The Effect of Financial Development on Energy Intensity in China

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ABSTRACT

In this study, we analyse the relationship between financial development and energy intensity in 28 Chinese provinces over the period 1999 to 2014. Using a wide variety of financial development measures, as well as specific indicators capturing the level of state intervention in the financial system and the degree of market-driven financing in the economy, we examine whether limited access to finance acts as a barrier to reducing energy intensity. Our estimations control for variables such as state investment, stock market capitalization and the composition effect. Further, a GMM estimator is used to control for endogeneity in our models. Our results provide evidence that a poorly functioning financial system constrains the reduction of energy intensity across regions. However, the strength of these effects has been gradually declining over time, especially following the implementation of the Green Credit Policy. Limitations in domestic access to finance as well as the misallocation of funds and the efficient use of capital have policy implications, as they can reduce the incentives for investment in the energy sector. These findings are a source of considerable interest in light of the new policy based on green credit, and they highlight new opportunities as well as challenges to sustainable economic growth.

Key words: Energy intensity; financial development; Chinese regions; Green Credit Policy.

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1. INTRODUCTION

The upsurge in energy demand fuelled by global economic growth has resulted in growing concern regarding the environmental impact of using fossil fuels, and the need to reduce emissions and protect the environment. Along with these environmental concerns, there is an increasing awareness that universal access to sustainable energy plays an essential role in promoting economic development, protecting ecosystems and reducing inequality. In September 2011, the United Nations launched its Sustainable Energy for All (SE4All) initiative, which aimed to make universal access to sustainable energy a reality in 2030. The initiative has three interlinked objectives: to provide universal access to modern energy, to double the share of renewable energy in the global energy mix, and to double the global rate of improvement in energy efficiency. Although advanced economies have generally achieved a low level of energy intensity, for the majority of developing countries using energy more efficiently is a challenge. The international community soon recognized that these objectives would require large amounts of investment, especially from the private sector, and that the development of the financial system would therefore be critical to meeting these targets (Mathews et al., 2010).

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Among developing countries, China is an interesting case. It is the most populated country in the world and has experienced rapid economic growth, coupled with intense energy consumption. During the 1960s and 1970s, China accounted on average for 4.5 per cent of the world's total primary energy consumption. In the 1980s and 1990s, this share increased to 8.4 per cent. In the 2000s, primary energy consumption in China rose rapidly to an average of 15.7 per cent (Ghoshray and Ordóñez, 2014), fuelling the Chinese energy-intensive growth path. Policy makers in China have recognized the importance of reducing energy intensity; the 11th and 12th Five-Year Plans set targets for a 20% and 16% reduction in energy intensity, respectively. Achieving these targets is not straightforward since they require large investment projects that need to be financed. The poor state of development of the Chinese financial sector (Guariglia and Poncet, 2008) may constrain investment and hinder the achievement of the energy intensity targets. Thus, an obvious question arises: Can access to finance reduce energy intensity in China? This question is not only relevant but also timely. In July 2007, the China Banking Regulatory Commission (CBRC), the Ministry of Environmental Protection (MEP) and the People's Bank of China (PBOC) jointly launched the Green Credit Policy with the aim of directing credit away from highly polluting or energy-intensive firms and projects, towards environmentally-friendly or energy-saving firms and projects. Against this backdrop, banking institutions are encouraged to promote green credit as a strategy for optimizing the allocation of capital investment and thus transforming the Chinese growth model into a more sustainable and less energy-intensive one.

Existing research has examined the relationship between finance and growth in the Chinese economy (Guariglia and Poncet, 2008); however, to the best of our knowledge this is the first paper that analyse sthe effect of financial development on energy intensity in China. Previous papers, such as Wu (2012), document the declining trend in China's energy intensity over the past decades, finding that the main driving force behind this change is—to a much greater extent than structural changes in the economy—the improvement in energy efficiency. In addition, Yuxiang and Chen (2010) find a positive link between government expenditure and energy intensity, and this relationship is much stronger during the Asian financial crisis than after the economic recovery. Our contribution is two-fold. First, we investigate how financial development can help to improve energy intensity, using a wide selection of financial development indicators; we consider not only those most commonly-used in the relevant literature but also those that might capture the degree of government intervention and the transition to a more market-oriented economy. Unlike Guariglia and Poncet (2008), we also introduce into the analysis loans from the industrial sector, as this industry consumes 70% of total energy. Second, we use provincial-level data to capture the geographic dimension of the analysis. The distribution of energy resources, the concentration of firms and urban populations, as well as the process of economic development itself, all have a significant geographic component.

After controlling for other determinants, our results suggest that the poor state of development of the Chinese financial system can limit incentives to reduce energy intensity. Considering the whole sample, our results suggest that investments financed by self-raised funds is the only variable leading to a reduction in energy intensity. However, as the Chinese financial system has been subject to continuous reforms in recent years, we allow the parameters on financial development to change before and after the entry into force of the Green Credit Policy. By doing so, we obtain evidence that the Green Credit Policy has contributed to a change in the pattern of investment funding and access to finance. More specifically, our estimates suggest that following the introduction of the Green Credit Policy, the size of the banking sector, the misallocation of funds and the efficient use of capital all help to improve energy efficiency. Despite general agreement that the financial sector in China still needs further reforms, especially related to the participation of foreign enterprises and investors,

our results are positive. There are promising signs that the financial sector has developed enough to play a role in China's transition towards a low-carbon economy. More generally, the results also give reason to be confident about the Chinese government achieving its recently-announced objectives to further raise the level of power generation from green energy technologies.

