On the nexus of financial development, economic growth, and energy consumption in China: New perspective from a GMM panel VAR approach

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ABSTRACT
This paper studies the endogenous relationships among financial development, energy consumption, and economic growth in China by applying a GMM panel VAR approach with a panel data of 30 Chinese provinces over the period 1996Q1–2015Q4. Financial development is measured by six individual indicators and by a comprehensive indicator obtained through the PCA method. We also account for regional heterogeneity by dividing our sample into three regions: eastern region, central region, and western region. We underline our findings in three aspects. First, financial development measured by most individual indicators (m2, credit, revenue of the insurance industry, and stock market value) and the comprehensive one has a significantly negative impact on economic growth. Second, energy consumption can significantly contribute to economic growth in all regions, while no feedback effect is found except in the western region. This result is further supported by the Granger causality tests. Last, financial development in the sense of m2, credit, stock turnover, and the comprehensive indicator can significantly lessen energy consumption in all regions. But this inhibitory effect is found to be largest in the western region, followed by the eastern region, and be smallest in the central region. The Granger causality tests confirm further the existence of heterogeneity across regions. A bidirectional Granger causality between the two variables is found in the eastern region, a unidirectional Granger causality running from energy consumption to financial development is identified in the central region, and no significant causal relationship shows up in the western region. Our findings provide valuable policy implications for China heading for a green economic growth.

1. Introduction
In 2016, China, the world’s largest energy consumer since 2009, consumes a total of energy around 3123 Mtoe, taking up 22.97% of the world total energy consumption.1 With such a huge amount of energy consumption, China exceeded the U.S. as the largest energy-related CO2 emitter in the world in 2006, and keeps this position thereafter.2 Therefore, understanding the precise relationship between energy consumption and economic activities is very crucial and imperative for leading a sustainable and green economic development in China, and even in the whole world. Indeed, starting with Kraft and Kraft (1978) four decades ago, the nexus of energy-growth has been extensively studied in the literature due to its great significance. These studies apply various proxy variables and econometric methodologies, cover different countries across different time periods, and finally reach varied, sometimes even conflicting, empirical outcomes. Basically, the results can be categorized into four cases. First, “feedback hypothesis” holds when there exists a bidirectional causality between energy consumption and economic growth (e.g., Soytas and Sari, 2003; Fuinhas and Marques, 2012). Second, “growth hypothesis” is supported when there exists only a unidirectional causality running from energy consumption to economic growth (e.g., Lee and Chang, 2008; Al-mulali and Sab, 2012; Ahmad et al., 2017; Tsanì, 2010; Song et al., 2011; Lin and Wesseh Jr, 2014; Aqeel and Butt, 2001). Third, “conservation hypothesis” is implied when there exists only a unidirectional causality running from economic growth to energy consumption (e.g., Kraft and Kraft, 1978; Islam et al., 2013). Last, “neutrality hypothesis” is indicated when there

exists no causality between the two variables (e.g., Stern, 1993; Huang et al., 2008).

Therefore, no consensus is reached among these studies attributing to the differences in econometric approaches, variable selections and model specifications (Karanfil, 2009; Smyth and Narayan, 2015). Furthermore, Karanfil (2009) also suggests that there exists other important variables, like financial variables, that could impact the demand for energy. Indeed, as pointed out by Sadorsky (2010), development of financial sector could affect energy consumption in the economy by reducing financial risk and lending costs, promoting transparency between debtors and creditors, accessing to more advanced technologies.3 Thereafter, in the spirit of Karanfil (2009) and Sadorsky (2010), there emerge a few studies that add financial development into the energy-growth nexus (e.g., Chang, 2015; Kakar, 2016; Le, 2016; Shahbaz et al., 2013; Shahbaz and Lean, 2012; Shahbaz et al., 2017). These papers confirm the existence of linkages among financial development, energy consumption and economic growth, but still reach no agreement.

Likewise, some studies find a bidirectional relationship between financial development and energy consumption (e.g., Shahbaz et al., 2013; Shahbaz and Lean, 2012). But the others identify only a unidirectional effect either running from financial development to energy consumption (e.g., Sadorsky, 2010; Al-mulali and Lee, 2013; Komal and Abbas, 2015; Rafindadi and Ozturk, 2016; Xu, 2012; Islam et al., 2013, Zhao et al., 2016), or the other way around (e.g., Al-mulali and Binti Che Sab, 2012; Furukawa, 2015).

Regarding the lack of census in the literature, we conjecture that this is so because previous studies suffer from several limitations. First, most of the studies often use time series data in a short period owing to data availability, especially in the analysis of most developing countries (e.g., Kakar, 2016; Shahbaz and Lean, 2012). A pretty long period, however, is required to properly capture the persistent dynamics in the time series. As an alternative, a few studies also attempt to use the cross-country panel data sets (e.g., Chang, 2015; Coban and Topcu, 2013). Yet, each country has its individual financial histories, environments, institutions, and policies, the broad comparative analyses conducted at the aggregate level are hardly able to capture and account for such complexity. Furthermore, including the unobserved country-specific effects in the error term might lead to biased and inconsistent estimators (Pesaran and Smith, 1995).

