instead of the same or general policies for all kinds of the air pollution proxy variables. Therefore, policymakers in countries should concentrate more on air pollution issues to prevent happiness from declining in the future.

Moreover, when we controlled the air pollution proxy variables, the basic equation tended to underestimate the income effect (the GDP per capita) on happiness, but magnitude differences among the GDP per capita coefficients were significant. This result is an important contributor to the Easterlin paradox claiming that economic growth may not bring more happiness. Negative signs of the coefficients of the interaction term also implied that the partial effect of economic growth on happiness is decreasing with different levels of air pollution. Hence, to keep the economic growth and happiness relationship increasing, it is necessary to employ environmental protection policies. In addition, although negative signs of the coefficients for female population implied that women are not happier than men in these countries, the coefficients were not significant. Our results also indicated that an increase in the GDP per capita decreases happiness if air pollution sufficiently penetrates, and, in contrast, increases happiness if the air pollution level is too low.

As a result, although there are a few gaps in this study, our findings have important implications for policymakers dealing with policies to increase happiness. An implication from our study is that in order to benefit from economic growth without decreasing happiness, the restriction of air pollution is indispensable because with the increment of air pollution, the cost sides of air pollution such as related physical and mental diseases will function well, thereby making an increase in the GDP per capita that leads to a decrease in happiness. Our research emphasises that improving air quality is an important policy measure to increase happiness in developing countries. Along with economic growth, the current focus on related costs of physical health ignores other hidden costs of pollution on mental health (happiness). If counting these additional costs, the benefits of reducing pollution would be higher.

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Conflict of interest

On behalf of all the authors, the corresponding author states that there is no conflict of interest.

References

Alfaro, L., Chanda, A., Kalemli-Ozcan, S. and Sayek, S. (2004) 'FDI and economic growth: the role of local financial markets', *Journal of International Economics*, Vol. 64, No. 1, pp.89–112.

Andreas, K. and Steffen, R. (2009) *Income, Happiness and the Disutility of Labor*, ECONSTOR Working Paper, pp.1–6.

Beatty, T.K.M. and Shimshack, J.P. (2014) 'Air pollution and children's respiratory health: a cohort analysis', *Journal of Environmental Economics and Management*, Vol. 67, No. 1, pp.39–57.

Clark, A., Frijters, P. and Shields, M. (2008) 'Relative income, happiness and utility: an explanation for the Easterlin paradox and other puzzles', *Journal of Economic Literature*, Vol. 46, No. 1, pp.95–144.

Crosby, F.J. (1982) Relative deprivation and working women, New York: Oxford University Press.

Darlington, R.B. (1990) *Regression and Linear Models*, McGraw-Hill, New York.

Di Tella, R. and MacCulloch, R. (2008) 'Gross national happiness as an answer to the Easterlin paradox?', *Journal of Development Economics*, Vol. 86, No. 1, pp.22–42.

Diao, X.D., Zeng, S.C., Tam, C.M. and Tam, V.WY. (2009) 'EKC analysis for studying economic growth and environmental quality: a case study in China', *Journal of Cleaner Production*, Vol. 17, No. 5, pp.541–548.

Diener, E., Ng, W., Harter, J. and Arora, R. (2010) 'Wealth and happiness across the world: material prosperity predicts life evaluation, whereas psychosocial prosperity predicts positive feeling', *Journal of Personality and Social Psychology*, Vol. 99, No. 1, pp.52–61.

Easterlin, R.A. (1974) 'Does economic growth improve the human lot?', in David, P.A. and Melvin, W.E. (Eds.): *Nations and Households in Economic Growth*, pp.98–125, Stanford University Press, Palo Alto, CA.

Ferreira, S., Akay, A., Brereton, F., Cuñado, J., Martinsson, P., Moro, M. and Ningal, T.F. (2013) 'Life satisfaction and air quality in Europe', *Ecological Economics*, Vol. 88, No. C, pp.1–10.

Fleurbaey, M. (2009) 'Beyond GDP: the quest for a measure of social welfare', *Journal of Economic Literature*, Vol. 47, No. 4, pp.1029–1075.

Foell, W.K. and Green, C.W. (1990) 'Acid rain in Asia: an economic, energy and emissions overview', in *Proceedings of the Second Annual Workshop on Acid Rain in Asia*, Asian Institute of Technology, Bangkok, Thailand, 19–22 November, p.38.

Fotourehchi, Z. (2016) 'Health effects of air pollution: an empirical analysis for developing countries', *Atmospheric Pollution Research*, Vol. 7, No. 1, pp.201–206.

Gallagher, P., Lazarus, W., Shapouri, H., Conway, R., Bachewe, F. and Fischer, A. (2010) 'Cardiovascular disease risk benefits of clean fuel technology and policy: a statistical analysis', *Energy Policy*, Vol. 38, No. 2, pp.1210–1222.

Gropper, D.M., Lawson, R.A. and Thorne Jr., J.T. (2011) 'Economic freedom and happiness', *Cato Journal*, Vol. 31, No. 2, pp.237–256.

