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Research Article

CO_2 Emissions and Economic Growth of SAARC Countries: Evidence from a Panel VAR Analysis[1]

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Abstract

The paper examined the causality in both static and dynamic framework between CO2 emissions and economic growth of SAARC countries over the period 1972-2010 using panel approach. The paper presents the facts obtained on the basis of panel unit root test, panel-co-integration test, panel VECM and Impulse Response functions (IRFs) and Variance decomposition (VDs). IRFs and VDs analysis indicate that CO2 emissions, GDP have positive impact on each other. The result from the application of VECM analysis suggests unidirectional causality running from economic growth to CO2 emissions. The result found contradicts the Environmental Kuznets Curve hypothesis.

Keywords: SAARC, economic growth, CO2 emissions, Panel VAR

JEL Codes : C23, Q56, Q53

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1. Introduction

South Asian Association for Regional Cooperation (SAARC) consists of eight countries which are Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. The SAARC region is characterized by varied land forms and agro-climatic conditions ranging from tropical to temperate, and from humid to arid. A large part of the land area of this region does, however, fall in the arid and the semi-arid zones.

The intergovernmental panel on climate change (IPCC, 2007) reported a 1.1 to 6.4 c (projected temperature increase by the end of the century) increase of the global temperatures and a rise in sea level of about 16.5 to 53.8 cm by 2100. This would have tremendous negative impact on half of the world's population that lives in coastal zones (Lau et al., 2009). The data shows that CO2 emissions of SAARC countries was 1.17 metric tons per capita in 1972 which increased to 3.6 metric tons per capita in 1992 and in 2010 it is 7.95 metric tons per capita. The CO2 emissions of India alone in 2010 was 1.67 metric tons per capita which is more than the CO2 emissions of entire SAARC countries in 1972. Moreover, the CO2 emissions per capita of the entire SAARC region in 1992 was 3.6 metric tons per capita which is nearer to emissions produced by Maldives alone in 2010. These facts clearly indicate that how rapidly CO2 emissions are rising. Emissions account for the largest share of total greenhouse gas emissions which are most largely generated by human activities (World Bank, 2007). Rapid increase of emissions is mainly the results of human activities due to the development and industrialization over the last decades. Various human activities especially the eagerness to achieve higher growth rate, development and industrialization has led to rapid increase of emissions.

Various attempts have been made in the literature to determine the connection between economic growth and the quality of environment. Few studies such as Vincent (1997), Holtz-Eakin & Seldon (1992) found that higher economic growth leads to higher pollution since it is associated with more use of natural resources, more production of waste and pollution. The optimist, however, argued that growth is the panacea for all economic evils- poverty, unemployment, overpopulation, inequality etc.- all can be solved through economic growth. Relying on growth in this way might be fine if the global economy existed in a void but it does not (Daly 2005). Similarly, Grossman and Krueger (1991), Shafik and Bandopadhyay (1992), Panayoutou (1992) provide an optimistic view that environmental degradation can be solved through economic growth. This view has been named Environmental Kuznets Curve hypothesis which purports that with ongoing growth in Gross Domestic Product, pollution at first increases, reaches a maximum and then declines.

The present study investigates the dynamic relation between economic growth and CO_2 emissions using the panel data of SAARC countries covering a period of data from 1972-2010. Due to data limitations, data of only five SAARC countries (Bangladesh, India, Nepal, Pakistan and Sri lanka) has been used in the study. Moreover, the contribution of these remaining countries (Afghanistan, Bhutan and Maldives) in Gross Domestic Product of SAARC region is less than 10 percent. The stationary properties of the variables and the co-integration analysis have been examined using panel unit root test and panel co-integration approach. Since, the result was able to find co-integrating relationship, static and dynamic causality relationships among the variables have been examined in panel Vector Error Correction Model.

The organizational structure of this paper is as follows: Section 2 re- views related literature; Section 3 discusses econometric model framework Section 4 provides results and analysis and section 5 concludes with a summary of the main findings and policy implications.

2. Literature Review

The Environment-growth literature was initiated in the early 1990s by a paper of Grossman and Krueger (1991) investigating the environmental impacts of a North American free trade agreement that claim that economic growth of North American Free Trade Agreement would lead to environmental degradation.