The rest of this paper is organized as follows. Section 2 provides an overview of the relationship between economic development, energy intensity and access to finance. Section 3 covers data and methodological issues. In section 4, we report the empirical results. Conclusions are drawn and discussed in Section 5.

2. LITERATURE REVIEW

Energy intensity is commonly defined as the ratio of energy consumption to income, generally measured by gross domestic product (GDP). The relationship linking these two variables has been widely studied in the empirical literature, but without a clear consensus on the direction of the relationship. The theoretical literature does not help to solve the question of the nature of the possible causal link between energy consumption and income (and growth). According to ecological economic theory, the scarcity of energy resources can limit growth; therefore, there should at least be a causal effect from energy consumption to income. In contrast, neoclassical growth theory states that energy resources are not essential inputs for growth, arguing that technological progress and substitution possibilities may serve to circumvent scarcity problems.

One of the most common criticisms directed at the studies on the link between energy consumption and growth is the use of a bivariate framework, which means that possible causal channels between these two variables are neglected (Bartleet and Gounder, 2010).This critique has led authors to use a variety of control variables when analysing the causal link between energy consumption and growth. However, these control variables have been selected on a rather ad hoc basis, according to the subjective rationale of the authors (Camarero, et al., 2015).

Among the set of control variables used to model the energy consumption-income nexus, the financial variables merit special interest, and in particular, the degree of financial development and access to finance (Karanfil, 2009). Financial variables are key to understanding this nexus since they can affect both energy consumption and growth. Since the seminal work by Schumpeter (1911), a large body of empirical literature has highlighted the influence of a well-developed financial system in the process of economic growth (Levine, 2005). Financial development improves the economic efficiency of a country's financial system, promoting foreign direct investment (FDI) as well as banking and stock market activity and, consequently, reducing adverse selection, financial risk and borrowing costs and increasing transparency and access to finance. As argued above, financial development can also affect energy consumption. According to Sadorsky (2010), financial development can negatively affect energy demand in that it can facilitate access to the latest energy-efficient products and cutting-edge technology; however, it can also positively affect demand by increasing business fixed investment and consumption of durable goods. Moreover, financial development can facilitate access to financing for housing purchases and thus accelerate the urbanization process, which in turn can affect the patterns of energy consumption (Herrerias et al., 2016).

Furuoka (2015) surveys the literature and finds that the empirical work on the finance-energy nexus is inconclusive: whereas some studies find a positive causal relation between financial development and energy consumption, others find a negative link. The analysis by Sadorsky (2010) is among those that conclude in favour of a positive relationship between these two variables. Using a dynamic panel model for 22 emerging economies over the period 1990–2006, this author finds that financial development increases energy consumption. Similar results are reported in Shahbaz and

Lean (2012), indicating that a developed financial system tends to increase energy consumption as it encourages industrialization and urbanization processes. In another study, Omri and Kahouli (2014) apply a dynamic panel method to 65 countries over the period 1990–2011 and also find a positive causal relationship between financial development and energy consumption. Conversely, Islam et al. (2013) argue that financial development can reduce energy usage due to more energy-efficient technologies. Furthermore, there are studies that find bi-directional causality between financial development and energy consumption (Al-Mulali and Sab, 2012a, and Khan et al., 2014), unidirectional causality from energy consumption to financial development (Furuoka, 2015), and even no causal relationship at all (Al-Mulali and Sab, 2012b).

As financial development may affect both economic growth and energy consumption, it might potentially have an impact on energy intensity. The effect of financial development on energy intensity is however unknown a priori. On the one hand, as stated above, financial development positively affects energy use through industrial growth, urbanization and new infrastructure, and can lead to higher energy intensity (Sadorsky, 2010; Shahbaz et al. 2013a). On the other hand, the financial sector encourages investment opportunities involving embodied technological progress in the energy sector, leading to an improvement in energy intensity (Herrerias and Orts, 2012). Financial institutions can offer a lower interest rate on certain loans, allocating them to the most productive energy-investment projects, monitoring their performance and diversifying the risk (Levine, 2005; Shahbaz et al., 2013b). Moreover, it is well documented in the empirical literature that a well-developed financial sector attracts FDI, which is a source of knowledge transfer from developed to developing countries and can enhance the use of green technology and competitiveness (Frankel and Romer, 1999; Sadorsky, 2010).

Surprisingly, the relationship between financial development and energy intensity remains almost entirely unexplored in the empirical literature. A notable exception is the work by Mielnik and Goldemberg (2002). These authors examine the relationship between the share of FDI in gross domestic investment and energy intensity in 20 developing countries between 1987 and 1998, finding a negative relationship between financial development and energy intensity. However, as Zhang et al. (2016) point out, previous literature has generally tried to explain the determinants of energy intensity by considering factors other than financial development; these include economic indicators (such as real GDP, unemployment and the capital-to-labour ratio), energy and environment factors, demographic factors, industrial characteristics, openness indicators and transportation factors. The effect of financial variables on energy intensity has been largely ignored in the literature.

To sum up, as financial development can influence economic growth and energy consumption, it may potentially have an effect on energy intensity. However, the net effect would depend on what the main driving force is in such processes: innovation and technological progress or economic development.

3. DATA AND METHODOLOGY

3.1 Data description

To test the effect of access to finance on total energy intensity (TOTALEI),[1] we use a wide variety of financial indicators to capture the size of the banking sector, the efficient use of capital and the misallocation of funds, for 28 Chinese regions (provinces) from 1999 to 2014.

