The Armey Curve Hypothesis-based Environmental Kuznets Curve (EKC) Hypothesis Testing Across the US States with Government Spending

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Hypothesis Testing Across the US States with Government Spending**

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Abstract: This study re-tests the EKC hypothesis for US states with a new methodology that differs from all previous empirical studies using traditional EKC models. To this aim, this methodology, for the first time, unifies two seemingly different but strongly interrelated hypotheses (models), namely the Armey curve (AC) and traditional EKC models, into one single composite model. The rationale for creating this composite model is twofold. First, the functional propositions of these two hypotheses are depicted with inverted U-shaped curves. Second, they also have economically interrelated-causal relationships. This means that rising government spending (through the AC hypothesis) increases real GDP per capita (RGDPPC) and, consequently, increases in RGDPPC (through the EKC hypothesis) increase CO₂ emissions. The composite model created may also allow US state policymakers to determine a single maximum spending level that will maximize or minimize CO₂ emissions. Empirical findings indicate that the composite model is capable of testing the EKC hypothesis for 7 US states. Additionally, for 7 US states, maximum spending level was calculated to be around 15% of their RGDPPCs. Hence, with this calculated spending level, policymakers of these states may be able to determine-adjust their golden spending levels so as not to cause environmental degradation and declines in GDP.

Keywords: The Armey curve hypothesis, the EKC hypothesis, New version of the EKC hypothesis testing.

Jel Classification: E62, Q50.

1. Introduction

The roles of the governments in economic growth have been discussed for a long time. In the theoretical discussion, the neoclassical growth model, developed by Solow (1956), postulates that fiscal policies through taxation and government spending can affect the economic growth up to only a steady-state rate of growth, which is determined by the exogenous rate of technological progress. On the other hand, the endogenous growth model, pioneered by Romer (1986), Lucas (1988), and Barro (1990), postulates that a government can affect the economic growth since transition and steady-state growth rates and government is considered endogenous. This means that governments play a serious role in the economy. From a closer perspective, this discussion implicitly arises from a basic question about how much should a government be involved in the economy? According to Armev (1995), rises in government spending trigger economic growth only up to a threshold (turning) point. Further rises in spending lead to falls in growth and the initially linear relationship between growth and spending becomes nonlinear just after this threshold point (optimal government spending level). This nonlinear relationship postulated draws a parabolic inverted U-shaped curve, the so-called Armev curve shown in Figure 1. The rationale of this expectation is that real GDP per capita will initially increase by increasing productive government spending and eventually decrease after a threshold (turning) point due to different dynamics, such as the crowding-out effect, taxation, the law of diminishing returns, and bureaucratic costs (Bastiat 1983; Barro, 1990; Scully, 1996; Karras, 1997; Chao and Grubel, 1998; Sarte, 2001; Colombier, 2009).

Figure 1: Armey Curve

The pattern of this curve gives government policymakers the maximum level of spending which could maximize their real GDP per capita. On the basis of causal interconnectivity among the macroeconomics variables in the economy, the Armey curve resembles another inverted U-shape curve, the so-called Environmental Kuznets Curve (EKC), developed by Grossman and Krueger (1991), shown in Figure 2. According to the EKC hypothesis, in the first stages of economic growth, rises in the real GDP per capita initially lead to increases in environmental degradation (CO₂ emissions) but further rises eventually lead to decreases in emissions after a certain turning point. In a way similar to the Armey curve hypothesis, this certain point gives government policymakers the maximum level of real GDP per capita, which will trigger declines in CO₂ emissions.

Figure 2: Environmental Kuznets Curve

When these two hypotheses (curves) are closely examined, a sequentially causal relationship can be clearly seen from the Armey curve hypothesis to the EKC hypothesis. This means that rises in government spending lead to increases in real GDP per capita in the Armey curve model and, thereby, rises in real GDP per capita lead to increases in CO₂ emissions in the EKC model. Moreover, this variable-level causal relationship between the two models was constructed on the same inverted U-shaped mathematical proposition. Therefore, we believe that these two hypotheses can be jointly examined, both theoretically and mathematically. This means that such similarity may enable us to test the EKC hypothesis through the Armey curve hypothesis (model). Therefore, it can be interpreted that the EKC hypothesis can be potentially tested by a kind of transmission mechanism of the Armey curve model. In this context, a single composite model derived from these two hypotheses (models) can be set up. To the best of our knowledge, this new methodological approach proposed using a single composite model will be the only attempt used in testing the EKC hypothesis in relevant literature. This alternative approach of testing the EKC hypothesis and transmission mechanism can be shown in the following Figure 3:

Figure 3: EKC Hypothesis Testing Through
the Army Curve Hypothesis

Therefore, we will try to test the EKC hypothesis in this methodological context for 50 US states from 1990-2017 based on the latest available year data. The rationale of a state-level empirical study is that US states have different levels of real GDP per capita, spending, CO₂ emissions, and energy policies. These differences make the USA a unique sample country. Another advantage of sampling US states is that this country provides a wide range of data at the state level for more detailed empirical results. The necessary conditions for testing the EKC hypothesis through the Army curve model are as follows: first, the Army curve must be validated for a sample US state. Second, the composite model must be significant for the same US state. This means that the curve shape of the Army model must be inverted U-shaped. However, significant composite model can be either U-shaped or inverted U-shaped. If the composite model's curve is also inverted U-shaped, this will imply that the EKC hypothesis is validated through the Army curve hypothesis (Case 1 in Figure 4). Otherwise, significant but U-shaped curve will not validate this hypothesis through the Army curve model (Case 2 in Figure 5). In the following Figures 4 and 5, we graphically

depict these two potential curve cases of the composite EKC model with a validated Armey curve hypothesis.