Until recently, two sets of literature have been found on the relationship between economic growth and environment pollution. The first set of studies has focussed on the economic growth- environmental pollutants nexus and focus on testing the Environmental Kuznets Curve hypothesis. The studies of Grossman and Krueger (1991), Shafik and Bandyopadhyay's (1992), Panayotou (1995) and Omotor & Orubu (2011), Gupta and Alhuwalia, Kashyna (2011) ,Khajuria et.al (2012), Galeotti et al. (2006) and many others found results in support of Environmental Kuznets Curve.

The studies of Vincent (1997), Dinda et al. (2000), Holtz- Eakin & Seldon (1992), Moomaw & Unruh (1998), Hill & magnani (2000), Gangadharan and Valenzuela (2001), Granados & Carpintero (2009) Mythili and Mukherjee (2011) Agras and Chapman (1999), Ghosh (2010), Jha and Murthy (2003), Kathuria and Mukherjee (2006) comes under second category as they do not support the existence of Environmental Kuznets Curve Hypothesis.

However, the main point of criticism with these studies is that Environmental Kuznets Curve hypothesis states that emission is a function of income and assumes that there is unidirectional causality running from income to emissions. But this may not always be true. It may happen that causality runs from emissions to income i.e. emissions occur in production process and, as a result, income rises. Keeping, these things in mind, some studies have examined the causal relation between economic growth and environment pollutant.

Menyah & Rufael (2010) examined causality between economic growth and CO_2 of South Africa for the period 1965 – 2006 by using Auto- regressive distributed lag bound test and Granger causality and found unidirectional causality from CO_2 to economic growth.

Testing also for causal relationship, Fodha and Zaghdoud (2010) finds the evidence of uni-directional causality running from income to pollution (measured by per capita CO_2 emissions and SO_2 emissions) in Tunisia in both short and long run. On the other hand, Ghosh (2010) finds bi-directional short-run causality between the two, while there is no evidence of long-run equilibrium relationship or long-run causality between CO_2 emissions and income in India during the period of 1971 to 2006.

Dinda & coondoo (2005) conducted such study by using panel data set of 88 countries and applied co-integration and ECM methodology to find the causality between environment pollution and economic growth. They found bidirectional causality between the variables for the world as a whole.

No doubt, these studies have definitely improved literature on environment – growth relation. The available literature on environment – growth nexus for SAARC countries varies from simple time series analysis of each individual SAARC country to a more complex panel analysis. For instance, Ahmed *et.al* (2013) conducted a panel Vector Auto- regressive analysis of the four SAARC countries for three variables CO_2 emissions, industrial growth and population and found unidirectional causality from industrial growth and population to CO_2 emissions. Banerjee *et.al* (2012) conducted time series analysis for SAARC using CO_2 emissions, industrial output growth, population and Foreign Direct Investment and found long run relationship between the variables only for Bangladesh. To the best of our knowledge no study has directly analysed environment – growth nexus for five SAARC countries using panel Vector Auto-regressive analysis, Impulse Response Function [IRFs] and Variance

Decomposition [VDs]. Moreover, only few studies have taken non- stationarity of the variables into account. This study is designed to evaluate the causal relationship between economic growth and carbon emissions by studying the dynamic causal relationship between carbon dioxide emissions and economic growth of SAARC countries using panel VAR modelling approach covering a period of data from 1972-2010 and suggest some policies to policy makers.

3. Data and Methodology

Annual data for CO_2 emissions (CO_2 metric tons per capita), GDP per capita (constant 2005 US $) which is used as the proxy of economic growth has been collected from the World Bank's Development Indicators for five SAARC countries -Bangladesh, India, Nepal, Pakistan and Srilanka-, since long time series data were not available for remaining SAARC countries . The panel data of five SAARC countries is for the period 1972 to 2010. Following the literature CO_2 emissions metric tons per capita has been used as proxy for environment quality, GDP per capita (constant 2005 US $) as proxy for economic growth.

