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China's Effect on World Energy-Growth Nexus: Spillovers Evidence from Financial Development and CO₂ Emissions

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Abstract: This paper aims to extend the literature on the impacts of China's policies on the world energy-growth nexus by analyzing the spillover effects of financial development and CO₂ emissions. An autoregressive distributed lag approach was applied to annual series data from 1977 to 2016. Models for four world regions were developed, as well as a global model. The results reveal the traditional feedback hypothesis on the whole, both in the short- and long-run. Additionally, the results support that China's CO₂ emission and financial development promote world energy consumption. In regard to the four world regions, heterogeneous results were observed. Overall, China's financial development and CO₂ emissions also have heterogenous worldwide impacts with distinct magnitudes. Accordingly, no country should be indifferent to China's policies, and independence should be promoted for Europe, Central Asia and Asia Pacific aggregates.

1. Introduction

China is the second-largest economy globally with the largest growth market for energy for more than fifteen consecutive years. Although China's primary energy consumption has still been increasing in recent years, it aims to adjust its economy to a more sustainable growth pattern by changing from coal to clean energy, thus reducing its CO₂ emissions. In 2020, as part of Nationally Determined Contribution under the Paris Climate Change Agreement adopted by the European Union and 195 more countries, China announced that it would aim to achieve carbon neutrality by 2060. Following the Agreement that incentivized the decarbonization of energy markets, China aims to peak their carbon emissions before 2030, accompanied by the official target of an 18% reduction in carbon emissions per unit of Gross Domestic Product (GDP). China's energy consumption transition will contribute to its sustainable development, promoting diversification and requiring efficient energy resources.

Nowadays, China's CO₂ emissions are the largest, as a percentage, in the world, with nearly 30% of the world's CO₂ emissions (see Figure 1). The opening to international trade allowed faster economic growth but triggered CO₂ emissions around 2004. China alone produces double the CO₂ emissions than the rest of the Asia Pacific, Europe and Central Asia and almost three times the emissions of Africa and the Middle East, an aggregate mostly dependent on the extract and exports of primary energy. China surpassed the United States of America (U.S.) CO₂ emissions in 2006 and their actual emissions exceed U.S. and European emissions combined.
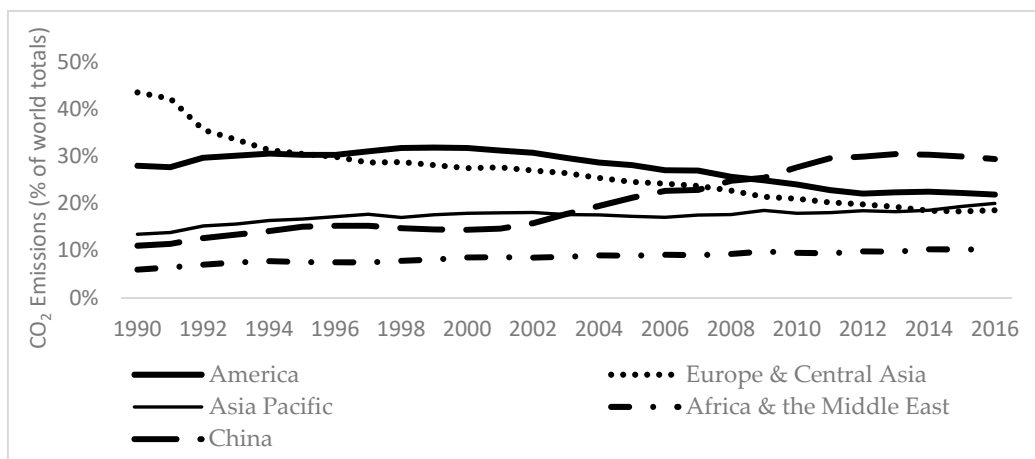
Figure 1. CO_2 emissions (% of world totals). Source: World Development Indicators.

Decoupling China's growth from CO_2 emissions is part of the Chinese decarbonization strategy and the world decarbonization strategy. A total of 73% of newly installed capacity in China is provided from renewable energy, which supports China's fast transition to renewable energy sources. This transition requires a high investment from China. Accordingly, the country' financial development is playing a major role. Nowadays, broad money in China is around 200% of their GDP (see Figure 2), near the double of world broad money in percentage of their GDP. Several articles link CO_2 emissions with financial variables, e.g., (Abbasi and Riaz 2016; Shahbaz et al. 2013; Bekhet et al. 2017; Jiang and Ma 2019). Moreover, for China, several studies link economic growth and CO_2 emissions with financial variables arising in the literature (Zhang 2011; Umar et al. 2020; Lahiani 2020). Despite doubts on existing positive or negative relationship significance between CO_2 and financial development, relationships between the variables are proven. Zhang (2011) stated that China's financial development is an important driver of increasing carbon emissions, as in China, it is around 200% of their GDP (see Figure 2), near double the world mean of emissions. Contrarily, Umar et al. (2020) found negative correlations between CO_2 emissions and financial development in the long run. In the same sense, Lahiani (2020) states that an increase in financial development helps to decrease CO_2 emissions.
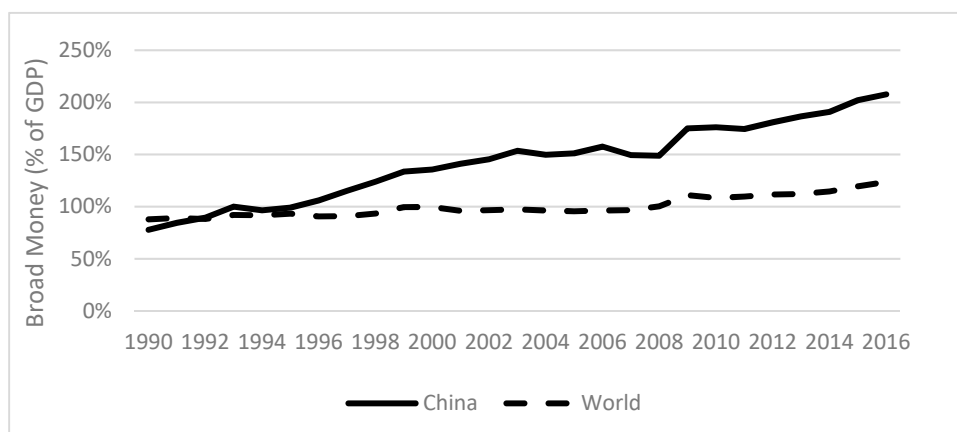
Figure 2. Broad Money (% of GDP). Source: World Development Indicators.

The transition to a low-carbon economy requires knowledge of the theoretical connection between sustainability and monetary economics, which is lacking in the literature, thus eliminating discordant results. The China case gains special interest for two mains reasons: (i) their high shares of world energy consumption and CO_2 emissions; and (ii), the need to monitor broad money that is needed to increase the available capital for in-

vestments given that low-carbon firms need credit to carry out their activities. That said, financial development could also promote an unintended increase in CO_2 emissions given the country-specific economic system as stated in the literature, e.g., (Jiang and Ma 2019; Zhang 2011).