Figure 4: Case 1

Figure 5: Case 2

This proposed alternative EKC hypothesis testing method may provide an important advantage to US state policymakers in these two different cases. Case 1 may enable them to determine a maximum (optimal) spending level (through a maximum real GDP per capita level: point A) that maximizes CO₂ emission (point B). Hence, the policymakers may know that additional spending after point A will decrease real GDP per capita and CO₂ emission, implying a dilemma between cleaner environment or lower real GDP per capita. From this point of view, they may determine a golden (optimal) ratio reckoning with the potential changes in real GDP per capita and CO₂ emission as a whole. Case 2 may enable them to determine a maximum (optimal) public spending level (through a maximum real GDP per

capita level: point A) that minimizes CO₂ emission (point C). Hence, policymakers may know that additional spending, after point A, will decrease real GDP per capita and increase CO₂ emission (point C), implying no more government spending is needed after point A. To some degree, this proposed methodological approach also enables US state policymakers to find out whether their economic growth and energy policies are compatible with each other and sustainable or how these two policies interact with each other. In this interpretation, while we regard economic growth policy with the Armey curve hypothesis (based on government spending), we regard energy policy with the EKC hypothesis (based on increases in real GDP per capita). Therefore, policymakers in cross-border states can develop some common economic and energy policies to ensure more sustainable environment. The following sections of the study are: Section 2 provides a summary literature review. Section 3 explains the empirical model and estimation methodology. Sections 4 and 5 provide the empirical findings and the conclusion with policy implications, respectively.

2. Literature Review

In this section, we provide the empirical studies which have tested the Armey and the EKC curves hypotheses individually for the US or in a group of countries such as those of the OECD and the G-7 group. Table 1 reports these studies with the empirical methodologies used and their findings.

Table 1: Empirical Studies in the Armey Curve and EKC Hypotheses

<i>Armey Curve Hypothesis</i>

	Methodology	Findings
Vedder and Gallaway (1998)	OLS Regression	Valid
Knoop (1999)	OLS Time Series	Not Valid
Dar and Amir Khalkhali (2002)	random coefficients model	Not Valid
Roy (2009)	Simultaneous Equations	Not Valid
Connolly and Li (2016)	GMM	Not Valid
Bozma, Başar, and Eren (2019)	ARDL Cointegration	Valid
Rajput and Tariq (2019)	GMM	Not Valid
<i>EKC Hypothesis</i>		
Dogan and Turkekul (2016)	Bounds Testing	Not Valid
Dogan and Ozturk (2017)	Bounds Testing and Gregory-Hansen Cointegration	Not Valid
Shahbaz et al. (2017)	Bounds Testing with Structural Break	Not Valid
Apergis et al. (2017)	Panel Estimators	Valid in 10 out of 48 US States
Aslan et al. (2018)	Bootstrap window estimation	Valid
Isik et al. (2019)	CCE	Valid in 5 out of 10 US States
Ongan et al. (2021)	Decomposition	Valid by Decomposed model

Khan and Hou (2021)	Cointegration Analysis	Valid
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Note: ARDL: Autoregressive distributed lag; OLS: Ordinary Least Square; GMM: Generalized Method of Moments; CCE: Common Correlated Effects.

Empirical studies in Table 1 clearly reveal mixed results about the validity of the Armey curve and EKC hypotheses. This may stem from the different methodologies applied, time frames examined, and different variables used in the models.

3. Empirical Model and Estimation Methodology

The empirical model of this study was theoretically constructed based on Figure 3 in the introduction section. Hence, to create our composite EKC model, we, first, write the following Armey curve model in the natural logarithmic form for the 50 US states:

$$\ln DI_{it} = \alpha + \beta \ln S_{it} + \gamma \ln S_{it}^2 + \zeta \ln EC_{it} + \varepsilon_{it} \quad (1)$$

where DI is state-level per capita real disposable personal income as the proxy of *real GDP per capita*. S and S^2 are state government spending and squared value of state government spending, respectively; EC is total energy consumption. According to the Armey curve hypothesis, the signs for β and γ are expected to be significantly positive and negative, respectively. If these two coefficients are characterized by these signs ($\beta > 0$; $\gamma < 0$), it is implied that the Armey curve hypothesis is valid for a US state. This means that rises in

spending will initially lead to increases in real GDP per capita up to a threshold point (optimal state government spending level) and eventually lead to decreases in it. The dataset and definitions of the variables are provided before the references section.

Following the Armey curve model in Eqn. 1, we present the EKC hypothesis model in the following form:

$$\ln CO2_{it} = a + b \ln DI_{it} + c \ln DI_{it}^2 + z \ln EC_{it} + \varepsilon_{it} \quad (2)$$

where CO_2 is state-level carbon emissions, DI and DI^2 are state-level per capita real disposable personal income and squared value of per capita real disposable personal income, respectively. EC is total energy consumption. According to the EKC hypothesis, the signs for b and c are expected to be significantly positive and negative, respectively. If these two coefficients are characterized by these signs ($b > 0$; $c < 0$), it is implied that the EKC hypothesis is valid for a US state. This means that rises in income will initially lead to an increase in CO_2 emissions and eventually lead to a decrease in it after a maximum point of income.

From the models in Eqns. 1 and 2, we create-obtain the following composite model without EC in Eqn. 3. To show the methodological approach of this study clearly, we have designed the model in the following form without EC :

$$\ln CO2_{it} = a + b \underbrace{(\alpha + \beta \ln S_{it} + \gamma \ln S_{it}^2)}_{DI} + c \underbrace{(\alpha + \beta \ln S_{it} + \gamma \ln S_{it}^2)}_{DI^2} \dots \dots \dots \varepsilon_{it} \quad (3)$$

214

215 Hence, with this model formula, we can test the EKC hypothesis through the Armey curve
 216 model mathematically since the independent variables of the EKC model (DI and DI^2) will
 217 be represented by the independent variables of the Armey curve model in parentheses (S
 218 and S^2). The EKC hypothesis is validated if the signs for b and c (corresponding to DI and
 219 DI^2) are positive and negative, respectively.