The empirical study is based on panel of five SAARC countries (Bangladesh, India, Nepal, Pakistan, Srilanka) over the period of 1972- 2010. The estimable equation is modelled as following:

$$LNCO_{2it} = \beta_0 + \beta_1 \, LNGDP_{it} \qquad + \beta_2 \, LN\{GDP^2\}_{it} \qquad (1)$$

where i= 1,...., N for each country in the panel and t=1,.....T refers to the time period. CO_2 is Carbon di-oxide metric tons per capita and GDP is GDP per capita constant 2005 US $. All the series are transformed into natural logarithm.

The empirical study has two objectives. The first is to examine the long-run relationship between CO_2 emissions and GDP. The second is to examine the dynamic causal relationship between the variables. The testing procedure entails following steps:

- In the first step whether each variable contains a panel unit root has been examined.
- If the variables contain a panel unit root, the second step is to test whether there is a long run panel co-integration relationship between the variables.
- The final step is to estimate Panel vector error correction model or Panel VAR model depending on the result of Panel co-integration analysis.

In order to investigate the possibility of panel co-integration, it is necessary to determine the existence of unit roots in the data series. The panel unit root test proposed by Im, Pesaran and Shin (2003) and Maddala and Wu (1999) has been used in the study. The result of Panel Unit root test has been given in Table 1.

The most common procedure in choosing the optimal lag length is to estimate a panel VAR model including all variables in levels. This VAR model should be estimated for a large number of lags, then reducing down by re-estimating the model for one lag less until we reach zero lag. In general, the model that minimizes Akaike Information Criterion [AIC] and Schwarz Information criterion [SBC] is selected as the one with the optimal lag length.

The next step is to test for the existence of a long-run co-integration among LNCO2 and LNGDP using Pedroni test of co-integration and Fishers test of co-integration which are based on the estimated residual of eq. (1). Basically, Pedroni tests employs four panel statistics and three group panel statistics to test the null hypothesis of no co-integration against the alternative hypothesis of co-integration. We will make use of seven panel co-integrations by Pedroni (1999), since he determines the appropriateness of the tests to be applied to estimated residuals from a co-integration regression after normalizing the panel statistics with correction terms. These seven statistics by Pedroni(1999) are Panel-v-statistics, panel-ρ- statistics, panel t-statistics (non- parametric), panel t-statistics (parametric), Group ρ- statistics, group t-statistics (non- parametric), group t-statistics (parametric).The first four statistics are within-dimension based statistics and the rest are between-dimension based statistics These tests are all based on residuals from eq.(1) and are variants of the Augmented Dickey Fuller [ADF] and Phillips-Perron [PP] tests. Another test used in the study is Fisher test of co-integration. Fisher test of co-integration combines Johansen and Juselius test. If co-integration exists among the variables, the ordinary least square method is employed to ensure that the estimates of eq. (1) does not lead to spurious regression result.

Next we examine the direction of causality between the variables in a panel context. The existence of co-integration indicates that there is long run equilibrium relationship among the variables and thereby Granger causality exists among them at least in one direction. Therefore, panel VECM is used to test the causality which is special case of panel VAR. The vector error correction model (VECM) is used for correcting disequilibrium in the co-integration relationship captured by the error correction term, as well as to test for long run and short run causality among the co-integrated variables. The panel based VECM is specified as follows:

$$\begin{bmatrix} \Delta LNCO_{it} \\ \Delta LNGDP_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} + \sum_{\rho=1}^{r} \begin{bmatrix} \beta_{11\rho} & \beta_{12\rho} \\ \beta_{21\rho} & \beta_{22\rho} \end{bmatrix} \begin{bmatrix} \Delta LNCO_{it-\rho} \\ \Delta LNGDP_{it-\rho} \end{bmatrix} + \begin{bmatrix} \theta_1 \\ \theta_2 \end{bmatrix} ECT_{it-1} + \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \end{bmatrix} \quad (2)$$

where *i= 1,....N* denotes the country and *t=1,....T* denotes the time; ε_{it} is assumed to be serially uncorrelated error term; *ECT* is the lagged error correction term derived from the long run co-integrating relationship.

After estimating the coefficients of the model and Wald statistic of the lagged values of the coefficients to test the static causality, the Impulse Response Function (IRFs) and Variance decomposition analysis (VDCs) using the Cholesky decomposition has been employed to test the dynamic causality among the variables. IRFs analysis traces out the responsiveness of the dependent variable in the VAR to shocks to each of the explanatory variables over a period of time (10 years in the present study, since it is long term period). Variance decomposition measures the proportions of forecast error variance in a variable that is explained by innovations in it and by the other variables in the system.