1. Energy intensity understood as the ratio of energy consumption (10,000 tce) to GDP (100 million yuan in 1978 real terms) is the standard indicator used to set targets in energy policy.

In line with Guariglia and Poncet (2008), we use three different sets of indicators to measure financial development (FINDEV) in China. Using a variety of indicators allows us to consider not only the size of the banking sector but also the quality of financial intermediation. First, we evaluate financial depth by means of (1) the ratio of total loans to GDP (TLOANSG) as a proxy for the size of the banking sector, and (2) loans to industrial enterprises as a percentage of GDP (LOANSINDG). Second, we use two indicators to capture the misallocation of funds due to state intervention in the financial system:(1) the ratio of total loans to total deposits (RTLOANDEP) and (2) the ratio of industrial enterprise loans to industrial enterprise deposits (RILOANDEP).[2] Both financial depth and misallocation of funds indicators come from *China Data Online*.

To capture the efficient use of capital in a context of widespread misallocation, we consider three indicators that represent three different types of investment categorized according to the source of funds: (1) the ratio of fixed asset investment financed by domestic loans to that financed by state budgetary appropriation (FADOMSTA), (2) the ratio of fixed asset investment financed by foreign funds to that financed by state budgetary appropriation (FAFORSTA) and (3) share of fixed asset investments financed by self-raised funds (FASELFTOT).According to Guariglia and Poncet (2008),self-raised funds tighten firms' budget constraints and are considered a more efficient means of resource distribution than state budget allocation.

In addition to our key variables of interest, we introduce several important control variables into our models. First, we control for the composition effect with the share of industrial output in GDP (INDUSTRYG). Second, we proxy the presence of the state sector in the financial system using the ratio of state investment to GDP (STINVG). Finally, we introduce the value of Chinese Stock Market Capitalization[3] as a percentage of GDP (STOCKM), collected at national level. All control variables and variables relating to the efficient use of capital come from the *National Bureau of Statistics of China*.

The summary statistics of our variables are reported in Table 1. The second column reports all province-year observations for the entire sample, while the third and fourth columns contain observations before (1999–2007) and after (2008–2014) the Green Credit Policy implementation, respectively.[4] Comparing the two sub-periods reveals that the impressive decrease in energy inten-

2. As the large state-owned banks dominate the Chinese banking sector (Guariglia and Poncet, 2008), the volume of deposits is determined by economic activity, and the volume of lending in each region depends on policy objectives (Lardy, 1998).

3. We would like to thank an anonymous referee for the suggestion to account for capital market effects. We acknowledge there are various ways to capture capital market effects. The use of market capitalization represents a proxy measure of capital availability, changes in which reflect both the scale of and confidence in the capital market, and implicitly encompass features such as market liquidity.

4. The split of our sample, closely aligned with the timing of the Global Financial Crisis (GFC), raises the question of whether our results might possibly be caused by spillover effects of the GFC. Despite this concern, existing literature has generally favoured the decoupling hypothesis, meaning that China is somewhat insulated from external shocks (Herrerías and Ordóñez, 2014). China did not invest heavily in securities linked to the US real estate market and, as a consequence, proved to be largely immune to the wealth and capital flows driven by the GFC. Although China's controls over foreign banks and international capital flows have been reduced, they are still effective enough to strongly limit international financial flows and the country's exposure to international financial instability (Li, et al., 2012). In March 2008, total assets of foreign-funded banks accounted for only 2.4% of total bank assets. China has very low levels of liberalization of its domestic financial market, and financial innovations such as Mortgage-Backed Securities (MBS) and Collateralized Debt Obligations (CDO) are almost non-existent. Furthermore, the effects of the GFC on China's net FDI position was temporary at most. Data from the World Bank Development Indicators on China's net FDI shows that from 2008 to 2009 FDI decreased by 42%, however, within a year FDI had returned to its pre-crisis levels.

Table 1: Descriptive Statistics

	All Sample 1999-2014	Before GCP 1999-2007	After GCP 2008-2014
Total Energy Intensity	5.690	6.195	4.986
	(3.244)	(3.279)	(3.067)
State Investment/GDP	0.191	0.182	0.203
	(0.084)	(0.072)	(0.098)
Share Industry/GDP	0.394	0.384	0.409
	(0.076)	(0.072)	(0.080)
Stock Market Capitalization/GDP	0.418	0.355	0.505
	(0.152)	(0.162)	(0.076)
Financial depth			
Total Loans/GDP	1.047	1.029	1.073
	(0.326)	(0.301)	(0.357)
Loans Industrial/GDP	0.146	0.157	0.097
	(0.066)	(0.064)	(0.052)
Efficient use of capital			
Fixed Assets domestic to FA state	5.180	5.913	4.606
	(5.597)	(5.654)	(5.499)
FA foreign to FA state	0.918	1.444	0.506
	(1.853)	(2.460)	(1.009)
FA self-raised to FA total	0.608	0.576	0.632
	(0.115)	(0.098)	(0.121)
Misallocation of funds			
Ratio total Loans/Total deposits	0.754	0.791	0.701
	(0.137)	(0.136)	(0.119)
Ratio Ind.Ent.Loans/Ind.Ent.Dep.	0.380	0.415	0.228
	(0.198)	(0.197)	(0.112)
Observations	431	251	180

Notes: Province-year observations. Table reports mean and standard errors (in parentheses). Industrial loans to GDP and industrial loans to industrial deposits are collected for 1999-2009, with the 1999-2014 sample restricted to 309 observations and the 2008-2011 subsample to 58 observations. The efficient use of capital indicators are collected for 2003-2014 due to methodological changes. Hence, the 1999-2014 sample is restricted to 316 observations and the1999-2007 subsample to 141 observations.

sity (19.5% on average)was accompanied by an increase in the share of industry (6.1%) and state investment (11.5%), with a particularly notable surge in stock market capitalization (42.3%).

