A CRITIQUE OF GEORGE HALKOS’ WORK

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There are no previous studies using Generalized Method of Moments (GMM) for the Environmental Kuznets Curve (EKC) theory. George Halkos is the first who applied this approach to mitigate overidentification. The sulfur emission is in use to test EKC presence since the pollution must be non-uniform to meet EKC conditions. His work is to challenge the work of Stern and Common. However, his approach has significant problem in model that is misspecified.

Keywords: Environmental Kuznets Curve, Duan’s Smearing Estimate, GMM, FGLS, FE, RE

May 21, 2021

INTRODUCTION

To addressing the Environmental Kuznets Curve (EKC) theory and models, George Halkos proposed a novel approach called Generalized Method of Moments (GMM). Not likely to Pooled Ordinary Least Squares (POLS) approach, the GMM is instrumental to mitigating overidentified problems and flexible enough to deviate from Gauss-Markov assumptions. The overidentification is a scenario when simultaneity exists in the model and the number of instruments is greater than that of parameters.

The simultaneity refers to certain scenarios where cause and effect are intertwined. The classical example of this is price and quantity in a system of demand and supply. For example, any change in price does not just affect quantity, but also the changes in quantity affect price (X causes Y and Y causes X). The simultaneity in every EKC model is indelible. By consideration of these models, Halkos asserted GMM is more appropriate. My task is to criticize his work through econometric reasoning and models.

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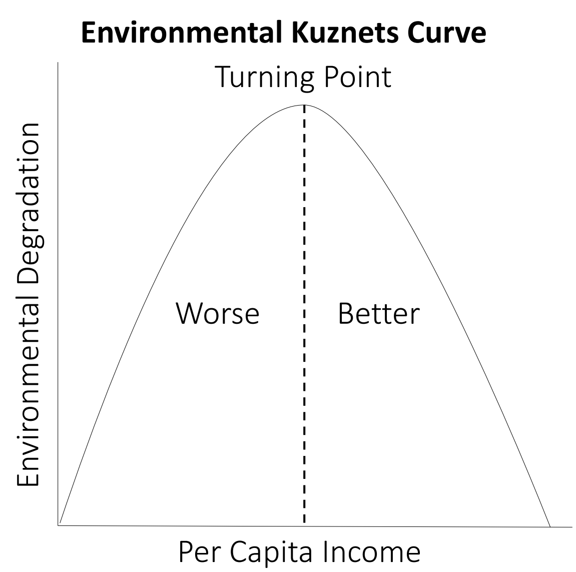
KUZNETS CURVE

Before I introduce my critique, it is vital to explain what the EKC is. The EKC is derived from Kuznets curve created in the 1950 and 1960 interpreting the relationship between inequality and income per capita as an inverted quadratic. Increase in income per capita leads to increases in inequality. When the turning point is made, inequality decreases and income per capita continues to increase. However, the EKC replaces inequality variable with environmental degradation variable. Environmental degradation increases when income per capita increases. When turning point is reached, environmental degradation decreases when income per capita increases.



Based on previous empirical studies, the presence of EKC is more likely to be present if pollution is regional or non-uniform (sulfur, deforestation, etc.). However, the carbon emission is uniform and purely non-excludable, the one very different from sulfur emission. In other words, this emission is not a good indicator of EKC. Additionally, the presence of EKC is likely to be present if the time period is mid-term. This is why Halkos, and previous authors use sulfur emission as an indicator of environmental degradation.

Additionally, a number of studies indicates that income elasticity of demand for environmental quality changes when turning point is present. Prior to reaching the turning point, the income elasticity is highly positive, which is called luxury goods. After this, the income elasticity equals 1, which is associated with normal goods. There is the last part worth mentioning. The locality of turning point is not predictable because, for example, the value of turning point may decrease if property rights are less attenuated (Shelby, 2020).

MODEL COMPARISONS

As usual, Halkos develops his GMM model by assessing the previous authors. The most authors used fixed effects (FE) to time-demean variables in order to eliminate composite error and maintain strict exogeneity. For example, the formula has an unobserved component that is a cause of serial correlation. To eliminate the unobserved component by time-demeaning variables means that observations with time subtracted by average observations over time.

$$y_{it} = x_{it}\beta + c_i + u_{it}$$
$$(y_{it} - \bar{y}_{it}) = (x_{it} - \bar{x}_{it})\beta + (u_{it} - \bar{u}_{it})$$

$$\ddot{y}_{it} = \ddot{x}_{it}\beta + \ddot{u}_{it}$$

The fixed effects are more efficient than first differences since the sample size is large and time period is small. These authors also use random effects as well. The random effects (RE) are similar to Feasible Generalized Least Squares (FGLS) that uses nuisance parameters to weigh unconditional variance of error term. However, identifying parameters for RE is different from FE by quasi-time demeaning the variables.