220 To determine the maximum (optimal) government spending level that will maximize (Case
 221 1 in Figure 4) or minimize (Case 2 in Figure 5) CO_2 emissions, we have created and used
 222 the following steps and formulae:

223

224 From the first order optimization condition $d\ln DI/d\ln S$ applied to Eqn. 1, we obtain the
 225 state government spending level as,

$$226 \quad \ln S = -\frac{\beta}{2\gamma}$$

227 The sufficient condition for maximization is $d^2\ln DI/d\ln S^2 = 2\gamma < 0$, so γ is expected
 228 to be < 0 . For data consisting of $S_i > 1$, $\ln S$ is positive, so β is expected to be > 0 . Later,
 229 we obtain the optimal level for the composite model in Eqn. (3), from the first-order
 230 condition dCO_2/dS :

$$231 \quad \ln S_1 = -\frac{\beta}{2\gamma}$$

$$232 \quad \ln S_{2,3} = \frac{-\beta \pm \sqrt{\beta^2 - 2\left(\frac{b}{c}\right)\gamma - 4\alpha\gamma}}{2\gamma}$$

233 The value of $\ln S = -\frac{\beta}{2\gamma}$ in Eqn.4 will be the optimal CO₂ emissions level for Eqn. (3).

234 When we insert the value of $\ln S = -\frac{\beta}{2\gamma}$ into $d^2\text{CO}_2 / d\ln S^2 = 2b\gamma + 2c(\beta + 2\gamma\ln S)^2 +$

235 $4c\gamma(\alpha + \beta\ln S + \gamma\ln S^2)$, we obtain the following formula:

236

237
$$\frac{d^2\text{CO}_2}{d\ln S^2}(\ln S_1) = -c\beta^2 + 2b\gamma + 4c\alpha\gamma$$

238

239 if $\gamma < 0$ and $-c\beta^2 + 2b\gamma + 4c\alpha\gamma > 0$, it means that the Arme y curve has an inverted U-
240 shape and the composite EKC is U-shaped. If $\gamma < 0$ and $-c\beta^2 + 2b\gamma + 4c\alpha\gamma < 0$, it
241 means that the Arme y curve and the composite EKC are both inverted U-shaped. Finally,
242 to estimate the coefficients of the model in Eqn. 3, we have followed several methodological
243 steps in the following sub-titles.

244

245 **3.1. Cross Sectional Dependence and Heterogeneity Tests**

246 The empirical analysis begins with testing cross-sectional dependence and slope
247 heterogeneity in the panel data set. The paper performs the Lagrange Multiplier (LM), CD,
248 CD_{LM}, and LM_{adj} tests to examine whether cross-sectional dependence exists. While the LM
249 test was produced by Breusch and Pagan (1980), CD and CD_{LM} tests were suggested by
250 Pesaran (2004). In addition, LM_{adj} test was propounded by Pesaran et al. (2008). The paper
251 also employs $\tilde{\Delta}$ and $\tilde{\Delta}_{\text{adj}}$ tests to investigate the possible presence of slope heterogeneity.
252 Both tests were developed by Pesaran and Yamagata (2008). While cross-sectional

dependence tests search for the null hypothesis of no cross-sectional dependence, heterogeneity tests examine the null hypothesis of slope homogeneity.

3.2. Pesaran (2007) Panel Unit Root Test

This paper carries out the augmented Dickey-Fuller (henceforth, CADF) panel unit root test of Pesaran (2007) to examine whether there is a unit root in the variables under consideration. This panel unit root test considers the null hypothesis of a unit root and can reveal biased and efficient output in the existence of slope heterogeneity and cross-sectional dependence in the panel data model.

3.3. Westerlund (2007) Panel Cointegration Test

To test cointegration in the presence of cross-sectional dependence, Westerlund (2007) produces panel cointegration tests based on the error correction model. Among these tests, P_t and P_a statistics are defined as panel statistics and they depend on pooling information on error correction across cross sections in the panel. Besides, G_t and G_a are called group mean statistics and they do not use the information utilized by panel statistics. The null hypothesis of no cointegration is tested for all tests. Westerlund (2007) uses the panel regression model defined as follows:

$$\Delta Y_{it} = \delta'_i d_t + \lambda'_i \Delta X_{it} + \gamma_i Y_{it-1} + \phi_i X_{it-1} + \varepsilon_{it}$$

where d_t indicates deterministic components, λ_i shows long-run parameters, and α_{ij} and γ_{ij} stand for short-run parameters. For P_α and P_τ tests, the null hypothesis of cointegration (H_0 : $p_i=0$ for all i) is tested against the alternative of cointegration (H_1 : $p_i<0$ for all i). P_α and P_τ tests are computed as,

$$P_\alpha = \left(\sum_{i=1}^N L_{i11} \right)^{-1} \sum_{i=1}^N L_{i12}$$

$$P_\tau = \hat{\sigma}^{-1} \left(\sum_{i=1}^N L_{i11} \right)^{-1/2} \sum_{i=1}^N L_{i12}$$