4. Analysis

When testing for unit roots, co-integration and causality the probability values of 0.05 and 0.1 have been chosen in this study, which are appropriate levels of significance.

The result of panel unit root tests is reported in Table 1. The test statistics for log levels of CO2, GDP and GDP2 are statistically insignificant at 1%, 5% or 10% level of significance in each of the test used in the study. Thus the log values of the variables GDP and CO2 emissions at levels indicate that the variables are panel non- stationary. However, when the panel unit root tests are applied to the first differences of the variables, each of the tests rejected the null hypothesis of non- stationary for both variables at 1 percent level of significance. Thus, from the entire test we can conclude that each of the variables contains a panel unit root at levels but the variables are stationary at first difference.

Table 1: Result of Panel of unit root test

	$LNCO_2$	LNGDP	$LNGDP^2$
IPS (2003) W-stat			
Level	2.41 (0.99)	5.02 (1.00)	10.29 (1.00)
First Difference	-11.54*** (0.00)	-7.33*** (0.00)	-4.36*** (0.00)
ADF- Fisher Chi- square			
Level	2.65 (0.99)	0.48 (1.00)	0.36 (1.00)
First Difference	131.16*** (0.00)	117. 69*** (0.00)	40.37*** (0.00)
Conclusion	I(1)	I(1)	I (1)

*Note: The null hypothesis is that the variable follows a unit root process. *** indicates that the parameters are significant at 1% level.*
Source : Compiled on the basis of data

The most common procedure in choosing the optimal lag length is to estimate a VAR model including all variables in levels. On the basis of table (2), it is clear that SBC criterion and AIC criterion have chosen 1 and 5 lag length respectively. However, on the basis of diagnostic checks (autocorrelation, normality test, homoscedasticity test) model with 5 lag length has been employed in the study.

Table 2: Results of Information Criterion

Lag	LR	FPE	AIC	SC	HQ
0	NA	0.122	3.577	3.616	3.593
1	1559.904	4.51e-06	-6.633	-6.516 *	-6.586
2	5.372	4.58e-06	-6.618	-6.422	-6.538
3	10.032	4.51e-06	-6.634	-6.359	-6.523
4	22.241 *	4.08e-06	-6.734	-6.382	-6.591 *
5	7.516	4.07e-06 *	-6.735 *	-6.304	-6.560
6	7.002	4.09e-06	-6.733	-6.223	-6.526
7	5.700	4.13e-06	-6.722	-6.133	-6.483
8	6.590	4.15e-06	-6.718	-6.051	-6.447

*Note: * indicate lag order selected by the criterion*
Source : Compiled on the basis of data.

Having established that each of the three variables is I(1), the panel co-integration between CO2 emissions and its determinants is checked using Pedroni and Fisher tests for SAARC panel data, and the results are presented in Table 3 and 4 respectively. According to the results of Pedroni test in table 3 for SAARC, two out of the four panel based statistic reveal evidence of panel co-integration among the variables at 1% level of significance. Additionally, all the three group statistics reveal evidence of panel co-integration at 1% level of significance.

Table 3. Result of Pedroni Residual Co-integration Test

	t –statistic	Prob.
Panel v-Statistic	1.21	0.11
Panel rho-Statistic	-1.23	0.10
Panel PP-Statistic	-1.88 ***	0.02
Panel ADF-Statistic	-1.84 ***	0.03
Group rho-Statistic	-1.66 **	0.04
Group PP-Statistic	-4.38 ***	0.00
Group ADF-Statistic	-3.68 ***	0.00

*NOTE: Null hypothesis: No co-integration, ** and *** indicates that the parameters are significant at 5% and 1% level respectively.*
Source : Compiled on the basis of data.