$$\hat{\lambda} = 1 - \sqrt{\frac{\hat{\sigma}_u^2}{T\hat{\sigma}_c^2 + \hat{\sigma}_u^2}}$$

The *symbol…* is the variance of unobserved component and the *symbol…* is the variance of error term while *T* is time series. The assumption is that the composite error exhibits strong persistence over time—unlikely to an AR model where endogenous correlations disappear over time. To obtain the RE parameters uses this lambda.

$$\tilde{y}_{it} = y_{it} + \hat{\lambda}\bar{y}_i$$
$$\tilde{x}_{it} = x_{it} + \hat{\lambda}\bar{x}_i$$
$$\tilde{y}_{it} = \tilde{x}_{it}\beta + \tilde{v}_{it}$$

The robust standard errors are also used to estimate RE. The authors often use both models for Durbin-Wu Hausman test. Under the null hypothesis, both RE and FE are consistent. Under the alternative hypothesis, RE is only consistent. The FE assumes that covariance of regressors and unobserved component is arbitrary while RE assumes that there is no correlation between them. A few authors use POLS that simply exhibits measurement error models due to serial correlation also known as a spurious regression problem (Goldstein, 2020).

Halkos assessed the models of previous authors and crossed the work of Stern and Common. These authors estimated the turning point of sulfur emission higher than previous authors using the same data. The value of turning point tends to fall between $3,137 and $10,620. However, Stern and Common estimated the turning point equal to $101,166, which is at least ten times higher than the previous authors. Their argument is that the relationship of sulfur emission and per capita income is not an I(0) process.

There is at least one condition in order for static models being acceptable. The first condition is instantaneous rate of change in the variables and the second condition covariance stationary. Both conditions are unlikely to be met. Thus, Stern and Common chose to use RE and FE. The strict exogeneity is—that is—prerequisite for the EKC.

HALKOS' GMM MODEL

However, Halkos proposed the GMM approach in order to mitigate the overidentification issue. By minimizing the squares of the differences between the sample moments and the population moments, there are three conditions needed for identification and consistency.

$$\beta_{GMM} = \left(E[X_i{}'Z_i]\widehat{W}E[Z_i{}'X_i]\right)^{-1}E[X_i{}'Z_i]\widehat{W}E[Z_i{}'y_i]$$

The identification for GMM parameters follows this formula because Weak Law of Large Numbers (WLLN) states that equation.... Basically, if there are no overidentifying restrictions in this equation, the βGMMβGMM will equal βSIVβSIV. In other words, the GMM approach is used to ensure that the moment conditions are satisfied. The model Halkos created is to use sulfur emissionS as a regressand and gross domestic product as a regressor plus sulfur emission as a lagged variable.

$$ln\left(\frac{S}{c}\right)_{it} = \beta_0 + \beta_1 ln\left(\frac{GDP}{c}\right)_{it} + \beta_2 ln\left(\frac{S}{c}\right)_{it-1} + u_{it}$$

Given that this model contains quadratic terms, the GDP regressor is a variable of interest that can transform into the turning point. The location of turning point is at the vertex of concave.

$$TP = e^{\frac{-\beta_1}{2\beta_2}}$$

As a result, the turning point is equal to 4,381 dollars. However, the two-step GMM indicates that turning point increases by 622 dollars. Even though the r-squared value equal to 9.61% seems low that might cause some causes, it is irrelevant to causal analysis. What is relevant is the Hausman test and Wald test. Both tests are statistically significant at 5% level. Intuitively, the endogeneity does exist, and the restrictions are not valid. In other words, at least one regressor correlates with error term, and lagged variable and other variables have effect on this model. With additional test called Sargan-Hansen test, the overidentification does exist, which should not be a concern due to the GMM model. Furthermore, the additional test shows that this data is consistent with the AR(1) model.

EVALUATION ON HALKOS' MODEL

The GMM model Halkos created indicates that Duan's Smearing Estimate, unfortunately, is present. In other words, one of conditions necessary for identification and consistency is not met. The conditional error mean should be zero, which is equation...

This result often occurs when one uses the logarithmic model.

$$ln\left(\frac{S}{c}\right)_{it} = \beta_0 + \beta_1 ln\left(\frac{GDP}{c}\right)_{it} + \beta_2 ln\left(\frac{S}{c}\right)_{it-1} + u_{it}$$

$$e^{ln\left(\frac{S}{c}\right)_{it}} = e^{X\beta + u_{it}}$$

$$S/C_{it} = e^{X\beta} e^{u_{it}}$$

$$E[y_{it}|x_{it}] = e^{X\beta} E[e^{u_{it}}|x_{it}]$$

As a result, because the error term is greater than zero, it correlates with regressors in violation of zero conditional mean. There are two different approaches to treat this misspecification problem. The first approach is to replace the error term with Monte Carlo integration (equation…) while the second approach is to use the nonlinear framework instead. The second approach is also known as Arellano-Bond estimator, which specifically addresses the Duan's Smearing Estimate.

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