Additionally, for G_α and G_τ tests, the null hypothesis of no cointegration is defined as H_0 : $p_i=0$ for all i , while the alternative hypothesis of cointegration is described as H_1 : $p_i<0$ for at least some i . G_α and G_τ test statistics are computed as shown below:

$$G_\alpha = \sum_{i=1}^N L_{i11}^2 L_{i12}$$

$$G_\tau = \sum_{i=1}^N \hat{\sigma}_i^{-1} L_{i11}^{-1/2} L_{i12}$$

3.4. Augmented Mean Group (AMG) Estimator

After detecting the presence of cointegration in a panel data model, the next step is to estimate long-run coefficients. Eberhard and Teal (2010) propound a two-stage panel data estimator. The regression equations for this estimator are shown as

$$(i) \quad \Delta y_{it} = b' \Delta x_{it} + \sum_{t=2}^T c_t D_t + e_{it} \quad \rightarrow \quad \hat{c}_t = \hat{\mu}_t^\circ$$

$$(ii) \quad y_{it} = a_i + b_i' x_{it} + c_i t + d_i \hat{\mu}_t^\circ + e_{it} \quad \rightarrow \quad \hat{b}_{AMG} = N^{-1} \sum_{i=1}^N \hat{b}_i$$

In the first step, a standard pooled first difference regression that incorporates T-1 dummies, namely $\hat{\mu}_t^\circ$, is estimated. In the second step, this variable is included in N standard unit regressions. The cointegration parameters of the variables in the empirical models are demonstrated by $\hat{b}_{AMG}$ for the panel.

4. Empirical Findings

Table 2 reports the cross-sectional dependence (CSD) and slope heterogeneity tests results for the Armeey curve, the traditional EKC, and composite EKC economic models.

Table 2: Cross-sectional Dependence and Heterogeneity Tests Results

<i>Armeey Curve Model</i>	Test statistic	p-value
$\ln DI = F(\ln S, (\ln S)^2, \ln EC)$		
Cross-sectional dependence tests		
LM	7707.202*	0.000
CD _{LM}	190.960*	0.000
CD	74.337*	0.000
LM _{adj}	119.031*	0.000
Heterogeneity tests		
$\tilde{\Delta}$	144.166*	0.000
$\tilde{\Delta}_{adj}$	42.908*	0.000
<i>Traditional EKC Model</i>	Test statistic	p-value
$\ln CO_2 = F(\ln DI, (\ln DI)^2, \ln EC)$		
Cross-sectional dependence tests		

LM	7162.865*	0.000
CD _{LM}	119.963*	0.000
CD	52.835*	0.000
LM _{adj}	252.897*	0.000
Heterogeneity tests		
$\tilde{\Delta}$	1525.583*	0.000
$\tilde{\Delta}_{adj}$	44.414*	0.000
<i>Composite EKC Model</i> $\ln CO_2 = F[(\ln S + (\ln S)^2),$ $(\ln S + (\ln S)^2)^2, \ln EC]$	Test statistic	p-value
Cross-sectional dependence tests		
LM	6429.641*	0.000
CD _{LM}	105.150*	0.000
CD	48.781*	0.000
LM _{adj}	216.052*	0.000
Heterogeneity tests		
$\tilde{\Delta}$	741.817*	0.000
$\tilde{\Delta}_{adj}$	56.913*	0.000

Note: * indicates 1% statistical significance.

Test results in Table 2 indicate that the null hypothesis of CSD is rejected at the 1% level of significance. This means all series of the models contains CSD and a shock in one of the US states can impact other US states. Furthermore, the null hypothesis of slope homogeneity can be rejected by both tests for all models. This means that US states have specific

characteristics in terms of the Armey and the EKC hypotheses. The results of the covariate-augmented Dickey-Fuller (*CADF*) unit root test are reported in Table 3.

Table 3: CADF Unit Root Test

Variable	Test statistic	
	Level	First difference
lnDI	-1.766	-2.213**
lnS	-2.026	-2.174**
(lnS) ²	-2.022	-2.170**
lnCO ₂	-1.423	-2.342*
(lnDI) ²	-1.762	-2.225**
(lnS+(lnS) ²)	-2.023	-2.170**
(lnS+(lnS) ²) ²	-2.015	-2.166**
lnEC	-1.008	-2.324**

Note: * and ** respectively indicate 1% and 5%

Statistical significance.

Test results in Table 3 indicate that all variables are integrated of order one (I(1)). This means that series are stationary at first differences. Hence, cointegration relationships in the models can be examined via the Westerlund (2007) panel cointegration test. The results of this test are reported in Table 4.

Table 4: Westerlund (2007) Panel Cointegration Test

	G_t	G_a	P_t	P_a
<i>Armey Curve Model</i>	-	-	-4.075*	-2.957
$\ln DI = F(\ln S, (\ln S)^2, EC)$	2.761*	0.937		
<i>Traditional EKC Model</i>	-	-	-12.905*	-4.625
$\ln CO_2 = F(\ln DI, (\ln DI)^2, EC)$	2.221*	5.242		
<i>Composite EKC Model</i>	-	-	-13.408*	-6.038**
$\ln CO_2 = F[(\ln S + (\ln S)^2), (\ln S + (\ln S)^2)^2, EC]$	2.114*	6.396		

Note: * and ** indicate 1% and 5% statistical significances, respectively. G_t and G_a denote group mean statistics, while P_t and P_a denote panel statistics.

As seen in Table 4, G_t test statistic indicates there is a cointegration relationship in the Armey curve model, while G_t and P_t test statistics explore whether cointegration exists in the EKC model. Besides, G_t , P_t , and P_a test statistics show there is cointegration in the composite model. Hence, the Westerlund (2007) panel cointegration test implies there is a cointegration relationship in all models and the long-run coefficients of the independent variables in the models can be estimated via the AMG estimator. Test results of the AMG estimator test results are reported in Table 5.