Taking this outlook into account, major changes in China's primary energy consumption and CO_2 emissions are expected, as well as its financial allocations. Policy and market reforms are underway, aiming to promote a quick peek in CO_2 emissions followed by a rapid decline. These major reforms are associated with the lack of knowledge of China's spillover effects across the world which could lead to unknown energy–growth dynamics in the international context in the following years. Therefore, it is of major interest to examine the possible spillover effects of China's emissions and financial development on the worldwide energy–growth nexus. Accordingly, the main research question arises: What are China's emissions and financial development spillovers on the world energy-growth nexus?

To answer the research question, the augmented energy–growth nexus with China's emissions and financial development was analyzed worldwide, as well as for four world regions (America; Europe and Central Asia; Asia Pacific; and Africa and the Middle East) between 1977 and 2016, by using an Autoregressive Distributed Lag (ARDL) approach. The results are consistent with the bidirectional causality between energy consumption and economic growth worldwide, both in the short- and long-run. Additionally, the results point to a positive impact of China's CO_2 emissions and financial development on worldwide energy consumption in the short- and long-run. Furthermore, there are heterogeneous spillover effects of China's CO_2 emissions and financial development in world regions.

The paper evolves as follows: Section 2 presents a brief literature review; Section 3 describes the used data and methodology; Section 4 presents the results, which are discussed in Section 5, and finally, Section 6 concludes.

2. Literature Review

For decades, the energy–growth nexus has received considerable attention, e.g., (Yu and Jin 1992; Lee and Chang 2007; Wang et al. 2016; Akarca and Long 1980). It started with Kraft and Kraft (1978), who examined the energy–growth causality relationship for the United States of America (USA). The research on the nexus evolved, leading to four testable relationships: (i) the neutrality hypothesis, where no relationships between energy and growth are found; (ii) the feedback hypothesis, where there is a bidirectional causality between energy and growth; (iii) the conservation hypothesis, that asserts that there is a unidirectional causality running from economic growth to energy consumption; and (iv), the growth hypothesis that asserts that there is a causality running from energy consumption to economic growth. Different methodologies, data and periods are being used, causing heterogeneous results. For example, Wang et al. (2011) found a unidirectional causality running from energy consumption to China's economic growth between 1972 and 2006. However, Wang et al. (2016) found a bi-directional causality between energy consumption and China's economic growth between 1990 and 2012. Consequently, the nexus research evolved, aiming to understand the inconsistent results found in the literature as well as solve arisen issues, e.g., (Ahmad et al. 2020).

The nexus literature has been extended by including variables such as the population, e.g., (Begum et al. 2015), urbanization, e.g., (Bakirtas and Akpolat 2018) and industrialization, e.g., (Wang et al. 2018), among others. Falkner (2014) stated that global environmental politics have begun to investigate emerging global governance architectures. That fact has led to the increasing interest in studying CO_2 emissions' impact on the energy–growth nexus, e.g., (Acheampong 2018; Morelli and Mele 2020). Moreover, financial development has been introduced to explain the energy–growth nexus, e.g., (Pradhan et al. 2018; Le 2020). It is also common to find research focused on the relationships between these two variables, e.g., (Xu et al. 2017; Rjoub et al. 2021). Results indicated that financial development could

significantly increase carbon emissions from a global perspective, and the analysis of the emerging market developing countries reached the same conclusion (Jiang and Ma 2019).

Chen et al. (2016) analyzed CO_2 emission impacts on the energy–growth nexus and found long-run relationships between energy consumption, economic growth and CO_2 emissions for 188 countries between 1993 and 2010. Additionally, Acheampong (2018) found that a bidirectional causality exists between carbon emissions and economic growth and a unidirectional causality running from energy consumption to carbon emissions for a panel of 116 countries between 1990–2014. Ouyang and Li (2018) conclude that financial development negatively affects economic growth and has heterogeneous impacts on energy consumption for 30 Chinese provinces between 1996 and 2015. Moreover, Pradhan et al. (2018) focused on financial development impacts on the energy–growth nexus and concluded that energy consumption and financial development are drivers of long-run growth in a panel of 35 Financial Action Task Force counties over 1961–2015. Recently, Doğanlar et al. (2021) found that economic growth has a negative and statistically significant effect on CO_2 emissions. In contrast, energy consumption and financial development positively and statistically significantly affected CO_2 emissions in Turkey between 1965–2018.

Globalization and/or trade openness have become variables of interest in the energy–growth nexus literature, e.g., (Shahbaz et al. 2016; Kyophilavong et al. 2015; Sadorsky 2012). Kyophilavong et al. (2015) assert that trade openness adds to economic growth and depended on Thailand's energy consumption between 1971 and 2012. Sadorsky (2012) found evidence of causal relationships between trade and energy consumption in South America between 1980 and 2007. Shahbaz et al. (2016) found that globalization's acceleration led to a decline in energy demand in India between 1971–2012. However, to the best of our knowledge, there is a lack of research on the spillover effects, i.e., it could be expected that some countries' policies can have impacts worldwide, namely in the presence of globalization. The research on spillover effects is far from new in other research areas, e.g., (Mensi et al. 2016; Zhang 2017; Koesler et al. 2016; Song et al. 2021). Following this path of research, analyzing the spillover effects of previously cited variables, such as financial development, population and urbanization, among others, could represent an added value to policymakers, namely by focusing it on the countries with the ability to promote changes in world nexus behaviors, such as China. For instance, Marques et al. (2019) analyzed China's energy consumption and economic growth impacts on four world regions. They concluded that China's energy consumption and economic growth have heterogenous long-run impacts across the world. They also revealed that the American aggregate is not affected by these two variables, highlighting the need to enlarge the research on China's spillover effects on the world energy-growth nexus.

Over the years, several authors analyzed the Chinese energy–growth nexus, e.g., (Wang et al. 2016; Ouyang and Li 2018) that has renewed interest in their determinants concerning the impacts of the energy transition in China. CO_2 emissions and financial development in China also caught researchers' attention due not only to the expected policies focused on their structural reforms but also due to the magnitude of the emissions involved, as well as the high levels of money supply and the proven relationships between both variables and the energy–growth nexus. Kirikkaleli (2020) studied the relationships between economic growth and CO_2 emissions in China and found a long-run cointegration linkage between both variables. At the same time, there is a two-way causality between regional financial development and CO_2 emissions in China (Zhao and Yang 2020). These relationships raised concerns about the Chinese energy transition. Recently, Mori (2018) analyzed political economy perspectives of the transition and concluded that the renewable energy effects and the future hybrid system could lead to the international displacement of coal consumption and carbon emissions. Notwithstanding, the possible impacts of China's energy in the international energy–growth nexus have been overlooked in the literature.

3. Data and Methodology

China's CO_2 emissions' and money supply's spillover effects on the world energy-growth nexus are evaluated from 1977 to 2016. To do so, we followed the empirical approach of Marques et al. (2019). The GDP (Y) is measured in constant 2010 dollars, China's CO_2 emissions (CO_2) are measured in kilotonnes, and China's Broad Money in % of GDP (M3) was extracted from the World Bank's Development Indicators. Primary Energy Consumption (E) data were extracted from the BP Statistical Review of World Energy. Gathered data has been reorganized into five regions allowing their comparability: (i) America (North and South); (ii) Europe and Central Asia; (iii) Africa and the Middle East; (iv) the Asia Pacific; and (v) World. The prefixes "L" and "D" denote the natural logarithm and the first difference of variables, respectively. Eviews 11 econometric software was used. Descriptive statistics are presented in Table 1.