Second, many studies measure financial development with only one or two variables (e.g., Komal and Abbas, 2015; Islam et al., 2013; Xu, 2012). However, financial development is in fact a multifaceted phenomenon. It is hard to imagine that any single rudimentary aggregated financial measure would be sufficient to provide a complete picture of financial development, particularly in cross-countries studies (Cole, 1988). Different countries differ in terms of their financial structure, degree of concentration of financial institutions, size of financial institutions and instruments, efficiency of financial intermediaries, volume of financial transactions and effectiveness of the financial regulatory framework (Ang, 2008). Therefore, using different measures of financial development may give rise to very different conclusions, for instance, Chang (2015), Coban and Topcu (2013), and Kakar (2016).

Last and foremost, most empirical methods in these studies are subject to endogeneity problem. Most of the literature typically employ a single equation approach of autoregressive distributed lag in specifying the relationship among financial development, energy consumption, and economic growth (e.g., Islam et al., 2013; Shahbaz and Lean, 2012). Thus, potential endogeneity problem is likely to result in biased and inconsistent estimators. To deal with this problem, some studies use instead GMM regression method (e.g., Coban and Topcu, 2013; Sadorsky, 2010; Sadorsky, 2011). Nevertheless, this single equation approach still cannot fully capture the interactions among financial development, energy consumption, and economic growth. As noted above, there are possibly bidirectional relationships between energy consumption and economic growth, financial development and energy consumption. Meanwhile, it is also well known in the literature on the finance-growth nexus that there possibly exists a bidirectional relationship between financial development and economic growth (Abu-Bader and Abu-Qarn, 2008; Ang, 2008; Al-mulali and Lee, 2013; Al-Yousif, 2002; Calderón and Liu, 2003; Demetriades and Hussein, 1996). Therefore, a single

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3 Specifically, see Sadorsky (2010) for three channels through which financial development could impact the demand for energy in details.

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Table 1
Indicators for financial development and data sources.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definition</th>
<th>Source</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>m2</td>
<td>Money and quasi money per capita (M2) in log form</td>
<td>China Financial Statistics Yearbook</td>
<td>Berdiev and Saunoris, 2016; Elgin and Uras, 2013</td>
</tr>
<tr>
<td>credit</td>
<td>The ratio of total credit to nominal GDP (%)</td>
<td>China Financial Statistics Yearbook</td>
<td>Levine, 1997; Levine and Zervos, 1998; Arestis et al., 2001; Beck and Levine, 2004</td>
</tr>
<tr>
<td>insur</td>
<td>The ratio of revenue of the insurance industry to GDP (%)</td>
<td>Provincial Statistical Yearbooks</td>
<td>Beck et al., 2000; Cull et al., 2005</td>
</tr>
<tr>
<td>stmv</td>
<td>The stock market value divided by nominal GDP (%)</td>
<td>Wind Database</td>
<td>Levine and Zervos, 1998; Arestis et al., 2001</td>
</tr>
<tr>
<td>Inturov</td>
<td>The stock turnover at constant 1996 price in log form (10^8 RMB)</td>
<td>Wind Database</td>
<td>Demirgic and Levine, 1996; Zhang, 2011</td>
</tr>
<tr>
<td>fdi</td>
<td>The ratio of net FDI inflows to GDP (%)</td>
<td>Wind Database</td>
<td>Sadorsky, 2010; Doytch and Narayanan, 2016</td>
</tr>
</tbody>
</table>

Table 2
Descriptive statistics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type</th>
<th>Mean</th>
<th>Std. dev.</th>
<th>Min</th>
<th>Max</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>lnc</td>
<td>Overall</td>
<td>9.751</td>
<td>0.844</td>
<td>6.691</td>
<td>11.492</td>
<td>N = 2400</td>
</tr>
<tr>
<td>lndgp</td>
<td>Overall</td>
<td>6.288</td>
<td>0.844</td>
<td>3.764</td>
<td>8.603</td>
<td>N = 2400</td>
</tr>
<tr>
<td>m2</td>
<td>Overall</td>
<td>2.536</td>
<td>0.957</td>
<td>0.996</td>
<td>8.190</td>
<td>N = 2400</td>
</tr>
<tr>
<td>finef</td>
<td>Overall</td>
<td>1.116</td>
<td>0.381</td>
<td>0.311</td>
<td>2.715</td>
<td>N = 2400</td>
</tr>
<tr>
<td>insura</td>
<td>Overall</td>
<td>0.094</td>
<td>0.043</td>
<td>0.000</td>
<td>1.000</td>
<td>N = 2400</td>
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<td>stva</td>
<td>Overall</td>
<td>0.418</td>
<td>0.938</td>
<td>0.018</td>
<td>10.833</td>
<td>N = 2400</td>
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<tr>
<td>Inturov</td>
<td>Overall</td>
<td>6.348</td>
<td>0.814</td>
<td>3.918</td>
<td>8.741</td>
<td>N = 2400</td>
</tr>
<tr>
<td>fdi</td>
<td>Overall</td>
<td>0.011</td>
<td>0.011</td>
<td>0.000</td>
<td>0.069</td>
<td>N = 2400</td>
</tr>
</tbody>
</table>

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