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Energy intensity and foreign direct investment: A Chinese city-level study

Robert J.R. Elliott [a,*], Puyang Sun [b], Siyang Chen [c]

[a] University of Birmingham, UK
[b] Nankai University, China
[c] National University of Singapore, Singapore

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A B S T R A C T

In this paper we investigate the relationship between the energy intensity of Chinese cities and the location of foreign firms employing a unique dataset of 206 of the largest prefecture-level cities between 2005 and 2008. Our results reveal a non linear inverted-U shaped relationship between energy intensity and city-level per capita income with the majority of cities on the downward slope of the curve. We also find evidence of a significant and negative relationship between the foreign direct investment (FDI) flows into a city and energy intensity. However, this effect varies by geographic location reflecting differences in the ability of regions to absorb and benefit from environmental spillovers. The relatively small economic effect of FDI can in part explained by the propensity for foreign firms to invest in energy intensive sectors coupled with the trend for China to invest heavily in capital intensive industries.

1. Introduction

China has experienced rapid economic growth in the last two decades stimulated by significant capital inflows from abroad. China is now one of the largest recipients of foreign investment in the world with inflows of over $95 billion in 2010 (World Development Indicators, 2010). As China has grown so have its energy needs. From 2000 to 2008 China experienced a 70% increase in total energy consumption at 2.91 billion t of standard coal (Chinese National Bureau of Statistics, 2010) and currently accounts for 17.7% of global energy consumption even though it produces just 8% of global output (BP Statistical Review of World Energy, 2011). The first five months in 2011 saw China's imports of oil reaching 55% of consumption, up from 33% in 2009 (Ministry of Industry and Information Technology, 2011). A commonly held view is that China's dependence on imported oil leaves future growth vulnerable to fluctuations in global energy prices and could also be considered an energy security threat.

As a result, an important element of China's sustainable development strategy, as evidenced by the recent Eleventh- (2006–2010) and Twelfth- (2011–2015) Five Year Plans, is the management of energy demand and supply. Between 1978 and 2001, when economic growth in China averaged around 9% a year, the demand for energy rose by just 4% a year and energy intensity fell from nearly 400 t of coal equivalent per million RMB to a little over 100 t of coal equivalent per million RMB. However, after 2001 growth in energy demand began to outstrip GDP growth with an average growth rate of 14% a year (Rosen and Houser, 2007).[1]

Although China's average energy intensity fell between 1980 and 2010 there was a period between 2002 and 2005 when the falling trend was reversed before it again began to fall (albeit at a much slower rate than the period up to 2001). The relatively slow rate of progress on reducing China's energy intensity since 2001 is a concern to China's government given the importance now placed on sustainable development. The lack of progress on reducing energy intensity is despite rapidly increasing household incomes, continued foreign investment and a

* Corresponding author. Tel.: +44 0121 4147700.
E-mail address: r.j.elliott@bham.ac.uk (R.J.R. Elliott).

[1] The Twelfth-Five Year Plan states that energy consumption per 10,000 GDP should fall to 0.87 t of standard coal (at 2005 prices) by 2015 which is a decrease of 16% from the 1.03 t of standard coal consumed in 2010 and a decrease of 32% from the 1.28 t of standard coal consumed in 2005. These figures translate into energy savings of 670 million t of standard coal. In 2004 China introduced the "Outline of China's Medium and Long Term Energy Saving Plan 2004–2020" with a goal of energy intensity decreases of 20% for the 2006 Eleventh Five Year Plan. If China can hit its 2020 target of a 20% reduction in energy intensity during the Twelfth-Five Year Plan it would mean a quadrupling of the economy should be accompanied by a mere doubling of energy consumption (Chen, 2011).