With regard to the variables of interest, the financial depth indicators show a decreasing trend between the two periods of time. Total loans over GDP (TLOANSG) increased slightly (4.3%) but, in sharp contrast, industrial loans over GDP (LOANSINDG) decreased by 38.2%. This change in the composition of total loans may have had a significant effect on energy intensity. The misallocation of funds indicators both show a similar decreasing pattern when comparing total loans over total deposits (–11.4%) and industrial enterprise loans over industrial enterprise deposits (–45.1%). The financial indicators capturing the efficient use of capital show mixed trends: FADOMSTA and FAFORSTA decreased by 22.1% and 65.0% respectively, whereas FASELFTOT increased by 9.8%. These changes imply that self-funding has played an increasingly important role in investment in China.

Table 2 presents the correlation matrix of our variables. The numbers in this table confirm the negative correlation between energy intensity and the other controls, except for the ratio of state investment to GDP variable, which shows a clear positive correlation. With respect to the financial depth indicators, total loans and industrial loans both show a positive correlation with energy intensity. Regarding the efficient use of capital, the ratio of fixed asset investment financed by domestic loans to that financed by state budgetary appropriation, and the ratio of fixed asset investment fi-

Table 2: Correlation Matrix

	TOTALEI	STINVG	INDUSTRYG	STOCKM	TLOANSG	LOANSINDG	FADOMSTA	FAFORSTA	FASELFTOT	RILOANDEP	RTLOANDEP
TOTALEI	1.0000										
STINVG	0.5849	1.0000									
INDUSTRYG	–0.0701	–0.2728	1.0000								
STOCKM	–0.0850	0.0027	0.1004	1.0000							
TLOANSG	0.0503	0.0590	–0.3538	–0.1288	1.0000						
LOANSINDG	0.0800	–0.1145	0.0259	–0.2305	0.6033	1.0000					
INVDLOAN	–0.3991	–0.4491	0.1939	–0.0417	0.4417	0.2163	1.0000				
FUNDFOREIGN	–0.4067	–0.4683	0.3844	–0.0891	0.0883	0.1100	0.7260	1.0000			
INVSELF	0.0094	–0.0678	0.5347	0.1660	–0.7439	–0.3527	–0.3597	–0.1389	1.0000		
RILOANDEP	0.1828	–0.1277	0.2366	–0.2605	–0.2743	0.4696	–0.2560	–0.1193	0.3658	1.0000	
RTLOANDEP	0.3531	0.2231	0.0087	–0.2221	0.1008	0.4359	–0.1001	–0.0581	–0.0132	0.6093	1.0000

nanced by foreign funds to that financed by state budgetary appropriation both show a clear negative correlation with energy intensity, while no correlation is observed for the share of fixed asset investments financed by self-raised funds indicator. Finally, the indicators measuring the misallocation of funds are both positively correlated with energy intensity.

3.2 Methodology

The aim of this paper is to estimate the effect that access to finance, as measured by the financial indicators defined above, has on energy demand and ultimately energy efficiency. For this purpose, we use the following empirical specification:

$$Y_{it} = \alpha Y_{it-1} + \beta' X_{it} + \gamma_1 FINDEV_{it} + \delta_i + \epsilon_{it} \quad (1)$$

where Y refers to energy intensity; X represents the set of controls used in all the specifications; FINDEV stands for one of our seven indicators used to capture financial development in China; and δ_i and ϵ_{it} are provincial effects and the residuals, respectively.[5] Due to the potential endogeneity among some of the variables included in this specification, we use a generalized method of moments (GMM)[6] estimation framework. A lagged dependent variable is included "*…to control the habitual inertia or adjustment cost of energy use…*" (Yuxiang and Chen, 2010), which, together with the presence of provincial fixed effects, leads us to use the GMM first-difference estimator developed by Arellano and Bond (1991). The use of a first-difference transformation of equation (1) eliminates the provincial fixed effects from the equation to be estimated:

$$\Delta Y_{it} = \alpha \Delta Y_{it-1} + \beta' \Delta X_{it} + \gamma_1 \Delta FINDEV_{it} + \Delta \epsilon_{it} \quad (2)$$

where Δ denotes the first-difference operator. The validity of our instruments is tested with the Arellano-Bond first- and second-order autocorrelation tests and the overidentifying restrictions test proposed by Hansen (1982).

4. RESULTS

4.1 Baseline model

Table 3 shows the GMM estimates for the model given in Equation (1). Among other factors, we control for the lag of energy intensity, as well as state investment, industry and stock market capitalization measured as a share of GDP. We can observe in Table 3 (columns 2–8) that, in all cases, the lag of the dependent variable—energy intensity—is significant with a positive sign. Similar to Herrerias et al. (2013), we find that state investment plays an important role in the energy sector in China, leading to improvements in energy efficiency. This result can be explained by a high degree of government participation in the energy sector. In addition, our estimates show that the composition effect measured by the share of industry in GDP is not significant in any of the estimated

5. We have excluded time dummies from the model specification as the variables considered show a trend, and we allow that the variable itself may account for the variation over time.