Table 1. Descriptive statistics.

Statistic	America		Europe and Central Asia		Africa and the Middle East		Asia Pacific		World		China	
	LY	LE	LY	LE	LY	LE	LY	LE	LY	LE	LCO2	LM3
Mean	30.364	4.787	27.578	4.814	30.510	3.231	29.743	3.973	31.380	5.940	15.091	4.556
Median	30.374	4.840	27.548	4.799	30.478	3.265	29.809	4.079	31.383	5.924	15.016	4.705
Maximum	30.840	4.970	28.731	4.911	30.905	4.000	30.266	4.610	31.853	6.311	16.147	5.336
Minimum	29.808	4.533	26.595	4.723	30.100	2.246	29.069	3.252	30.851	5.571	14.086	3.186
Std. Dev.	0.323	0.151	0.647	0.046	0.250	0.506	0.353	0.411	0.306	0.231	0.662	0.613
Skewness	−0.126	−0.347	0.142	0.689	0.006	−0.224	−0.332	−0.197	−0.104	−0.100	0.263	−0.657
Kurtosis	1.687	1.549	1.814	2.764	1.688	2.041	1.955	1.750	1.750	1.781	1.836	2.276
Jarque-Bera	2.980	4.913	2.480	3.256	2.870	1.868	2.555	2.861	2.675	2.543	2.717	3.755
Probability	0.225	0.116	0.289	0.196	0.238	0.393	0.279	0.239	0.263	0.280	0.257	0.153
Observations	40	40	40	40	40	40	40	40	40	40	40	40

As expected, the mean logarithm of energy consumption in the Asia Pacific is lower than in America or Europe and Central Asia due to the remotion of China from the aggregate. China alone accounts for almost the same amount of consumption as the entire America aggregate (4.85 for China and 4.95 for America aggregate in 2016). The standard deviation varying between 0.15 and 0.66 supports the presence of heterogeneity across the years and the aggregates but with no extreme outliers. The acceptance of the Jarque–Bera null hypothesis for all variables supports that skewness and kurtosis match for normal distribution.

In order to define the variables' integration order, a modified Dickey–Fuller (MDF) unit root test that follows Perron (1989) was performed (see Table 2). The MDF allows testing for a unit root in the presence of a single structural break.

The results show that LY and LE variables for America, Asia Pacific, Africa and the Middle East and the LCO2 and LM3 variables are I(1) by rejecting the null hypothesis of nonstationarity of their respective first differences. Additionally, the results also show that LY and LE for Europe and Central Asia are I(0) variables by rejecting the nonstationarity of the level variables at the statistical significance of % level. Given the heterogeneity in the variable's integration order, the ARDL methodology is suitable because it allows for the handling of different integration orders, either I(0) or I(1), in the same model. Additionally, ARDL models allow the estimation of long-run elasticities and the use of dummy variables to control for structural breaks. The basic form of an ARDL regression could be represented as follows:

$$Y_t = \gamma_0 + \gamma_1 t + \sum_{i=1}^{k} \gamma_{2i} Y_{t-i} + \sum_{i=0}^{k} \gamma_{3i} X_{t-i} + \varepsilon_{4t} \tag{1}$$

where Y is the independent variable, X is the vector of explanatory variables, t is the trend variable, ε_{4t} is the error disturbance term and k represents the number of lags. In

the presence of cointegration, the ARDL could be transformed into an unrestricted error correction model (UECM) in its equivalent ARDL bounds test:

$$\Delta Y_t = \delta_0 + \delta_1 t + \sum_{i=1}^{k} \delta_{2i}\Delta Y_{t-i} + \sum_{i=0}^{k} \delta_{3i}\Delta X_{t-i} + \delta_4 \Delta Y_{t-1} + \delta_5 \Delta X_{t-1} + \varepsilon_t, \quad (2)$$

Table 2. MDF unit root tests.

Regions		LY	LE	DLY	DLE
America	T-statistic	−4.792	−2.950	−5.603 ***	−7.664 ***
	Specification	1	2	3	1
	Break	2003	2001	1982	1983
Europe and Central Asia	T-statistic	−6.614 ***	−5.479 ***	−9.551 ***	−4.903 **
	Specification	2	3	2	4
	Break	2003	2009	1982	1988
Africa and the Middle East	T-statistic	−4.796 *	−4.128	−5.494 **	−10.240 ***
	Specification	3	1	1	3
	Break	2005	1995	2003	2001
Asia Pacific	T-statistic	−5.094 *	−3.546	−6.472 ***	−6.034 ***
	Specification	1	2	4	3
	Break	1987	1998	1997	1998
World	T-statistic	−4.189	−3.931	−6.034 ***	−4.880 **
	Specification	2	3	2	4
	Break	2008	2010	2003	1984
		LCO2	LM3	DLCO2	DLM3
China	T-statistic	−3.894	−4.274	−5.451 **	−9.444 ***
	Specification	1	3	1	2
	Break	1996	2003	2001	1983

Notes: Trend Specification/Break Specification: (1) Trend and intercept/Trend and intercept; (2) Trend and intercept/Trend only; (3) Trend and intercept/Intercept only; (4) Intercept only/Intercept only. ***, ** and * denote statistical significance at 1%, 5% and 10% levels, respectively.

The equivalent general UECM in its equivalent ARDL bounds test are:

$$DLY_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{k} \alpha_{2i} DLY_{t-i} + \sum_{i=0}^{k} \alpha_{3i} DLE_{t-i} + \sum_{i=1}^{k} \alpha_{4i} DLCO2_{t-i} + \alpha_5 LY_{t-1} + \alpha_6 LE_{t-1} + \alpha_7 LCO2_{t-1} + \mu_{8t}, \quad (3)$$

$$DLY_t = \alpha_9 + \alpha_{10} t + \sum_{i=1}^{k} \alpha_{11i} DLY_{t-i} + \sum_{i=0}^{k} \alpha_{12i} DLE_{t-i} + \sum_{i=1}^{k} \alpha_{13i} DLM3_{t-i} + \alpha_{14} LY_{t-1} + \alpha_{15} LE_{t-1} + \alpha_{16} LM3_{t-1} + \mu_{17t}, \quad (4)$$

where k represents the number of lags of the variables and μ represents the disturbance terms assuming white noise and normal distribution. The expected signs of parameters are $\alpha_0 \neq 0$, $\alpha_1 \neq 0$, $\alpha_{2i} \ldots \alpha_{4i} \neq 0$, $\alpha_5 < 0$, $\alpha_6 > 0$, $\alpha_7 \neq 0$, $\alpha_9 \neq 0$, $\alpha_{10} \neq 0$, $\alpha_{11i} \ldots \alpha_{13i} \neq 0$, $\alpha_{14} < 0$, $\alpha_{15} > 0$, $\alpha_{16} \neq 0$. The parameters $\alpha_{2i} \ldots \alpha_{4i}$ and $\alpha_{11i} \ldots \alpha_{13i}$, explain the short-run dynamic coefficients while $\alpha_{5 \ldots} \alpha_7$ and $\alpha_{14} \ldots \alpha_{16}$ explain the long-run multipliers. Negative α_5 and α_{14} are expected because it would be consistent with the presence of cointegration. Additionally, positive α_6 and α_{15} are expected, given that a negative coefficient would be consistent with a globe *curse hypothesis* where energy consumption leads to less economic growth, which is highly unlikely.