336 Table 5: AMG Estimator Results

State	Armey Curve Model			Traditional EKC Model			Composite EKC Model		
	lnS	(lnS) ²	lnEC	lnDI	(lnDI) ²	lnEC	(lnS+(lnS) ²)	(lnS+(lnS) ²) ²	lnEC
Alabama	1.111 [1.39]	-0.031 [-1.28]	0.037 [0.52]	2.494 [0.85]	-0.123 [-0.84]	0.580* [4.25]	-0.002 [-0.07]	0.001 [0.11]	0.638* [4.25]
Alaska	-1.566 [-0.44]	0.053 [0.48]	-0.225** [-2.26]	-2.477 [-1.57]	0.122 [1.60]	0.977* [20.34]	0.003 [0.11]	-0.001 [-0.06]	0.948* [16.52]
Arizona	-1.432*** [-1.89]	0.046** [2.07]	0.635* [5.49]	-13.361* [-4.14]	0.659* [4.11]	-0.839** [-2.53]	-0.097* [-3.64]	0.001* [3.62]	-0.409 [-1.12]
Arkansas	-0.542 [-0.62]	0.020 [0.74]	-0.048 [-0.44]	1.700 [0.43]	-0.085 [-0.43]	0.752* [3.37]	-0.011 [-0.30]	0.001 [0.29]	0.874* [3.83]
California	-4.548* [-6.67]	0.123* [6.79]	0.298* [3.57]	-6.002* [-2.99]	0.290* [2.98]	0.629* [3.36]	-0.055** [-2.03]	0.001** [2.02]	0.645* [2.74]
Colorado	3.986* [4.30]	-0.121* [-4.21]	-0.422* [-2.90]	-3.059* [-3.59]	0.146* [3.50]	1.030* [13.46]	-0.022** [-2.10]	0.001** [1.97]	1.086* [11.38]
Connecticut	5.369** [2.13]	-0.158** [-2.12]	-0.301*** [-1.94]	-2.071 [-0.60]	0.096 [0.58]	0.843* [3.98]	-0.036 [-1.00]	0.001 [0.96]	0.866* [4.59]
Delaware	2.431	-0.080	0.482	-25.291* [2.22]	1.221* [2.22]	1.071* [2.22]	-0.212* [2.22]	0.001* [2.22]	1.248* [2.22]

	[1.32]	[-1.27]	[2.35]	[-4.27]	[4.21]	[5.12]	[-3.68]	[3.56]	[4.47]
Florida	-2.779*	0.081*	0.419*	0.501	-0.025	1.127*	0.184	-0.001	1.097*
	[-3.97]	[4.05]	[5.49]	[0.746]	[-0.33]	[6.66]	[1.64]	[-1.64]	[6.61]
Georgia	4.507*	-0.137*	0.325**	-7.821**	0.385**	1.022*	-0.124*	0.001*	1.250*
	[3.32]	[-3.42]	[2.50]	[-2.46]	[2.43]	[5.13]	[-4.94]	[4.91]	[7.24]
Hawaii	-6.899*	0.230*	0.243*	6.759*	-0.326*	1.075*	-0.014	0.001	1.023*
	[-7.51]	[7.93]	[4.91]	[3.15]	[-3.12]	[25.88]	[-0.67]	[0.80]	[22.96]
Idaho	1.281***	-0.046**	0.082	-5.724***	0.294***	0.910*	0.032	-0.001	0.676*
	[1.93]	[-2.04]	[0.86]	[-1.88]	[1.92]	[5.99]	[0.88]	[-0.84]	[2.97]
Illinois	2.142*	-0.063*	0.106	5.492**	-0.261**	1.068*	-0.020	0.001	1.129*
	[3.06]	[-3.12]	[0.75]	[2.31]	[-2.25]	[4.29]	[-0.75]	[0.88]	[4.90]
Indiana	3.088**	-0.092**	-0.204	0.785	-0.042	0.786*	-0.040***	0.001***	0.725*
	[2.39]	[-2.34]	[-1.36]	[0.39]	[-0.42]	[4.37]	[-1.79]	[1.78]	[4.34]
Iowa	0.334	-0.011	0.242**	1.679	-0.091	1.181*	0.145	-0.001	1.108*
	[0.47]	[-0.51]	[2.39]	[0.70]	[-0.77]	[7.15]	[0.33]	[-0.38]	[6.70]
Kansas	-2.797**	0.089**	0.008	3.659	-0.176	1.404*	0.027	-0.001	1.359*
	[-2.51]	[2.51]	[0.03]	[1.29]	[-1.26]	[5.98]	[0.97]	[-0.87]	[6.00]
Kentucky	2.105*	-0.060*	-0.071*	6.381**	-0.323**	0.671*	0.054***	-0.001***	0.728*

	[6.68]	[-6.31]	[-2.94]	[2.11]	[-2.13]	[4.06]	[1.69]	[-1.72]	[4.22]
Louisiana	-0.154	0.012	-0.065	-3.901*	0.197*	0.878*	-0.044*	0.001*	0.814*
	[-0.17]	[0.46]	[-0.82]	[-2.62]	[2.65]	[10.61]	[-3.56]	[3.69]	[12.81]
Maine	3.091*	-0.094*	-0.205**	0.257	-0.011	0.781	0.133**	-0.001**	-0.205
	[3.11]	[-2.93]	[-2.54]	[0.05]	[-0.04]	[0.23]	[1.98]	[-1.96]	[-0.65]
Maryland	-1.604	0.053	0.379*	-2.522	0.117	0.604*	-0.051***	0.001***	0.570*
	[-1.05]	[1.21]	[3.36]	[-1.04]	[1.00]	[2.77]	[-1.74]	[1.70]	[2.68]
Massachusetts	-0.006	-0.001	-0.061	-7.010*	0.331*	0.422***	-0.023	0.001	0.285
	[-0.0019]	[-0.004]	[-0.46]	[-3.10]	[3.02]	[1.79]	[-0.61]	[0.50]	[1.11]
Michigan	-0.248	0.012	0.363**	4.175**	-0.213**	0.769*	0.071*	-0.001*	0.608*
	[-0.10]	[0.17]	[2.53]	[2.31]	[-2.38]	[7.51]	[2.76]	[-2.84]	[5.66]
Minnesota	1.840***	-0.053*	0.060	0.154	-0.011	0.859*	0.001	-0.001	0.848*
	[1.81]	[-1.75]	[0.54]	[0.08]	[-0.13]	[5.44]	[0.03]	[-0.08]	[5.13]
Mississippi	1.944*	-0.054*	-0.228**	-2.903	0.160	0.613***	0.001	0.001	0.542
	[3.05]	[-2.66]	[-2.49]	[-0.70]	[0.76]	[1.79]	[0.04]	[0.09]	[1.51]
Missouri	2.154*	-0.062*	-0.096***	4.494	-0.215	0.597**	0.007	-0.001	0.714*
	[3.71]	[-3.49]	[-1.96]	[1.09]	[-1.05]	[2.18]	[0.19]	[-0.11]	[2.72]
Montana	-5.657*	0.189*	0.077	-12.478*	0.629*	0.156	-0.120*	0.001*	0.234