6. We could not employ the external instruments typically used in the literature, such as legal origin, as Chinese provinces share a common legal system and similar institutions (Guariglia and Poncet, 2008).

Table 3: Energy Intensity and Financial Development. Difference-GMM

	Financial depth		Efficient use of capital			Misallocation of funds	
Dependent variable:	(1)	(2)	(1)	(2)	(3)	(1)	(2)
Total Energy Intensity t	Loans / GDP	Ind.Loans / GDP	FA domestic / FA state	FA foreign / FA state	FA self-raised / FA total	Ind.loans / Ind.depos.	Total.loans / Tot.depos.
Total Energy Intensity t–1	0.640***	0.486***	0.805***	0.934***	0.632***	0.644***	0.687***
	(0.070)	(0.079)	(0.135)	(0.093)	(0.105)	(0.098)	(0.095)
State Investment / GDP	–4.078	–4.895**	–5.345**	–4.149***	–6.639**	–2.893	–6.460**
	(2.884)	(2.238)	(2.424)	(1.421)	(2.636)	(2.116)	(3.047)
Share Industry/GDP	–3.483	–0.787	–6.497	–3.182	–0.199	–3.287	–0.804
	(2.595)	(2.518)	(5.513)	(4.045)	(2.817)	(3.180)	(2.412)
Stock market Cap. / GDP	–0.717	–0.872***	–0.182	–0.039	–0.209	–0.807***	–0.068
	(0.480)	(0.239)	(0.244)	(0.163)	(0.194)	(0.252)	(0.485)
FINDEV	–0.728	1.334	0.080	0.049	–4.465***	–0.561	–0.001
	(0.884)	(1.417)	(0.049)	(0.038)	(1.172)	(0.599)	(0.919)
AR(1) test	–1.69	–1.82	–2.44	–2.11	–1.73	–1.62	–1.83
	[0.092]	[0.068]	[0.015]	[0.035]	[0.083]	[0.106]	[0.067]
AR(2) test	–0.34	–0.03	–1.47	–1.85	–0.07	–0.35	–0.38
	[0.738]	[0.975]	[0.142]	[0.064]	[0.947]	[0.723]	[0.701]
Hansen test	24.29	24.27	24.68	25.69	22.29	26.89	25.52
	[0.279]	[0.280]	[0.261]	[0.219]	[0.383]	[0.174]	[0.225]
Observations	431	309	316	316	316	309	431
Number of provinces	29	29	29	29	29	29	29

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. AR(1) and AR(2) denote Arellano and Bond first- and second-order autocorrelation tests. The Hansen test is a test of overidentifying restrictions where the null hypothesis is that the instruments are valid, i.e., uncorrelated with the error term. The *p*-values of the above tests are shown in brackets.

models once we control for the financial indicators considered in this paper. Finally, our results also suggest that stock market capitalization seems to play a role (Table 3, columns 3 and 7) in improving energy efficiency, but we do not consider this an entirely robust finding since it is insignificant in several other model specifications.[7]In preliminary work we included several other potential control variables into the model, such as the urbanization rate, however the estimates showed they were not significant in any case and they were therefore removed from the final model.

With respect to our variables of interest, the financial development indicators, our findings suggest that the size of the banking sector (measured by total loans and industrial loans as a percentage of GDP) is not statistically significant in our models. Later, however, we will see that that the nature of this effect varies over time (specifically pre- versus post-Green Credit Policy implementation), thus supporting our claim that, for the future development of the energy sector in China, structural reforms in the financial sector should be more market oriented.

The variables that capture misallocation of funds have no effect on energy intensity, meaning that they do not play a role in reducing energy efficiency. Once again, these effects do become statistically significant once the time variation is allowed in the parameters. These results are somewhat consistent with those of Guariglia and Poncet (2008), who found that misallocation of funds has a negative effect on growth, and in line with Rojas-Suárez and Weisbrod (1995), who argued that the small, poorly-developed financial sector in developing countries is a barrier to improving environmental quality. These results also tie in with the additional finding in Guariglia and Poncet (2008)

7. We would like to extend our thanks to an anonymous referee for the suggestion to add information relating to the scale of the financial market into our empirical model.

that state-owned banks may channel capital preferentially to inefficient state-owned enterprises to avoid creating unemployment through bankruptcies. Intuitively, this suggests that GDP growth and energy efficiency are not the only criteria used by financial institutions in making credit allocation decisions.

Columns 4–6 in Table 3 show that the indicators which capture the effects of more market-oriented and profit-oriented financial transactions (the efficient use of capital indicators) generally do not contribute to an improvement energy intensity, despite the fact that, as shown by Guariglia and Poncet (2008), they promote GDP growth. According to our estimates, only investments financed using self-raised funds have a beneficial effect on energy efficiency. None of the remaining indicators considered in this work were statistically significant, therefore indicating that there is much room for improvement with respect to access to finance and its effects on energy intensity.[8]

4.2 Evolution over time

As pointed out in the introduction of this paper, Chinese government concerns over energy security and environmental issues led to the launch of the Green Credit Policy in 2007. As a consequence, we would expect to see a strengthening of the effect that the financial development indicators have on energy intensity following the implementation of the policy. We may expect effects on a different scale for the financial development indicators relating to loans made by Chinese banks (namely, financial depth, misallocation of funds and investment financed by domestic loans over total fixed assets). Further, we may also expect some indirect effects of the other two indicators (investment financed by foreign funds and through self-funding).