$$DLE_t = \beta_0 + \beta_1 t + \sum_{i=1}^{k} \beta_{2i} DLE_{t-i} + \sum_{i=0}^{k} \beta_{3i} DLY_{t-i} + \sum_{i=0}^{k} \beta_{4i} DLCO2_{t-i} + \beta_5 LE_{t-1} + \beta_6 LY_{t-1} + \beta_7 LCO2_{t-1} + \mu_{8t}, \quad (5)$$

$$DLE_t = \beta_9 + \beta_{10}t + \sum_{i=1}^{k}\beta_{11i}DLE_{t-i} + \sum_{i=0}^{k}\beta_{12i}DLY_{t-i} + \sum_{i=0}^{k}\beta_{13i}DLM3_{t-i} + \beta_{14}LE_{t-1} + \beta_{15}LY_{t-1} + \beta_{16}LM3_{t-1} + \mu_{17t}, \quad (6)$$

where the expected signs of parameters are $\beta_0 \neq 0$, $\beta_1 \neq 0$, $\beta_{2i}\ldots\beta_{4i} \neq 0$, $\beta_5 < 0$, $\beta_6 > 0$, $\beta_7 \neq 0$, $\beta_9 \neq 0$, $\beta_{10} \neq 0$, $\beta_{11i}\ldots\beta_{13i} \neq 0$, $\beta_{14} < 0$, $\beta_{15} > 0$ and $\beta_{16} \neq 0$. The parameters $\beta_{2i\,\ldots}\,\beta_{4i}$, and $\beta_{11i\,\ldots}\,\beta_{13i}$ explain the short-run dynamic coefficients while $\beta_{6\,\ldots}\,\beta_8$ and $\beta_{14\,\ldots}\,\beta_{16}$ explain the long-run multipliers. Negative β_5 and β_{14} are expected in the presence of cointegration and β_6 and β_{15} are expected to be positive, with global economic growth driving the development of productive and non-productive activities, thus increasing energy consumption.

Regarding the structural breaks, the MDF unit root tests revealed some possible breaks. To confirm the need to control for structural breaks, the visual inspection of the model's residuals, the inspection of the CUSUM and CUSUM of squares tests and the Chow (1960) breakpoint was performed. Subsequently, the validity of the final models was evaluated through a battery of diagnostic tests. First, the Jarque–Bera normality test developed by Jarque and Bera (1980) is used to test whether the residuals are normally distributed within the series. Then, the Breusch–Godfrey serial correlation LM test that derives from the works of Breusch (1978) and Godfrey (1978) is used to assess for the presence of serial correlation in the residuals. The ARCH test (Engle 1982) is used to test for heteroskedasticity and the Ramsey (1969) RESET test is used to test for for model specification. After the specification tests, the ARDL bounds test tests the short- and the long-run elasticities.

Toda and Yamamoto (1995) Granger Causality tests were performed as a robustness check. Toda and Yamamoto (1995) Granger Causality is based on estimating the augmented Vector Autoregressive (VAR) model where the VAR is set up in levels, with the appropriate maximum lag length defined by information criteria. In our case, we followed the Akaike information criteria. Then, *m* additional lags of each variable are added to the equation, where *m* is the maximum integration order of the variables, which is 1 in our case. Afterward, the Granger Causality is applied. The use of Toda and Yamamoto (1995) Granger Causality to assess causality after an ARDL approach is far from new in the literature, e.g., (Marques et al. 2019; Uzar and Eyuboglu 2019; Nusair and Olson 2021).

4. Results

Following the Equations (3)–(6), 20 ARDL models have been developed. Let A mean America, ECA mean Europe and Central Asia, AME mean Africa and the Middle East, AP mean the Asia Pacific, Y-CO2 will represent the growth model with CO_2 emissions resulting from Equation (3), Y-LM3 will represent the growth model with Financial Development resulting from Equation (4), E-CO2 will represent the energy consumption model with CO_2 emissions resulting from Equation (5) and E-LM3 will represent the energy consumption model with Financial Development resulting from Equation (6).

4.1. Short-Run and Long-Run Analysis

The ARDL models were performed using a maximum of one lag with automatic lag selection criteria in Eviews. It allows estimating short- and long-run elasticities without compromising the results due to losing too many degrees of freedom. The model selection criteria follow the Akaike Information Criterion. Accordingly, the models were kept as narrow as possible, and the stabilization process, as well as quality checks, are available in Section 4.2. The ARDL bounds test approach was followed for the cointegration analysis, and their results are shown in Table 3.

Table 3. Bounds test.

	Y-CO2	Case	Y-M3	Case	E-CO2	Case	E-M3	Case
Americas	4.552 *	(3)	4.305 *	(3)	6.919 ***	(3)	19.350 ***	(1)
Europe and Central Asia	4.572	(5)	14.413 ***	(4)	10.430 ***	(1)	9.484 ***	(1)
Africa and the Middle East	11.356 ***	(5)	25.314 ***	(1)	27.053 ***	(3)	8.862 **	(3)
Asia Pacific	4.408 *	(3)	44.486 ***	(1)	25.355 ***	(3)	17.985 ***	(3)
World	4.272 *	(3)	8.509 ***	(3)	9.423 ***	(3)	7.200 ***	(1)

Notes: K = 2. F-statistic. Critical values were obtained from Pesaran et al. (2001). (1) denotes Case 1—No constant and No trend. Critical Values for bottom and top are 3.88 and 5.3 for 1%; 2.72 and 3.83 for 5%; and 2.17 and 3.19 for 10%. (3) denotes Case 3—Unrestricted Constant and No trend. Critical Values for bottom and top are 5.15 and 6.36 for 1%; 3.79 and 4.85 for 5%; and 3.17 and 4.14 for 10%. (4) denotes Case 4—Unrestricted Constant and Restricted Trend. Critical Values for bottom and top are 4.99 and 5.85 for 1%; 3.88 and 4.61 for 5% and 3.38 and 4.02 for 10%. (5) denotes Case 5—Unrestricted Constant and Unrestricted Trend. Critical Values for bottom and top are 6.34 and 7.52 for 1%; 4.87 and 5.85 for 5%; and 4.19 and 5.06 for 10%. ***, ** and * denote significance at 1%, 5% and 10% levels, respectively.

Cointegration was found for all the models at the statistical significance of 10%, except for the model Y-CO2 for Europe and Central Asia. Accordingly, several long-run relationships are running in the estimated models. For this reason, the short- and long-run elasticities were performed and presented in Tables 4 and 5.