In sum, five of the seven tests suggest that there is panel co-integration among the variables in eq. (1). In addition, the Johansen Fisher test in table (4) also rejects the null hypothesis of no cointegraton. Overall, there is strong statistical evidence in favour of panel co-integration among the variables for SAARC countries. Evidence of co-integration among the variables also rules out the possibility of the estimated relationship being spurious. The panel co-integration equation can be written as:

$$LNCO = -1.83^{*}LNGDP + 0.27^{*}LN\{GDP^{2}\} \quad (3)$$

where * indicates 1% level of significance. The system estimated R^2 value is 0.48. Therefore, our results do not support the EKC hypothesis in the case of the SAARC countries. The signs of the coefficients indicate U shaped relationship between carbon emissions and economic growth in the context of SAARC countries.

Table 4. Result of Fisher Co-integration test

Null Hypothesis	Trace statistics	Prob.	Max – eigen statistics	Prob.
No co-integration	33.95	0.00	26.31	0.00

Note: Null hypothesis : No co-integration
Source: Compiled on the basis of data.

The existence of a panel long run co-integration relationship among emissions and economic growth suggests that there must be Granger causality in at least one direction. Therefore, static and dynamic causality analysis is carried out in the framework of VECM model. Since, the variables are co-integrated there will be an error correction term to show long run causality. In order to test the significance of the lagged values of the coefficients, Wald Chi- square (χ^2) test has been used in the study (Table 5).

Table 5. Result of Panel Causality test – Wald Coefficient Diagnostic

DEPENDENT VARIABLE	NULL HYPOTHESIS	SOURCE OF CAUSALITY (INDEPENDENT VARIABLE)		
		LONG RUN		
		ECT	LNCO2	LNGDP
LNCO2	GDP does not cause CO_2.	-0.01 (0.02)		9.87 (0.07)
LNGDP	CO_2 does not cause GDP	0.02 (0.10)	2.47 (0.78)	

Source : Compiled on the basis of data.

Let us first discuss the estimation result for CO2 emissions. The estimated coefficient for the lagged values of changes in LNGDP are statistically significant at 10 %level, which implies the presence of short run causality running from economic growth to carbon emission. The estimated coefficient for the lagged values of changes in LNCO2 are statistically not significant at the 5% level or 10 %level, which implies the absence of short run causality running from carbon emission to economic growth. The coefficients of the ECT is significant and negative only in the first case which implies there exist a long run panel causality link that runs from economic growth to carbon emissions. The dynamic properties of the VAR system have been analyzed using Variance decompositions (VDs) and Impulse Response Functions (IRFs). One can find similar results from VDs and IRFs which is given in Table 6.1, 6.2 and figure 1 respectively. The forecast period of 10 years has been chosen. The result of IRFs is given in figure 1. One SD shock in LNCO2 has positive impact on its own value and economic growth. Similarly, the impact on one SD shock in LNGDP is positive on both the variables.