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much greater awareness of the damaging effects of pollution on health and the natural environment.[2]

One explanation for the slowing rate of energy intensity improvement in the last decade is the increase in demand for automobiles and air conditioners. However, over the same period China experienced a relative shift in its industrial production patterns towards heavy and energy intensive industries such as cement, iron, and steel and aluminum. In 2007 China accounted for 35% of global steel production, 28% of aluminum production and 48% of global cement production (Rosen and Houser, 2007). Even accounting for a dramatic reduction in energy intensity from 1978 to 2001 China still lags behind the international average energy intensity levels for these industries. The World Bank estimates that Chinese steel, cement and ethylene firms use 20%, 45% and 70% more energy than the developed country averages respectively (New York Times, 2007).[3] Although certain industries experienced reductions in energy intensity, as a result of technological advances, innovation and the adoption of new technologies, it is the change in industrial composition that has kept China's aggregate energy intensity at such relatively high levels. An important negative externality from China's energy consumption is the environmental damage as a result of increases in the emissions of local and global pollutants. In 2008 China's emissions of sulfur dioxide (SO_2) and carbon dioxide (CO_2) were the highest and second highest in the world at 23 million and 2.7 billion t respectively.[4]

Two important determinants of the change in China's industrial structure were the relocation of heavy industry from developed countries and a proliferation of foreign joint ventures in energy intensive industries not just only to satisfy local demand in China but also to serve global export markets where the demand for energy intensive outputs was also increasing. These developments have reopened the debate on the role of foreign firms in China. The motivation of this paper is to understand the relationship between per capita income growth, energy consumption, energy intensity and the role of foreign firms against a background of China's changing industrial structure. Specifically, this paper will allow us to gauge the extent to which foreign direct investment has contributed to changes in China's energy intensity at the national and regional levels.

An early approach to understanding the relationship between GDP growth and energy consumption growth was to use a range of decomposition techniques. This literature searches for evidence of decoupling with the expectation that the growth in energy demand plateaus while economic growth continues on an upward trajectory (see e.g. Ma and Stern, 2008; Wang et al., 2005; Wu et al., 2005; Zhang, 2000; Chen, 2011). According to Fan et al. (2007) in their study of carbon intensity in China between 1980 and 2003 evidence of decoupling is a result of improved energy efficiency in the primary and materials sectors.[5]

A second, related, literature uses time series country-level data to look at the impact of economic growth on energy consumption. This literature is related to the well known environmental Kuznets curve (EKC) literature (Cole et al., 1997; Dinda, 2004; Forsten et al., 2012) which describes a non-linear inverted-U shape relationship between per-capita income and per capita emissions or per capita energy consumption (see e.g. Galli, 1998; Cole, 2006). There are also several studies on the relationship between economic development and environmental quality in China. He (2006) considers the relationship between FDI and the location of firms in Chinese provinces. Cole et al. (2011) investigate the relationship between economic growth and industrial pollution emissions in China using data for 112 major cities between 2001 and 2004 and find that most air and water emissions rise with increases in economic growth at current income levels. He and Wang (2012) analyze the impact of economic structure, development strategy and environmental regulation on the shape of the EKC using a panel of 74 Chinese cities for the period 1990–2001 and find that all three have important implications for the relationship between environmental quality and economic development but that the impact can vary at different development stages. These studies provide empirical evidence for the existence of different slopes for the pollution–income curve.

The literature on the effect of foreign firms on energy intensity is limited. A recent exception is Hübler and Keller (2009) who argue that foreign capital and the transfer of energy-saving technologies from developed countries are a possible channel by which the energy intensity of newly industrializing countries can be reduced (based on the productivity-enhancing technology transfer and spillovers literature e.g. Keller, 2004). The hypothesis that multinational enterprises (MNEs) use less energy per unit of output than their domestic counterparts in developing countries is confirmed by a number of firm-level studies. For example, Eskeland and Harrison (2003) and Cole et al. (2008) show that foreign ownership is associated with more energy-efficient production in the former's analysis of manufacturing plants in Cote d'Ivoire, Mexico and Venezuela and the latter's study of Ghana. One explanation is that MNEs utilize more advanced technologies that also tend to be energy-saving whether by design or simply as a positive externality from using newer materials and processes. However, Hübler and Keller's (2009) study of 60 developing countries for the period 1975–2004 fails to confirm that FDI reduced energy intensity in developing countries. One constraint of their study is the failure to employ micro-level data in terms of foreign investment and energy use. Energy intensity is determined by many cultural, political, and constitutional factors that can differ greatly across countries. Our data is ideally suited to a study of this type as it has regional GDP data and energy intensity data not usually available in studies of this type.