In this section, we therefore investigate whether the relationship between the financial development indicators and energy intensity changes over time as a consequence of the introduction of the Green Credit Policy. For this purpose, we estimate the following equation:

$$Y_{it} = \alpha Y_{it-1} + \beta' X_{it} + \gamma_1 FINDEV_{it} + \gamma_2 FINDEV_{it} * LATE_t + \delta_i + \epsilon_{it} \tag{3}$$

where $LATE_t$ is a dummy that takes the value 1 when the observation pertains to the period from 2008 to 2014, and 0 otherwise.[9] This variable is interacted with the financial development indicators in order to check for differences in the role that these indicators play before and after implementation of the Green Credit Policy. This alternative specification allows us to distinguish between the effect that the financial development indicators had on energy intensity before (γ_1) and after ($\gamma_1 + \gamma_2$) that policy was adopted, and thus provides an indication of its effectiveness. Results are reported in Table 4. In what follows, we focus on the financial development indicators, as the set of control variables present similar results to the baseline case.

The γ_1 estimates for the indicators capturing the size of the banking sector—total loans and industrial loans both over GDP—are not statistically significant (Table 4), however, the estimated γ_2 coefficients are statistically significant in both cases, with a negative sign. They thus make a positive contribution to improvements in energy efficiency as a consequence of the introduction of the Green Credit Policy.

Differences from the baseline scenario emerge with the other two sets of financial indicators considered in this paper, namely, the efficient use of capital and the misallocation of funds, which

8. We introduced an alternative definition of these efficient use indicators by keeping the numerators and dividing them by the regional GDP. Signs and significance of the resulting new measures remained the same.

9. Our results were generally robust to setting the $LATE_t$ equal to 1 from 2007 to 2014.

Table 4: Energy Intensity and Financial Development, Evolution over time. Difference-GMM

	Financial depth		Efficient use of capital			Misallocation of funds	
Dependent variable:	(1)	(2)	(1)	(2)	(3)	(1)	(2)
Total Energy Intensity t	Loans / GDP	Ind.Loans / GDP	FA domestic / FA state	FA foreign / FA state	FA self-raised / FA total	Ind.loans / Ind.depos.	Total.loans / Tot.depos.
Total Energy Intensity t –1	0.580***	0.426***	0.919***	0.898***	0.739***	0.463***	0.550***
	(0.063)	(0.085)	(0.109)	(0.107)	(0.095)	(0.108)	(0.091)
State Investment / GDP	–3.199	–3.093	–4.875**	–4.996***	–5.452*	–1.199	–3.157
	(2.373)	(1.828)	(2.022)	(2.109)	(2.725)	(1.792)	(2.168)
Share Industry/GDP	0.323	0.652	–3.056	–4.024	–1.160	1.303	1.723
	(1.850)	(2.307)	(4.234)	(4.971)	(2.949)	(2.967)	(2.505)
Stock market Cap. / GDP	–0.223	–0.625**	–0.240	–0.228	–0.227	–0.566**	–0.118
	(0.425)	(0.231)	(0.183)	(0.225)	(0.144)	(0.244)	(0.249)
FINDEV	0.106	1.118	0.032	0.071	–3.588***	0.031	0.047
	(0.885)	(1.449)	(0.022)	(0.060)	(1.061)	(0.503)	(0.793)
FINDEV * LATE	–0.416***	–3.110***	–0.001	0.110	–0.026	–1.686***	–0.811***
	(0.105)	(0.916)	(0.011)	(0.108)	(0.175)	(0.392)	(0.135)
AR(1) test	–1.66	–1.73	–2.76	–3.03	–2.50	–1.62	–1.96
	[0.096]	[0.084]	[0.006]	[0.002]	[0.012]	[0.105]	[0.050]
AR(2) test	–0.41	–0.37	–1.64	–1.52	–0.99	–0.63	–0.59
	[0.681]	[0.709]	[0.101]	[0.127]	[0.320]	[0.532]	[0.554]
Hansen test	26.89	25.41	27.11	26.03	26.32	25.17	25.27
	[0.261]	[0.148]	[0.251]	[0.300]	[0.286]	[0.155]	[0.337]
Observations	431	309	316	316	316	309	431
Number of provinces	29	29	29	29	29	29	29

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. AR(1) and AR(2) denote Arellano and Bond first- and second-order autocorrelation tests. The Hansen test is a test of overidentifying restrictions where the null hypothesis is that the instruments are valid, i.e., uncorrelated with the error term. The *p*-values of the above tests are shown in brackets.

prove to be statistically significant once we allow for a time change in the parameters. These findings suggest that, despite the fact that there is still much room for improvement in the Chinese financial system, the reforms undertaken as part of the Green Credit Policy are starting to have a positive effect on energy efficiency. Taken together, the results in Tables (3) and (4) would seem to suggest that increasing efficiency in the use of capital and avoiding misallocations of funds should be prioritized in future policy reforms.

Probably one of the most important challenges faced in both the energy and financial sectors in China concerns the role played by multinationals. Their presence is still relatively small when compared against other sectors in the economy, and our results indicate that the investments financed by foreign companies still do not have any significant impact on energy intensity. This result in itself raises the need for further policy action since investments made by foreign companies are often directed towards more advanced, environmentally-friendly production technologies. Empirical experience further supports the idea that increased foreign investment could play a critical role in supporting recently-announced Chinese government objectives to achieve a rapid transition to a low-carbon economy, with particular emphasis on the increased use of green power technologies.