The results are consistent with the bounds test, and the presence of long memory for all models except AP-E-M3, i.e., the error correction mechanism (ECM) is negative and statistically significant. For the ECA-Y-CO2 case, the ECM is consistent with the presence of long-run memory. However, the bounds test (Table 3) did not support the presence of cointegration. Thus, the presence of cointegration is not confirmed. Accordingly, no major inferences are made on the long-run relationships for the ECA-Y-CO2 case. America reveals a slow speed of adjustment in four models. Namely, in the growth equations, the ECMs above 0.1 show that the relationships between GDP, energy consumption and CO_2 emissions in America will require more than ten years to return to their long-run equilibrium after a shock in the nexus. For Europe and Central Asia, there is a moderate speed of adjustments, except for the ECA-Y-M3 model that shows a fast speed of adjustment, whereafter any shock, the relationships between GDP, energy consumption and M_3 require less than two years to converge to their long-run equilibrium. For Africa and the Middle East, moderate speed of adjustments between 0.17 and 0.40 are observed, except for the AME-E-M3 model with an ECM of −0.003, revealing that there is almost no adjustment to a long-run equilibrium after a shock in the independent variable. Similar behavior is observed for the Asia Pacific, where there is a moderate speed of adjustment for all models except the energy model with M_3 (AP-E-M3). In the AP-E-M3 case, the positive ECM is discordant with the bounds test results and does not support cointegration. For the World aggregate, all ECMs reveal negative and statistically significant coefficients between −0.12 and −0.47, which are consistent with a moderate speed of adjustment to the long-run equilibrium.

The short-run elasticities reveal a bi-directional causality between energy consumption and economic growth for America and World aggregates in the short-run. In Europe and Central Asia, there is a short-run impact running from energy consumption to economic growth shown in model ECA-Y-CO2. Due to the optimal model specification (Table 6), the contemporaneous relationship (the sum of lagged and first-order variables) is shown instead of the short-run elasticity for ECA-Y-ME3. The contemporaneous coefficients are also consistent with the presence of short-run impacts. The short-run impacts between energy consumption and economic growth were also accessed through the contemporaneous effect in Africa and the Middle East. The results are consistent with only uni-directional impacts running from economic growth to energy consumption. In fact, for Africa and the Middle East, one of the models shows statistical evidence of negative short-run impacts of energy consumption on economic growth at the statistical significance of 1% level. There are only bi-directional impacts between energy consumption and economic growth for the Asia Pacific aggregate when the contemporaneous relationships were assessed.

Table 4. Short- and long-run elasticities.

	Americas				Europe and Central Asia				Africa and the Middle East			
	A-Y-CO2	A-Y-M3	A-E-CO2	A-E-M3	ECA-Y-CO2	ECA-Y-M3	ECA-E-CO2	ECA-E-M3	AME-Y-CO2	AME-Y_M3	AME-E-CO2	AME-E-M3
Short-run												
LY(-1) + DLY	-	-	-	-	-	-	-	-	-	-	0.260 ***	0.316 ***
DLY	-	-	0.972 ***	0.948 ***	-	-	−0.167	−0.289 *	-	-	-	-
LE(-1) + DLE	-	-	-	-	-	0.107 **	-	-	−0.104 ***	0.028	-	-
DLE	0.735 ***	0.739 ***	-	-	0.371 **	-	-	-	-	-	-	-
LCO2(-1) + DLCO2	0.010	-	0.035	-	-	-	-	-	-	0.052 **	-	-
DLCO2	-	-	-	-	−0.049	-	0.156 ***	-	-	-	0.128 ***	-
LM3(-1) + DLM3	-	0.005	-	0.013	-	−0.254 ***	-	-	-	0.019	-	-
DLM3	-	-	-	-	-	-	-	−0.091 *	-	-	-	−0.095 *
ECM	−0.097 ***	−0.075 ***	−0.240 ***	−0.141 ***	−0.398 ***	−0.897 ***	−0.227 ***	−0.205 ***	−0.247 ***	−0.167 ***	−0.426 ***	−0.003 ***
Long-run												
LY	-	-	0.412 ***	0.135 ***	-	-	0.181 ***	0.181 ***	-	-	1.067 ***	1.887 ***
LE	2.022 ***	2.409 ***	-	-	−0.024	0.120 **	-	-	−0.244 ***	8.376	-	-
LCO2	0.104	-	−0.029	-	0.228 ***	-	0.001	-	-	0.123 ***	0.257 ***	-
LM3	-	0.062	-	0.092 **	-	−0.283 ***	-	0.034	-	5.864	-	−0.080

Notes: ECM means Error Correction Mechanism. ***, ** and * means statistical significance at 1%, 5% and 10% levels, respectively.

Table 5. Short- and long-run elasticities.

	Asia Pacific				World			
	AP-Y-CO2	**AP-Y-M3**	**AP-E-CO2**	**AP-E-M3**	**W-Y-CO2**	**W-Y-M3**	**W-E-CO2**	**W-E-M3**
Short-run								
LY(-1) + DLY	-	-	0.377 ***	-	-	-	-	-
DLY	-	-	-	0.187	-	-	0.748 ***	1.072 ***
LE(-1) + DLE	0.156 **	-	-	-	-	-	-	-
DLE	-	0.012	-	-	0.776 ***	0.703 ***	-	-
DLCO2	0.195 ***	-	−0.389 ***	-	−0.064 ***	-	0.117 ***	-
LM3(-1) + DLM3	-	-	-	-	-	-	-	0.023 ***
DLM3	-	−0.009	-	-	-	−0.012	-	-
ECM	−0.489 ***	−0.506 ***	−0.173 ***	0.014 ***	−0.123 ***	−0.250 ***	−0.472 ***	−0.137 ***
Long-run								
LY	-	-	0.772 ***	1.793 ***	-	-	0.506 ***	0.159 ***
LE	0.902 ***	10.580 ***	-	-	1.596 ***	1.277 ***	-	-
LCO2	0.226 **	-	0.253 **	-	−0.076	-	0.144 ***	-
LM3	-	−2.628 **	-	−0.255 **	-	0.038	-	0.169 ***

Notes: ECM means Error Correction Mechanism *** and ** means statistical significance at 1% and 5% levels, respectively.

Table 6. Diagnostic tests.