	[-5.85]	[5.95]	[1.00]	[-3.49]	[3.51]	[1.06]	[-2.81]	[2.87]	[1.51]
Nebraska	-1.397	0.047	0.302*	3.030	-0.149	0.857*	0.061***	-0.001***	0.899*
	[-1.38]	[1.39]	[2.98]	[1.04]	[-1.05]	[4.96]	[1.76]	[-1.77]	[6.17]
Nevada	0.669	-0.018	0.701*	-1.554	0.057	0.976*	0.020	-0.001	0.506***
	[1.07]	[-0.90]	[7.87]	[-0.28]	[0.21]	[4.02]	[0.51]	[-0.71]	[1.88]
New Hampshire	1.204	-0.038	0.297*	-7.791***	0.385***	0.258	-0.096**	0.001*	0.356
	[1.30]	[-1.22]	[2.61]	[-1.78]	[1.80]	[0.97]	[-2.49]	[2.61]	[1.49]
New Jersey	1.861*	-0.054*	-0.090***	-2.918	0.140	1.154*	0.013	-0.001	1.144*
	[2.70]	[-2.76]	[-1.76]	[-1.25]	[1.24]	[7.78]	[0.43]	[-0.45]	[7.73]
New Mexico	0.314	-0.003	-0.004	-3.069	0.147	0.300	-0.028	0.001	0.312
	[0.79]	[-0.23]	[-0.05]	[-0.82]	[0.79]	[1.31]	[-1.19]	[1.12]	[1.53]
New York	-5.228*	0.138*	-0.048	-5.999*	0.284*	0.940*	-0.081*	0.001*	1.010*
	[-3.61]	[3.49]	[-0.47]	[-3.40]	[3.31]	[8.58]	[-3.98]	[3.85]	[11.09]
North Carolina	1.376	-0.042	0.187	-0.281	0.015	1.404*	0.003	-0.001	1.318*
	[0.81]	[-0.85]	[1.08]	[-0.14]	[0.15]	[7.47]	[0.14]	[-0.10]	[6.12]
North Dakota	2.954	-0.088	0.586**	-0.487	0.026	0.260**	0.037*	-0.001*	0.440*
	[0.99]	[-0.93]	[2.19]	[-0.40]	[0.42]	[2.34]	[2.68]	[-2.77]	[4.86]
Ohio	1.775	-0.056	-0.044	-0.632	0.030	0.319***	-0.080**	0.001**	0.516*

	[1.33]	[-1.44]	[-0.37]	[-0.21]	[0.21]	[1.70]	[-2.19]	[2.21]	[2.78]
Oklahoma	-2.579***	0.088***	0.845**	-4.089	0.206	-0.097	-0.037	0.001	0.175
	[-1.72]	[1.94]	[2.52]	[-1.51]	[1.52]	[-0.29]	[-0.84]	[0.87]	[0.58]
Oregon	-0.981**	0.034**	0.381*	-0.746	0.043	0.446**	-0.009	0.001	0.453***
	[-2.07]	[2.36]	[3.66]	[-0.21]	[0.24]	[2.24]	[-0.25]	[0.31]	[1.82]
Pennsylvania	-1.169*	0.034*	0.050	0.549	-0.030	0.432**	-0.016	0.001	0.437**
	[-3.23]	[3.28]	[0.99]	[0.22]	[-0.25]	[2.58]	[-0.61]	[0.59]	[2.53]
Rhode Island	0.307	-0.006	-0.089***	36.391*	-1.784*	0.908*	0.536*	-0.001*	0.672*
	[0.35]	[-0.22]	[-1.67]	[5.15]	[-5.14]	[3.76]	[4.11]	[-4.09]	[2.59]
South Carolina	1.293	-0.041	0.087	1.538	-0.071	0.236	-0.050***	0.001**	0.641*
	[1.49]	[-1.57]	[1.15]	[0.56]	[-0.52]	[1.03]	[-1.85]	[1.97]	[2.86]
South Dakota	1.338***	-0.044***	0.439*	7.187*	-0.361*	0.455*	0.115**	-0.001**	0.395*
	[1.81]	[-1.71]	[5.27]	[2.93]	[-2.94]	[3.04]	[2.49]	[-2.49]	[2.69]
Tennessee	5.038*	-0.151*	-0.249*	6.215**	-0.319**	1.481*	0.081*	-0.001*	1.061*
	[5.11]	[-5.00]	[-3.23]	[2.19]	[-2.26]	[5.03]	[2.87]	[-2.99]	[3.96]
Texas	-0.029	0.002	0.050	-1.553**	0.074**	0.908*	-0.003	0.001	0.877*
	[-0.05]	[0.13]	[0.71]	[-2.10]	[2.01]	[31.22]	[-0.52]	[0.38]	[26.30]
Utah	-0.659	0.019	0.251***	-3.442	0.162	0.362**	-0.042	0.001	0.358***