Summing up, our results suggest that the Green Credit Policy has been relatively successful in terms of improving the allocation of loans to less energy-intensive activities. This fact leads us to believe that the Chinese financial sector is helping to develop a less energy-intensive economic growth model. However, while these are positive findings, the sensitivity of some of the results in the estimated models serves as a reminder that there is still much room for improvement.

5. CONCLUSIONS

In this paper, we question whether limited access to finance acts as a barrier to reducing energy intensity. To test the link between financial development and energy intensity we use several indicators which capture the level of state intervention in the economy as well as the degree of market-driven financing in the economy. The analysis is carried out at regional level for the period 1999 to 2014. Our research question is not only relevant but timely, as there is now empirical evidence to test the effectiveness of the Green Credit Policy, which was implemented in mid–2007. This initiative aims to redirect credit away from highly polluting or energy-intensive firms or projects, towards environmentally-friendly or energy-saving firms and projects. To the best of our knowledge, our paper is the first in the empirical literature that investigates this aspect, and thus provides novel insights into the design and implementation of energy policy in the Chinese economy.

According to our results, the effect of financial development and access to finance has had a major impact on energy intensity since the introduction of the Green Credit Policy by the Chinese government in 2007. The relatively poorer state of development of the Chinese financial system prior to this policy implementation appeared to limit the incentives to reduce energy intensity. This is reflected by the financial development coefficients either being not significant or showing a positive sign in a number of the estimated models. During the sample period, the Chinese financial sector as a whole underwent notable changes; however, the resulting benefits to energy efficiency mostly appear after 2007, consistent with the implementation of the Green Credit Policy. Our findings suggest that the size of the banking sector and the misallocation of funds have been the most influential factors in energy efficiency improvements. Though the evidence is not overwhelmingly conclusive, the model results imply that improvements in the efficient use of capital have been beneficial in terms of energy efficiency levels. This is particularly noteworthy in the context of China, where state-ownership is not uncommon, and given that it is generally understood that state-ownership—whether in China or elsewhere—tends to coincide with less than efficient use of capital. This is evidenced by the consistent significance and negative sign of state investment in our estimated models. Finally, in some cases, we observe that stock market capitalization is also a significant factor.

The majority of our results appear to support the conclusion that the Green Credit Policy has made a positive contribution to the improvement in energy efficiency. These benefits emerge through several different mechanisms intended to reallocate the funds in the financial sector towards 'greener' firms and projects. However, the state sector plays a noteworthy and interesting role as a driver of energy efficiency improvements. This investment coincides with a limited presence of foreign multinationals, but this reduced presence does not outweigh the benefits of increased state investment aimed at encouraging changes in energy efficiency. The future development of policies aimed at using advanced/mature financial systems to promote energy efficiency improvements in China should be multi-dimensional. First, there is a need to conclude the reforms in the financial sector, allowing a more market-oriented allocation of funds; and second, there seems to be some merit in continuing to promote the entry of foreign companies, as they can contribute new technologies and working practices, thus helping to further reduce energy intensity. The topics addressed in this paper will continue to attract a lot of attention in the coming years, with an ambitious and well-resourced Chinese government committed to promoting low-carbon economic development. Of growing interest are the different initiatives in place for the development of the renewable energy sector, to change the current energy mix. As these alternative energy power technologies have significant entry barriers and costs, access to finance would be a necessary and sufficient condition to achieve that goal. Future research might look to extend our analysis here by examining the effects of interfuel substitution, especially relating to the adoption of renewable energies.

In summary, we find that policies aimed at improving the efficiency of the financial system can have a positive effect on energy intensity levels, through a more careful allocation of funds towards investment projects in the energy sector. The Green Credit Policy, implemented as part of the 12th Five-Year Plan, has seemingly proved fit-for-purpose in promoting the structural transformation of the Chinese economy while managing the pressure of increasing energy consumption.

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REFERENCES

Al-Mulali U, Sab CNC (2012a). "The impact of energy consumption and CO_2 emission on the economic growth and financial development in the Sub Saharan African countries." *Energy* 39: 180–186. https://doi.org/10.1016/j.energy.2012.01.032.

Al-Mulali U, Sab CNC (2012b). "The impact of energy consumption and CO_2 emission on the economic and financial development in 19 selected countries." *Renewable Sustain Energy Reviews* 16: 4365–4369. https://doi.org/10.1016/j.rser.2012.05.017.

Arellano, M. and S. Bond (1991). "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations." *Review of Economic Studies* 58: 277–297. https://doi.org/10.2307/2297968.

Bartleet, M. and R. Gounder (2010). "Energy consumption and economic growth in New Zealand: results of trivariate and multivariate models." *Energy Policy* 38: 3505–3517. https://doi.org/10.1016/j.enpol.2010.02.025.

Camarero, M., A. Forte, G. García-Donato, Y. Mendoza, and J. Ordóñez (2015). "Variable selection in the analysis of energy consumption-growth nexus." *Energy Economics* 52: 207–216. https://doi.org/10.1016/j.eneco.2015.10.012.

Frankel, J. and D. Romer (1999). "Does trade cause growth?" *American Economic Review* 89(3): 379–399. https://doi.org/10.1257/aer.89.3.379.

Furuoka, F. (2015). "Financial Development and Energy Consumption: Evidence from a Heterogeneous Panel of Asian Countries." *Renewable and Sustainable Energy Reviews* 52: 430–444. https://doi.org/10.1016/j.rser.2015.07.120.