	Specification	ARS	SER	LL	JB	LM	ARCH	RESET
A-Y-CO2	ARDL(1,1,0)	0.999	0.008	134.184	1.907	1.330	0.587	0.304
A-Y-M3	ARDL(1,1,0)	0.999	0.008	133.873	1.135	2.221	1.425	0.444
A-E-CO2	ARDL(1,1,1)	0.996	0.010	129.205	0.780	4.997 *	0.348	2.964 *
A-E-M3	ARDL(1,1,0)	0.996	0.010	128.798	1.376	6.786 **	0.063	1.991
ECA-Y-CO2	ARDL(1,1,1)	0.999	0.013	120.124	1.046	0.855	0.216	2.827
ECA-Y-M3	ARDL(1,0,0)	0.999	0.011	127.081	1.269	0.855	1.919	0.263
ECA-E-CO2	ARDL(1,1,1)	0.897	0.014	114.746	0.589	0.227	0.005	0.106
ECA-E-M3	ARDL(1,1,1)	0.868	0.016	109.929	0.491	1.336	0.009	0.005
AME-Y-CO2	ARDL(1,0,0)	0.998	0.010	128.251	4.305	2.699	0.906	1.903
AME-Y-M3	ARDL(1,0,0)	0.999	0.007	140.764	0.218	2.330	0.000	1.813
AME-E-CO2	ARDL(1,0,1)	0.999	0.014	117.949	3.915	0.375	0.273	0.592
AME-E-M3	ARDL(1,0,1)	0.999	0.013	116.597	2.757	0.537	0.469	4.020 *
AP-Y-CO2	ARDL(1,0,1)	0.999	0.010	130.631	0.350	3.552	0.014	2.551
AP-Y-M3	ARDL(1,1,1)	0.999	0.010	129.783	0.097	0.709	0.299	0.036
AP-E-CO2	ARDL(1,0,1)	0.998	0.019	105.164	2.246	5.527 *	2.927 *	0.038
AP-E-M3	ARDL(1,1,1)	0.997	0.021	99.326	0.333	4.046	0.836	0.042
W-Y-CO2	ARDL(1,1,1)	0.999	0.004	167.433	1.506	5.824 *	0.194	0.326
W-Y-M3	ARDL(1,1,1)	0.999	0.005	154.673	3.340	0.732	0.030	2.187
W-E-CO2	ARDL(1,1,1)	0.999	0.005	160.325	2.515	7.440 **	0.032	0.387
W-E-M3	ARDL(1,1,0)	0.999	0.007	140.412	1.207	5.404 *	0.128	0.782

Notes: ARS means adjusted R-squared. SER means standard error of the regression. LL means Log-likelihood. JB means Jarque–Bera normality test. LM means Breusch–Godfrey serial correlation LM test. ARCH means ARCH test. Reset means Ramsey RESET test. JB matches normality, LM follows Chi-square distribution, and ARCH and RESET follow an F-test. Finally, ** and * means statistical significance at 5% and 10% levels, respectively.

Regarding the long-run elasticities, they reveal a bi-directional causality between energy consumption and economic growth for America, Asia Pacific and World aggregates. For Europe and Central Asia, Africa and the Middle East, the results do not consistently show long-run relationships from energy consumption to economic growth. However, there is evidence of a unidirectional causality running from economic growth to energy consumption in Europe and Central Asia and evidence of the negative impact of energy consumption on economic growth for Africa and the Middle East aggregate.

The results also show that, in the long-run, China's CO_2 emissions and broad money positively impact World energy consumption at the statistical significance of 1% level. However, by analyzing the world in four regions, heterogeneous effects are observed. For the American aggregate, China's broad money revealed a positive impact on economic growth. On the contrary, China's broad money promotes a negative impact on Europe's and Central Asia's growth, while no impacts are revealed in Africa and the Middle East. Further, China's broad money revealed positive impacts on energy consumption and economic growth for the Asia Pacific. Finally, regarding China's CO_2 emissions, positive impacts are observed in Europe's growth and Africa and the Middle East's and Asia Pacific's energy consumption and economic growth. In short, the results allow for the conclusion that both China's broad money and CO_2 emissions tend to influence worldwide energy consumption. In fact, only the American aggregate is not affected by China's CO_2 emission, while China's broad money does not impact Africa and the Middle East aggregate.

4.2. Stability of the Models

Following the inspection of models' residuals, the CUSUM and CUSUM of Squares graphs[1] and Chow Breakpoint Tests (Tables A1 and A2), instability in models was found due to the presence of structural breaks. Accordingly, we control for all the models with several impulses and shift dummies. The models tested all the possible structural breaks identified in CUSUM and CUSUM of Squares and Chow Breakpoint Tests. Following a conservative approach, we dropped any dummy with a non-statistically significant coefficient and without a clear contribution to the model stability. Accordingly, in the American models, we controlled for the period after 1987/1988. In Europe and Central Asia, there was a need to control for a large number of periods. For models with CO_2, the periods after 1993 and 2009 were controlled, while for models with M_3, there was a

need to control for periods after 1988, 1993, 1997 and 2008. In the Asia Pacific, the periods that revealed permanent impacts on energy–growth relationships are 1983, 2006 and 2008. For Africa and the Middle East case, the periods after 1979, 1980, 1981, 1983, 1990, 2004 and 2008 needed to be controlled across the four models, revealing the region's greater instability. Finally, there was a need to introduce shift dummies in the World case after 1993, 1997, 2001, 2004 and 2009.

After introducing dummies, all the CUSUM and CUSUM of squares tests and the ARDL residuals (Figure A1) do not reveal major disturbances in the models' stability. Some minor variations are still observable, but the need to control these periods was tested, and no major changes in the results were observed. The quality of the models is assessed by the battery of diagnostic tests shown in Table 6.

Overall, the 20 models surpassed the battery of diagnostic tests that were indicated earlier, revealing the residuals' normality, no serial correlation, no heteroskedasticity and stability of the models. For the models, A-E-M3 and W-E-CO2, the Breusch–Godfrey serial correlation LM test revealed the possibility of serial correlation at the statistical significance level of 5%. However, the inspection of the correlograms (not shown to preserve space) does not confirm the presence of serial correlation in the models. Further, occasional cases of weak statistical significance in some tests for the other models should not be a problem regarding the models' quality.

4.3. Robustness Checks

To access the robustness of our results, the Toda and Yamamoto (1995) causality test was performed (see Table 7). Following the Akaike information criteria, one lag was defined as optimal lag length. Then, $m = 1$ additional lag was added to each variable.

The Toda and Yamamoto (1995) causality results revealed consistency with the elasticities of Tables 4 and 5 for the majority of the cases. Accordingly, for Europe and Central Asia, there is a causality running from economic growth to energy consumption at the statistical significance levels of 1% and 10%, for the model with CO_2 and the model with M_3, respectively. Further, there is causality running from M_3 to both LY and LE. For Africa and the Middle East, there is evidence of a causality running from LY to LE at the statistical significance level of 5% and causality running from LE to LY at the statistical significance levels of 5% and 10% for the models with CO_2 and M_3, respectively. For Asia Pacific regions, evidence of a causality running from LY to LE at the statistical significance of 1% level, while the reverse relationship of causality running from LE to LY is detected only in the model with CO_2 at the statistical significance of 1% level.

Further, there is evidence of a causality running from CO_2 to LE at the statistical significance of 5% level and causality running from M_3 to LE and M_3 to LY at the statistical significance of 5% and 10% levels, respectively. Contrary to these results, in America's aggregate, no causal relationships were found between the variables. On the world aggregate, a causality running from LE to LY was found at the statistical significance of 1% level in the model M_3, respectively, while causality running from LY to LE was found at the statistical significance of 5% and 1% levels in the models with CO_2 and M_3, respectively. Regarding the CO_2 and M_3 impacts on world aggregate nexus, only CO_2 revealed to granger cause LE at the statistical significance of 10% level.

Table 7. Toda–Yamamoto Causality Test.