	[-0.77]	[0.69]	[1.79]	[-1.61]	[1.51]	[2.22]	[-1.43]	[1.31]	[1.88]
Vermont	0.833***	-0.022	-0.038	4.431	-0.220	0.346***	0.085	-0.001	0.433**
	[1.92]	[-1.58]	[-0.76]	[1.10]	[-1.11]	[1.66]	[1.64]	[-1.65]	[2.03]
Virginia	-2.693*	0.084*	0.390*	2.021	-0.100	0.517	0.053	-0.001	0.592***
	[-3.56]	[3.71]	[5.72]	[0.60]	[-0.61]	[1.36]	[1.36]	[1.36]	[1.66]
Washington	-0.287	0.006	0.047	-5.137	0.246	0.391**	0.028	-0.001	0.275
	[-0.43]	[0.33]	[0.61]	[-1.51]	[1.47]	[2.18]	[0.53]	[-0.58]	[1.25]
West Virginia	-0.691	0.021	0.188***	3.777	-0.186	1.230*	-0.004	0.001	1.073*
	[-0.93]	[0.90]	[1.71]	[1.06]	[-1.07]	[4.15]	[-0.07]	[0.09]	[4.14]
Wisconsin	1.887**	-0.053**	0.039	-0.628	0.026	1.303*	-0.002	0.001	1.257*
	[2.33]	[-2.18]	[0.57]	[-0.43]	[0.36]	[12.48]	[-0.013]	[0.04]	[11.20]
Wyoming	0.226	-0.002	0.400**	-0.144	0.004	0.284**	0.064**	-0.001**	0.458*
	[0.16]	[-0.005]	[2.44]	[-0.08]	[0.05]	[2.04]	[2.16]	[-2.21]	[3.66]

337

338

339

340 Test results in Table 5 indicate that the Armey curve hypothesis is validated only for 15 US
 341 states out of the 50, namely, Colorado, Connecticut, Georgia, Idaho, Illinois, Indiana,
 342 Kentucky, Maine, Minnesota, Mississippi, Missouri, New Jersey, South Dakota, Tennessee,
 343 and Wisconsin. However, the composite EKC model is significant for only 7 of them, namely,
 344 Colorado, Georgia, Indiana, Kentucky, Maine, South Dakota, and Tennessee. This means that
 345 it is possible to test the EKC hypothesis with the proposed methodological approach of this
 346 study only for these 7 US states since the Armey curve hypothesis has been validated and the
 347 composite model is significant for these states. Furthermore, the composite EKC model
 348 hypothesis is validated only for Kentucky, Maine, South Dakota, and Tennessee since $\gamma < 0$
 349 and $-c\beta^2 + 2b\gamma + 4c\alpha\gamma < 0$ (two inverted U-shaped curves: Case 1 in Figure 4). However,
 350 the composite EKC hypothesis is not validated for Colorado, Georgia, and Indiana since $\gamma <$
 351 0 and $-c\beta^2 + 2b\gamma + 4c\alpha\gamma > 0$ (inverted U-shaped Armey curve and U-shaped composite
 352 EKC model in Case 2 in Figure 5). Furthermore, the maximum (optimal) state government
 353 spending levels that will maximize CO₂ emissions for Kentucky, Maine, South Dakota, and
 354 Tennessee were calculated as 17.5%, 16.4%, 15.2% and 16.6% of real GDP per capita of these
 355 states, respectively. This can be depicted in Case 1 in Figure 4. Similarly, the maximum
 356 (optimal) state government spending levels that will minimize CO₂ emissions for Colorado,
 357 Georgia, and Indiana were calculated as 16.40%, 16.45, and 16.7% of real GDP per capita of
 358 these states, respectively. This can be depicted in Case 2 in Figure 5. Apart from the
 359 methodological approach of this study, the traditional EKC hypothesis is validated for only 7
 360 US states out of the 50 since the signs for b and c in Eqn. 2 are positive and negative,
 361 respectively (inverted U-shaped curves).

362

363 Additionally, rises in energy consumption (*EC*) increase CO₂ emissions in 41 US states out
364 of the 50 since the signs of this variable are significantly positive. Table 6 shows the curve
365 shapes of the Arme y, traditional EKC, and composite EKC models. We also created US state-
366 level maps (in Figures 6,7, and 8) to show the validations of the Arme y curve, the traditional
367 EKC, and composite EKC hypotheses. We believe that these maps will help state
368 policymakers to re-review the results of their economic and energy polices in terms of these
369 models. The Federal Government will also be enabled to re-review the states' positions based
370 on a holistic picture from these maps since the impact of the states' economics-energy policies
371 on CO₂ emissions vary from one another.

372

373 Table 6: Curve Shapes of the Arme y, EKC, and Composite Models

State		Traditional EKC Model	Arme y Curve Model	Composite EKC Model
Number	Name			
1	Alabama	-	-	-
2	Alaska	-	-	-
3	Arizona	U	U	U
4	Arkansas	-	-	-
5	California	U	U	U
6	Colorado	U	∩	U
7	Connecticut	-	∩	-
8	Delaware	U	-	U
9	Florida	-	U	-
10	Georgia	U	∩	U
11	Hawaii	∩	U	-