Ghoshray, A. and J. Ordóñez (2014). "The Chinese Energy-Intensive Growth Model and its Impact on Commodity Markets." In *Energy Security and Sustainable Economic Growth in China*, 31–51. Palgrave Macmillan, United Kingdom.

Guariglia, A. and S. Poncet (2008). "Could financial distortions be no impediment to economic growth after all? Evidence from China." *Journal of Comparative Economics* 36: 633–657. https://doi.org/10.1016/j.jce.2007.12.003.

Hansen, L.P. (1982). "Large sample properties of generalized method of moments estimators." *Econometrica* 50: 1029–1054. https://doi.org/10.2307/1912775.

Herrerias, M.J. and V. Orts (2012). "Equipment investment, Output and Productivity in China." *Empirical Economics* 42: 181–207. https://doi.org/10.1007/s00181-010-0418-z.

Herrerias, M.J., A. Cuadros, and V. Orts (2013). "Energy Intensity and Investment ownership across Chinese Provinces." *Energy Economics* 36: 286–298. https://doi.org/10.1016/j.eneco.2012.08.043.

Herrerias, M.J. and J. Ordóñez (2014). "If the United States sneezes, does the world need 'pain-killers'?" *International Review of Economics and Finance* 31: 159–170. https://doi.org/10.1016/j.iref.2014.01.015.

Herrerias, M.J., A. Cuadros, and D. Luo (2016). "Foreign versus indigenous innovation and energy intensity: Further research across Chinese regions." *Applied Energy* 162: 1374–1384. https://doi.org/10.1016/j.apenergy.2015.01.042.

Islam, F., M. Shahbaz, and M. Alam (2013). "Financial development and energy consumption nexus in Malaysia: a multivariate time series analysis." *Economic Modelling* 30: 435–441. https://doi.org/10.1016/j.econmod.2012.09.033.

Karanfil, F. (2009). "How many times again will we examine the energy-income nexus using a limited range of traditional econometric tools?" *Energy Policy* 37(4): 1191–1194. https://doi.org/10.1016/j.enpol.2008.11.029.

Khan, M.A., M.Z. Khan, K. Zaman, D. Irfan, and H. Khatab (2014). "Questing the three key growth determinants: energy consumption, foreign direct investment and financial development in South Asia," *Renew Energy* 68: 203–15. https://doi.org/10.1016/j.renene.2014.02.021.

Lardy, N. (1998). *China's Unfinished Economic Revolution*. Brooking Institution Press.

Levine, R. (2005). "Finance and growth: Theory and evidence." Chapter 12. In *Handbook of Economic Growth*, P. Aghion and S. Durlauf (eds.),. Elsevier Science, The Netherlands. https://doi.org/10.1016/S1574-0684(05)01012-9.

Li, L., T.D. Willett, and N. Zhang (2012). "The Effects of the Global Financial Crisis on China's Financial Market and Macroeconomy." *Economics Research International* 1–6. https://doi.org/10.1155/2012/961694.

Mathews, J., S. Kidney, K. Mallon, and M. Hughes (2010). "Mobilizing private finance to drive an energy industrial revolution." *Energy Policy* 38: 3263–3265. https://doi.org/10.1016/j.enpol.2010.02.030.

Mielnik, O. and J. Goldemberg (2002). "Foreign direct investment and decoupling between energy and gross domestic product in developing countries." *Energy Policy* 30: 87–9. https://doi.org/10.1016/S0301-4215(01)00080-5.

Omri A. and B. Kahouli (2014). "Causal relationships between energy consumption, foreign direct investment and economic growth: fresh evidence from dynamic simultaneous-equations models." *Energy Policy* 67: 913–22. https://doi.org/10.1016/j.enpol.2013.11.067.

Rojas-Suarez, L. and S. Weisbrod (1995). "Financial fragilities in Latin America: the 1980s and 1990s." Occasional Paper 132. IMF. https://doi.org/10.2139/ssrn.2559972.

Sadorsky, P. (2010). "The impact of financial development on energy consumption in emerging economies." *Energy Policy* 38: 2528–2535. https://doi.org/10.1016/j.enpol.2009.12.048.

Shahbaz, M. and H. Lean (2012). "Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia." *Energy Policy* 40: 473–479. https://doi.org/10.1016/j.enpol.2011.10.050.

Shahbaz, M., S. Khan, and M.I. Tahir (2013a). "The dynamic links between energy consumption, economic growth, financial development and trade in China: fresh evidence from multivariate frame work analysis." *Energy Economics* 40: 8–21. https://doi.org/10.1016/j.eneco.2013.06.006.

Shahbaz, M., S.A. Solarin, H. Mahmood, and M. Arouri (2013b). "Does financial development reduce CO_2 emissions in Malaysian economy? A time series analysis." *Economic Modelling* 35: 145–152. https://doi.org/10.1016/j.econmod.2013.06.037.

Schumpeter, J.A., (1911). *The Theory of Economic Development*, Cambridge, MA: Harvard University Press.

Wu, Y. (2012). "Energy intensity and its determinants in China's regional economies." *Energy Policy* 41: 703–711. https://doi.org/10.1016/j.enpol.2011.11.034.

Yuxiang, K. and Z. Chen (2010). "Government expenditure and energy intensity in China." *Energy Policy* 38: 691–694. https://doi.org/10.1016/j.enpol.2009.10.031.

Zhang, D., H. Cao, and Y-M. Wei (2016). "Identifying the determinants of energy intensity in China: a Bayesian averaging approach." *Applied Energy* 168: 672–682. https://doi.org/10.1016/j.apenergy.2016.01.134.