	Americas				Europe and Central Asia				Africa and the Middle East			
	LY	LE	LY	LE	LY	LE	LY	LE	LY	LE	LY	LE
LY		0.012		0.101		6.661 ***		3.179 *		4.380 **		5.416 **
LE	1.922		0.971		0.346		0.135		5.806 **		2.851 *	
LCO2	0.900	0.531			2.914 *	0.133			5.442 **	9.909 ***		
LM3			0.465	0.3637			3.870 **	8.375 ***			5.239 **	2.548

	Asia Pacific				World			
	LY	LE	LY	LE	LY	LE	LY	LE
LY		27.509 ***		11.036 ***		4.038 **		10.131 ***
LE	9.719 ***		2.661		2.311		8.357 ***	
LCO2	1.921	4.446 **			0.004	3.276 *		
LM3			6.162 **	2.873 *			0.139	0.088

Notes: ***, ** and * means statistical significance at 1%, 5% and 10% levels, respectively.

5. Discussion

Until 2025, non-renewable fuels, oil, coal and gas will remain the main components of primary energy consumption. Despite the tendency of decline in the use of oil and coal, gas usage will remain and continue to grow. Additionally, fossil fuel prices have risen over the past decade, and this trend is set to continue. Those effects will most likely promote the diversification of energy sources. In fact, the trend for diversification already exists, driven by the Paris agreement to globally reduce carbon emissions. As stated before, in China's case, diversification is being taken as a path to reduce CO_2 emissions. Taking this into account, the results make us aware that changes in China's energy policies will most likely spread some effects across the worldwide energy–growth nexus.

The main goal of unveiling China's CO_2 emissions and financial development on the world energy-growth nexus was achieved using an ARDL bounds test approach. This approach proved to be of particular interest given the presence of cointegration. The ARDL methodology allowed us to distinguish both the short- and long-run behaviors of the energy–growth nexus worldwide as well as on four world regions. Furthermore, this methodology allowed us to cope with shift dummies to control several historical periods that impacted the nexus. Africa and the Middle East were the regions that revealed greater instability in the nexus requiring the introduction of quite a few dummies.

The traditional feedback hypothesis was observed in the short-run in World and America aggregates. Further, there is some evidence of the short-run feedback hypothesis in the Asia Pacific for the models with CO_2 emissions. However, given that the model with financial development does not show the same feedback relationships, it does not allow us to confirm the bi-directional relations between energy and growth for the Asia Pacific in the short-run. For the Europe and Central Asia aggregate, in the short-run, the growth hypothesis is observed. In contrast, in Africa and the Middle East, the conservation hypothesis was shown in the results. In fact, our results show some evidence of the curse hypothesis in the short-run for Africa and the Middle East aggregate, i.e., the natural abundance of resources in primary energy led to ineffective consumption of energy, which in turn leads to a decrease in the economic growth. These results slightly differ from those previously observed by Marques et al. (2017) who found the short-run feedback hypothesis across the world.

Considering the long-run, evidence of the feedback hypothesis was observed in America, Asia Pacific and the worldwide aggregates. However, the Toda and Yamamoto (1995) causality tests only confirm the feedback hypothesis for the Asia Pacific and the worldwide aggregates. Similarly, there is also some evidence of energy consumption's positive impacts on Europe and Central Asia's growth. However, for the sake of results robustness, we can only confirm the conservation hypothesis. The Toda and Yamamoto (1995) causality tests showed a causality running from energy consumption to economic growth for Europe and Central Asia. For Africa and the Middle East case, once again, evidence of the curse hypothesis is found, but now on the long-run and the causality running from energy consumption to economic growth asserted by the Toda and Yamamoto (1995) causality tests. This negative relationship is far from new in the literature, e.g., (Fuinhas and Marques 2013). This most likely happens because energy consumption occurs mainly in activities that are not directly productive, which do not add to output as a consequence of a rentier mentality present in several countries in this region. Further, the Africa and Middle East aggregate also shows a causality running from economic growth to energy consumption.

In regard to China's CO_2 emissions and financial development, both have long-run impacts across the worldwide nexus. Overall, the results support that China's CO_2 emissions and financial development promote energy consumption on the world aggregate. However, when analyzing the four world regions, we came across heterogeneous results once again. In the long-run, China's CO_2 emissions growth will most likely positively impact economic growth in Europe and Central Asia, Africa and the Middle East and the Asia Pacific and promote energy consumption in Africa and the Middle East and the Asia Pacific aggregates. Further, China's financial development promotes energy consumption

in the America aggregate while negatively impacting Europe and Central Asia's and Asia Pacific's growth. Moreover, Asia Pacific's energy consumption shows a negatively long-run elasticity with China's financial development. However, the existence of the long-run relationship was not validated, given that a positive ECM was found.

In the short-run, China's CO_2 emissions negatively impact world aggregate growth while improving world energy consumption. Furthermore, China's CO_2 emissions have positive short-run impacts on European and Central Asia's and Africa and the Middle East's energy consumption and positive impacts on Africa and the Middle East's growth. Regarding China's financial development, positive short-run impacts on Europe and Central Asia growth are observed. At the same time, there is also evidence of negative impacts on energy consumption of European and Central Asia and Africa and the Middle East aggregates. Additionally, in the short-run, China's financial development promotes the world's energy consumption.

Considering our results, no country should be indifferent to China's energy and financial policies. Namely, China's surrounding countries appear to be highly impacted by China's CO_2 emissions and financial development changes. European and Central Asian countries should have special attention, given that the results are consistent with a hamper on their economic growth driven by China's financial development. Additionally, America can indirectly suffer in its economic growth via an energy consumption slowdown. Several factors can help to explain the worldwide impacts of China' CO_2 emissions and financial development, such as China's dependence on foreign oil and gas leading to huge import levels improving the balance of trade and consequently promoting economic growth in several countries, the heavy amounts spent in trade and investments contributing to the development of other regions or even their position as the largest recipient of foreign direct investment. However, further research is advisable to clarify China's CO_2 emissions' and financial development's spillover channels leading to major levels of worldwide energy consumption and economic growth in other regions.

Countries need to improve their economies to promote independence from China's policies, namely in the current context of China's attempts to decouple growth from carbon emissions, which can lead to financial development policies to assure credit lines to low-carbon firms and investments. This expected outcome follows the negative correlations between CO_2 emissions and financial development found in China (Umar et al. 2020), where an increase in financial development helps decrease CO_2 emissions (Lahiani 2020). The above-cited diversification path may be a common solution, given that diversification tends to turn economies more responsive to any shocks. For example, the impacts of programs like the Belt and Road Initiative should be carefully weighed and analyzed. The Belt and Road Initiative aims to promote the connectivity of Asia, Eastern Africa, Eastern Europe and the Middle East and their adjacent sea. Currently, 71 countries that represent almost a third of the World's GDP are taking part. On the one hand, the policy coordination promoted by the program can represent an added value. On the other hand, the financial integration, the funding and the unimpeded trades, among others, should be made carefully. A common economic market across the participating countries and increasing China's soft power (Voon and Xu 2020), namely in the energy programs, could represent a future barrier to the above-cited diversification path.

6. Conclusions

The impacts of China's CO_2 emissions and financial development on the energy–growth nexus were analyzed worldwide and for four world regions: America; Europe and Central Asia; Asia Pacific; and Africa and the Middle East. Using an ARDL approach with annual time series data from 1977 to 2016, the behaviors were analyzed both in the short- and long-run. The study of the spillover effects of China's CO_2 emissions and financial development is supported by the expected changes in CO_2 emissions policies and possible linkages with financial development. The analysis of both variables' spillovers proved their

interest by revealing their impacts not only on the worldwide nexus but also on different world regions.