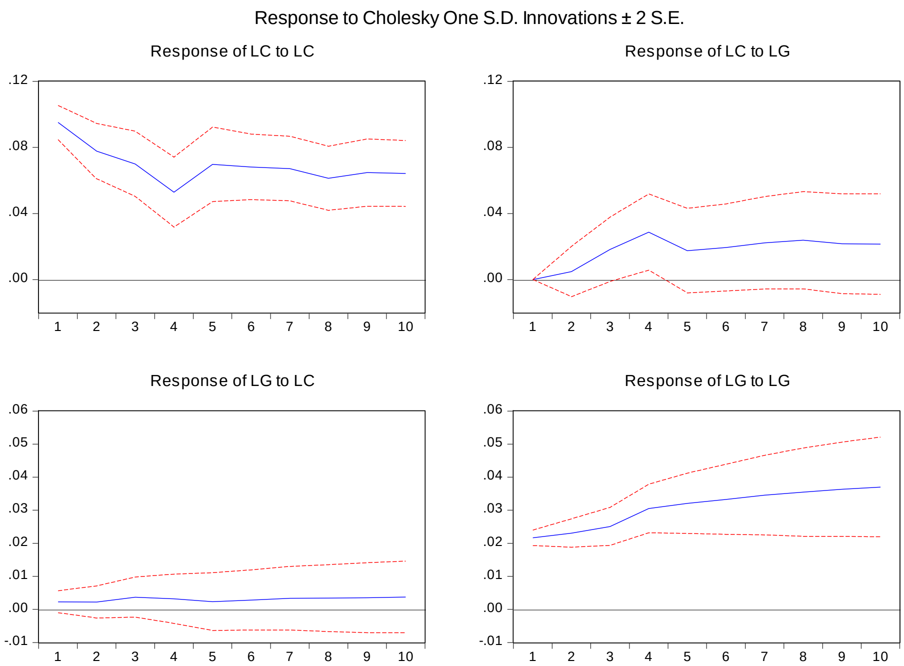
The result of VDs of LNCO2 is given in Table 6. In the short run period, that is for period 3rd, impulse or innovation or shock to LNCO2 account for 98.23 percent variation of the fluctuation in LNCO2 (own shock). However, the shock in LNGDP can cause only 1.76 percent fluctuations in LNCO2. In the long run say for 10th period impulse or innovation or shock to LNCO2 account for 92.66 percent variation of the fluctuation in LNCO2 (own shock) and the shock in LNGDP can cause only 7.33 percent fluctuation in LNCO2. Thus, as compared to short run, in the long run the impact of shock to economic growth on emission has increased and it is rising. The result of VDs of LNGDP is also given in Table 6. In the short run period, that is for period 3rd, impulse or innovation or shock to LNGDP account for 98.55 percent variation of the fluctuation in LNGDP (own shock). However, the shock in LNCO2 can cause only 1.44 percent fluctuations in LNGDP. In the long run say for 10th period impulse or innovation or shock to LNGDP account for 99.02 percent variation of the fluctuation in LNGDP (own shock) and the shock in LNCO2 can cause only 0.97 percent fluctuation in LNGDP. Thus, both in the short run as well as long run story remains more or less same i.e., impact of shock to CO_2 emissions is very less (not even more than 5 percent) on economic growth.

Table 6: Result of Variance Decomposition (VDs):

PERIOD	Variance decomposition of LNCO2		Variance decomposition of LNGDP	
	LNCO2	LNGDP	LNCO2	LNGDP
1	100.000	0.000	1.108	98.892
2	99.842	0.158	1.008	98.992
3	98.233	1.767	1.440	98.560
4	95.044	4.956	1.315	98.686
5	94.873	5.127	1.092	98.909
6	94.519	5.481	1.004	98.996
7	93.957	6.043	0.990	99.010
8	93.252	6.748	0.977	99.023
9	92.928	7.072	0.968	99.032
10	92.666	7.334	0.975	99.025

Source : Compiled on the basis of data.

Figure 1. Impulse response function (irfs) analysis



5. Observation, Conclusion and policy implications:

The paper examined the linkage between CO_2 emissions and economic growth using panel data of SAARC countries over the period 1972-2010 by applying Panel co-integration approach. Stationary properties of the study variables indicate that all the variables are non-stationary at level form and stationary in first difference form. Panel co-integration analysis indicates that the linear combinations of these explanatory variables are co-integrated. Therefore, static Granger causality among the test variables has been examined through Panel VECM approach test and dynamic Granger causality has been examined through Impulse Response Functions (IRFs) and Variance Decomposition (VDs) analysis. The result from the application of VECM analysis suggest that CO_2 emissions does not cause economic growth but economic growth cause CO_2 emissions. The result found contradicts the Environmental Kuznets Curve hypothesis and U – shaped relation has been found between environmental degradation and economic growth for SAARC countries. This implies that economic growth of SAARC countries cannot help in reducing CO_2 emissions automatically as suggested by some studies in the literature. This may be due to the fact that SAARC region mainly consists of developing countries and less developed countries and therefore, the GDP of SAARC countries have not reached the turning point of Environmental Kuznets Curve hypothesis. This also implies that with ongoing growth in GDP, environmental degradation is rising. Similar results found from IRFs and VDs analysis. Results from dynamic Granger causality analysis shows that the SD shock in CO_2 emissions has positive impact on GDP. Also, the impact of the SD shock in GDP has positive impact on CO2 emission which implies that increase in growth rate encourages CO_2 emissions.

Therefore, the governments of SAARC region should emphasis on various environmental regulation policies to control emissions. For example, these governments should emphasize on industrial structure which is not very energy intensive and should emphasize on the development of renewable energy sources. The government should make its environmental policies and tools more transparent.

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