Grossman, G.M. and Krueger, A.B. (1991) *Environmental Impacts of the North American Free Trade Agreement*, NBER Working Paper, No. 3914.

Guriev, S. and Zhuravskaya, E. (2009) '(Un) Happiness in transition', *Journal of Economic Perspectives*, Vol. 23, No. 2, pp.143–168.

Inglehart, R., Foa, R., Peterson, C. and Welzel, C. (2008) 'Development, freedom, and rising happiness: a global perspective (1981–2007)', *Perspectives on Psychological Science*, Vol. 3, No. 4, pp.264–285.

Levinson, A. (2012) 'Valuing public goods using happiness data: the case of air quality', *Journal of Public Economics*, Vol. 96, No. 9, pp.869–880.

Lleras-Muney, A. (2010) 'The needs of the army: using compulsory relocation in the military to estimate the effect of air pollutants on children's health', *Journal of Human Resources*, Vol. 45, No. 3, pp.549–590.

Luechinger, S. (2010) 'Life satisfaction and transboundary air pollution', *Economics Letters*, Vol. 107, No. 1, pp.4–6.

Luechinger, S. and Raschky, P.A. (2009) 'Valuing flood disasters using the life satisfaction approach', *Journal of Public Economics*, Vol. 93, No. 3, pp.620–633.

Luttmer, E. (2005) 'Neighbors as negatives: relative earnings and well-being', *Quarterly Journal of Economics*, Vol. 120, No. 3, pp.963–1002.

Norberg, J. (2010) 'GDP and its enemies: the questionable search for a happiness index', *CES Policy Brief*, Centre for European Studies, Brussels.

Pouwels, B., Siegers, J. and Vlasblom, D.J. (2008) 'Income, working hours, and happiness', *Economics Letters*, Vol. 99, No. 1, pp.72–74.

Sacks, D.W., Stevenson, B. and Wolfers, J. (2010) *Subjective Well-Being, Income, Economic Development and Growth*, NBER Working Paper, No. 16441.

Sacks, D.W., Stevenson, B. and Wolfers, J. (2011) *Growth in Income and Subjective Well-Being Over Time*, Mimeo, New York.

Stevenson, B. and Wolfers, J. (2008) 'Economic growth and subjective well-being: reassessing the Easterlin Paradox', *Brookings Papers on Economic Activity*, Spring, pp.1–87.

Tanaka, S. (2015) 'Environmental regulations on air pollution in China and their impact on infant mortality', *Journal of Health Economics*, Vol. 42, No. 7, pp.90–103.

Unsworth, M.H. and Ormrod, D. (1982) *Effects of Gaseous Air Pollution in Agriculture and Horticulture*, Vol. 532, p.42, Butterworth Scientific, London.

Van den Bergh, J. (2009) 'The GDP paradox', *Journal of Economic Psychology*, Vol. 30, No. 2, pp.117–135.

Zhang, X., Zhang, X. and Chen, X. (2017) 'Happiness in the air: how does a dirty sky affect mental health and subjective well-being?', *Journal of Environmental Economics and Management*, pp.1–43 [online] http://dx.doi.org/10.1016/j.jeem.2017.04.001.

Notes

1 This is the first study that extends equation (1) by adding the square term of air pollution as well as the interaction term of air pollution and economic growth.

2 The paradox is simply that despite women being over-represented in jobs that are worse by many objective standards – they face lower wages, occupational segregation into jobs with lower payment and fewer opportunities for advancement (Crosby, 1982), they do not report significantly greater dissatisfaction with their payment.

3 Data published by World Happiness Report (2017) *Gallup World Poll Surveys (Life Evaluation Question)* [online] http://worldhappiness.report/.

4 Countries in our sample are: Albania, Algeria, Argentina, Armenia, Azerbaijan, Bangladesh, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Cameroon, China, Colombia, Congo, Costa Rica, Croatia, Dominican Republic, Ecuador, Egypt, El Salvador, Georgia, Guatemala, Honduras, India, Indonesia, Iran, Islamic Rep, Iraq, Jamaica, Jordan, Kazakhstan, Kenya, Kyrgyz Republic, Lebanon, Macedonia, Malaysia, Mauritania, Mexico, Mongolia, Montenegro, Nicaragua, Pakistan, Panama, Paraguay, Peru, Philippines, Romania, Russia, Serbia, South Africa, Tajikistan, Thailand, Turkey, Turkmenistan, Ukraine, Uzbekistan, Venezuela, Vietnam, Yemen, and Zambia.

5 Adding the interaction term may lead to multi-collinearity problems because it may be strongly correlated with original variables, based on which it is created (Darlington, 1990). The calculated variance inflation factor (VIF) indicates a symptom of multi-collinearity. To address multi-collinearity problems, we employed the method of centred variables. When using this method, the VIF does not show a symptom of multi-collinearity and the estimation results are similar to those in the case of using non-centred variables (the results can be provided upon request). Therefore, it is reasonable to conclude that our estimation did not have multi-collinearity problems, and we reported the original estimation results following many previous studies such as Alfaro et al. (2004).