The results reveal the traditional feedback hypothesis, both in the short- and long-run, worldwide. With regard to the four world regions, heterogeneous results were observed. The feedback hypothesis was observed in the Asia Pacific, while the conservation hypothesis was in Europe and Central Asia and Africa and the Middle East. Moreover, there is some evidence of long-run relationships between energy consumption and economic growth in the American aggregate. Finally, it is worth noting that some evidence of the curse hypothesis was found in Africa and the Middle East.

The results support that China's financial development and CO_2 emissions promote world energy consumption. Nevertheless, overall, the results also support that both China's financial development and CO_2 emissions have heterogenous spillover effects on the world. Consequently, countries must be aware of possible spillover effects on their energy–growth nexus, namely in Europe where a direct negative impact of China's financial development in their long-run growth is observed and the Asian Pacific countries which have their economic growth strongly impacted by both China's financial development and CO_2 emissions.

The major constraint of this study relies on the available time span for some variables, such as China's Broad Money. In addition, due to several structural breaks found in the models, it would be interesting to expand the database in the near future and compare the results. Lastly, in line with the observed spillover effects, further analysis of the impacts of Chinese energy policies on each aggregate or even at the country level is needed to assure energy security levels.

Appendix A

Figure A1. *Cont.*

Figure A1. *Cont.*

Figure A1. ARDL residuals.

Table A1. Chow Breakpoint Test.

Date		Americas				Europe and Central Asia				Africa and the Middle East			
		Y-CO2	Y-M3	E-CO2	E-M3	Y-CO2	Y-M3	E-CO2	E-M3	Y-CO2	Y_M3	E-CO2	E-M3
1982	(1)	0.791	0.791	1.589	1.589	7.807 ***	7.807 ***						
	(2)	3.791	3.791	7.272	7.272	27.177 ***	27.177 ***						
	(3)	3.165	3.165	6.355	6.355	31.229 ***	31.229 ***						
1984	(1)					5.548 ***							
	(2)					31.328 ***							
	(3)					33.287 ***							
1986	(1)												12.637 ***
	(2)												52.150 ***
	(3)												75.823 ***
1987	(1)				4.926 ***								
	(2)				28.838 ***								
	(3)				29.559 ***								
1988	(1)	3.006 **	2.370 *	3.481**				2.309*	2.094*				
	(2)	19.952 ***	16.499 **	22.346 ***				16.150**	14.901**				
	(3)	18.035 ***	14.218 **	20.885 ***				13.851**	12.564*				
1991	(1)							5.616 ***	3.138**		7.471 ***		
	(2)							31.592 ***	20.633 ***		38.159 ***		
	(3)							33.697 ***	18.828 ***		44.827 ***		
1992	(1)									2.291 *			
	(2)									16.048 **			
	(3)									13.744 **			
1993	(1)										6.607 ***		
	(2)										35.240 ***		
	(3)										39.648 ***		
1995	(1)											0.226	2.864 **
	(2)											1.911	19.208 ***
	(3)											1.356	17.184 ***
1999	(1)					2.432 *							
	(2)					16.853 ***							
	(3)					14.594 **							

Table A1. *Cont.*

Date		Americas				Europe and Central Asia				Africa and the Middle East			
		Y-CO2	Y-M3	E-CO2	E-M3	Y-CO2	Y-M3	E-CO2	E-M3	Y-CO2	Y_M3	E-CO2	E-M3
2001	(1)			4.547 ***	2.649 **							0.157	1.916
	(2)			27.237 ***	18.051 ***							1.333	13.834 **
	(3)			27.283 ***	15.892 **							00.939	11.496 *
2002	(1)						2.940 **						
	(2)						19.610 ***						
	(3)						17.641 ***						
2003	(1)	1.206	1.380			1.040	3.341 **			1.133	5.255 ***		
	(2)	9.260	10.433			8.110	21.657 ***			8.760	30.176 ***		
	(3)	7.236	8.281			6.241	20.047 ***			6.800	31.532 ***		
2005	(1)									1.767	5.990 ***		
	(2)									12.915 **	33.007 ***		
	(3)									10.599	35.939 ***		
2007	(1)							3.089 **					
	(2)							20.381 ***					
	(3)							18.532 ***					
2008	(1)						1.771	1.413			6.446 ***		
	(2)						12.94 ***	10.648 *			34.665 ***		
	(3)						10.624	8.476			38.673 ***		
2009	(1)						1.430		2.657 **	4.955 ***	4.134 ***		
	(2)						10.765 *		18.097 ***	28.955 ***	25.414 ***		
	(3)						8.583		15.943 **	29.729 ***	24.804 ***		

Notes: (1) F-statistic, (2) Log likelihood ratio, (3) Wald Statistic. ***, ** and * means statistical significance at 1%, 5% and 10% levels, respectively.

Table A2. Chow Breakpoint Test.

Date		Asia Pacific				World			
		AP-Y-CO2	AP-Y-M3	AP-E-CO2	AP-E-M3	W-Y-CO2	W-Y-M3	W-E-CO2	W-E-M3
1987	(1)	1.070	1.336						
	(2)	8.320	10.136						
	(3)	6.421	8.014						
1992	(1)	1.644		1.743					
	(2)	12.149 *		12.765 **					
	(3)	9.868		10.455					
1993	(1)							2.431 *	
	(2)							13.700 **	
	(3)							12.155 **	
1997	(1)	1.320	3.707 ***			7.144 ***	3.339 **		
	(2)	10.029	23.435 ***			37.077 ***	17.733 ***		
	(3)	7.918	22.241 ***			42.863 ***	16.695 ***		
1998	(1)			2.634 **	2.110 *				
	(2)			17.973 ***	14.994 **				
	(3)			15.806 **	12.659 **				
2001	(1)					2.222 *	2.629 **		2.776 **
	(2)					15652 **	14.578 **		15.256 ***
	(3)					13.333 **	13.144 **		13.882 **
2003	(1)			4.181 ***	4.263 ***	2.498 **	3.386**		
	(2)			25.625 ***	25.992 ***	17.222 ***	17.935 ***		
	(3)			25.086 ***	25.578 ***	14.990 **	16.932 ***		
2007	(1)					7.144 ***			
	(2)					37.077 ***			
	(3)					42.863 ***			
2008	(1)	3.667 ***		2.332 *		8.255 ***	5.836 ***	1.909	2.596 **
	(2)	23.244 ***		16.284 **		40.632 ***	27.135 ***	11.147 **	14.427 **
	(3)	22.000 ***		13.992 **		49.530 ***	29.153 ***	9.555 *	12.981 **
2009	(1)					9.698 ***			
	(2)					44.813 ***			
	(3)					58.189 ***			
2010	(1)	1.363	2.095 *					0.493	1.577
	(2)	10.321	14.907 **					4.053	9.382 *
	(3)	8.180	12.570 *					2.957	7.887

Notes: (1) F-statistic, (2) Log likelihood ratio, (3) Wald Statistic. ***, ** and * means statistical significance at 1%, 5% and 10% levels, respectively.

Note

[1] The graphs were not shown to preserve space and will be made available upon request.

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