12	Idaho	U	$\cap$	-
13	Illinois	$\cap$	$\cap$	-
14	Indiana	-	$\cap$	U
15	Iowa	-	-	-
16	Kansas	-	U	-
17	Kentucky	$\cap$	$\cap$	$\cap$
18	Louisiana	U	-	U
19	Maine	-	$\cap$	$\cap$
20	Maryland		-	U
21	Massachusetts	U	-	--
22	Michigan	$\cap$	-	$\cap$
23	Minnesota	-	$\cap$	-
24	Mississippi	-	$\cap$	-
25	Missouri		$\cap$	-
26	Montana	U	U	U
27	Nebraska	-	-	$\cap$
28	Nevada	-	-	-
29	New Hampshire	U	-	U
30	New Jersey	-	$\cap$	-
31	New Mexico	-		-
32	New York	U	U	U
33	North Carolina	-	-	-
34	North Dakota	-	-	$\cap$
35	Ohio	-	-	U
36	Oklahoma	-	U	-

37	Oregon	-	U	- 374
38	Pennsylvania	-	U	-
39	Rhode Island	∩	-	∩
40	South Carolina	-	-	U
41	South Dakota	∩	∩	∩
42	Tennessee	∩	∩	∩
43	Texas	U	-	-
44	Utah	-	-	-
45	Vermont	-	-	-
46	Virginia	-	U	-
47	Washington	-	-	-
48	West Virginia	-	-	-
49	Wisconsin	-	∩	-
50	Wyoming	-	-	∩

Note: Curve Shapes were obtained from Table 4. (U): U-shaped curve, (∩):

Inverted U-shaped curve, (-): insignificant model (curve).

Figures 6, 7, and 8: US state-level Maps

Note: States in green and red mean that the Armey curve, traditional EKC, and composite EKC hypotheses (models) were validated and not verified, respectively. The states in white mean that these three models were insignificant. Maps were created from empirical findings of the study.

5. Conclusion with Policy Implications

The testing methodology of this study's EKC hypothesis differs from all previous empirical studies, in relevant literature, that have used traditional EKC models. This methodology unifies two seemingly different but strongly interrelated hypotheses (models) into one single composite model. These are the Armey curve and EKC hypotheses, which were constructed on the same nonlinear mathematical propositions with inverted U-shaped curves. These two hypotheses (models) also have economically interrelated-causal relationships between their

394 independent and dependent variables. This can be explained because rising government
395 spending (based on the Arme y curve hypothesis) increases real GDP per capita and,
396 consequently, the increases in real GDP per capita increase environmental degradation (CO₂
397 emissions). In other words, the Arme y curve model's dependent variable is the independent
398 variable of the EKC model. Therefore, both mathematically and economically, we can create
399 a single composite model, which will be derived from the individual Arme y and EKC models,
400 to test the EKC hypothesis through the Arme y curve hypothesis (model) for US states. This
401 methodology proposed may also allow US state policymakers to determine a single maximum
402 (optimal) spending level that will maximize or minimize CO₂ emissions depending on the
403 composite model's curve shape. With this methodology, both economic policies through the
404 Arme y curve, based on government spending, and energy policies through the EKC
405 hypothesis, based on real GDP per capita, can be jointly examined to a certain extent. This
406 examination may also provide state policymakers to re-consider whether their economic and
407 energy policies are compatible with each other.

408

409 Empirical findings indicate that the methodology proposed in this study, with its composite
410 EKC model constructed based on the Arme y curve model, is capable of testing the EKC
411 hypothesis for 7 states namely, Colorado, Georgia, Indiana, Kentucky, Maine, South Dakota,
412 and Tennessee. For 4 of the 7 states, namely, Kentucky, Maine, South Dakota, and Tennessee,
413 the EKC hypothesis is validated but not for the other 3 states. But, more importantly,
414 regardless of the verification of the EKC hypothesis, with the model proposed by this study,
415 these 4 US states' policymakers will be able to determine the maximum spending levels that
416 will maximize the real GDP per capita and CO₂ emissions. Hence, they will know that

417 additional spending after this maximum threshold points will decrease environmental
418 degradation as well as real GDP per capita. This outcome, of course, may create a dilemma
419 for the policymakers who will have to choose between lower economic growth and cleaner
420 environment. However, they can determine a golden ratio that will ensure them sustainable-
421 compatible economic and energy policies at a lower cost. From the same methodological
422 context, the policymakers of Colorado, Georgia, and Indiana will be able to determine their
423 maximum spending levels that will maximize the real GDP per capita and minimize CO₂
424 emissions. Hence, they will know that additional spending after this maximum threshold
425 points will decrease real GDP per capita and increase CO₂ emissions. This outcome may give
426 them an ideal (optimal) maximum spending level rather than creating a dilemma, as was the
427 case with Kentucky, Maine, South Dakota, and Tennessee. Therefore, policymakers may slow
428 down their economies with no more spending for compatible-sustainable economic and
429 energy policies. Empirical findings of the models reveal that the maximum spending levels
430 that will maximize or minimize real GDP per capita and CO₂ emissions are between 15.2% -
431 17.5% of the states' real GDP per capita. Additionally, the map created in Figure 7 clearly
432 shows that the Armey curve hypothesis is validated in the states mostly located in the inner
433 agricultural areas of the USA. Additional spending in these states initially increases real GDP
434 per capita until a certain point and eventually decreases it.

435 All these outcomes and interactions expected between the variables should be considered
436 based only on the proposed methodology of the study incorporating the Armey curve and the
437 traditional EKC models and not on other macroeconomic variables of the economy. The
438 findings of this study show the need for further empirical studies that will re-approach and re-
439 test the old and recent hypotheses-theories based on multi-dimensional-functional

440 perspectives as we did for the EKC hypothesis. These types of approaches may enable
441 examining economic issues from a holistic point of view since macroeconomic variables
442 dynamically and causally interact with one another.

443 **Dataset:** *DI* and *S* are in USD; *C* is million btu. Data of state government spending were
444 obtained from the Urban Institute (Urban). Data of state-level total energy consumption-CO₂
445 emissions (metric million tons) and real *DI* were obtained from the U.S. Energy Information
446 Administration (EIA) and Data Planet, respectively.

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458

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