Studies of the relationship between foreign capital and energy intensity in China are scarce. Nevertheless, there are some studies that focus on the effect of foreign capital on environmental quality in China. He (2006) examines industrial SO_2 emissions for 29 Chinese provinces and shows that a one percent increase in FDI inflow increases industrial SO_2 emission by 0.098%. The emission increase caused by the positive FDI effect on economic growth and the structural composition of the economy cancels out any emission reductions due to the energy intensity gains from FDI. In a panel study in 112 cities in China, Cole et al. (2011) find that the share of output of domestic- and foreign-owned firms increases several pollutants in a statistically significant manner while output of firms from Hong Kong, Macao and Taiwan (HTM) either reduces pollution or is statistically insignificant.

[2] In this paper we refer primarily to energy intensity. However, energy intensity is closely related to the concept of energy efficiency and is often used interchangeably in the literature. However, strictly speaking energy efficiency is a parameter that depends primarily on the state of technology and methods of production and determines the amount of energy needed to deliver goods and services at the process level in similar plants, industries or subsectors (Birol and Keppler, 2000). Energy intensity on the other hand is defined by the energy consumption per unit of economic output (GDP). Energy intensity is therefore influenced by energy efficiency and can be used as an indicator of the aggregate level of energy efficiency of an economy, region or city. A reduction of aggregate energy intensity is not equivalent to, but is usually a response to an improvement in energy efficiency in a certain industry, and is typically realized through the use of energy-saving technology. For example, a shift in country's economic structure can also impact economy level energy intensity.

[3] See Fisher-Vanden et al. (2003) and Fisher-Vanden et al. (2006) for an analysis of changes in China's energy intensity.

[4] Environmental degradation in China is now a serious problem with 500 million people lacking access to clean drinking water and only 1% of China's city population of 560 million able to breathe air deemed safe by the European Union (New York Times, 2007). It is now reaching the point where environmental degradation is having a detrimental impact on future growth. The World Bank (2007) estimated the economic costs in 2007 to be in the region of 3.5 and 8% of GDP.

[5] Decomposition techniques include input–output structural decomposition, non-parametric distance functions, and index decomposition. See Ang and Zhang (2000) for a review.

Finally, it is important to note that understanding energy demand and energy efficiency in China is extremely complex and is complicated by a mix of central planning, regional competition, market forces and variable environmental regulation enforcement at the city and prefecture levels. The availability of finance, land allocation and competition between cities and provinces is also part of the explanation with cities often bidding against each other to attract foreign investment whatever the environment costs of implications for energy demand. Visibility is also obscured by security considerations and the secrecy that continues to surround many state-owned enterprises (SOEs). On a related note, the price firms pay for energy is not always transparent with local energy price subsidies which is an additional distortion to the market.[6]

The contribution of this paper is to investigate the relationship between energy intensity, per capita incomes and the role of foreign firms in China between 2005 and 2008 employing a dataset of 206 prefectural-level cities. The prefectural-level city is an administrative division, ranking below a province but above a county and represents the second level of the administrative structure in China. The benefits of this level of disaggregation are that China's integrated national statistical system provides data of comparable quality for energy intensity and a range of economic variables (He and Wang, 2012). Second, prefectural-level city policymakers are relatively independent and have the power to, for example, implement policies to attract more foreign investment or close down pollution intensive plants. Using data that is regionally disaggregated overcomes problems of heterogeneity experienced by country level studies. However, one caveat is that our prefecture-level energy intensity measure does not just capture urban energy use given any prefecture-level city is made up of a main central urban area (a city usually with the same name as the prefectural level city) and a much larger surrounding rural area that may contain a large number of smaller cities, towns and villages. Unfortunately, China's statistical system does not publish energy use in the main central urban area (Dhakal, 2009).

Another highlight of our study lies in that we are able to distinguish between three types of firm ownership: domestic; foreign; and Hong Kong, Taiwan and Macao (HTM) owned in order to better understand the relationship between foreign investment and local energy intensity. Finally, we examine the East, Central and Western regions of China separately. This helps to relate changes in energy intensity to China's eleventh and twelfth five year plans.

Our results reveal a non-linear inverted-U shape relationship between energy intensity and per capita income with the majority of cities on the downward sloping slide of the curve. We estimate turning points where possible. Our results also provide evidence of a significant and positive energy-saving effect through FDI although we find considerable differences in regions' ability to absorb and benefit from environmental spillovers from technology transfers. Our results indicate that the positive effect on energy saving from FDI is relatively weak in the East of China but is stronger in the relatively less developed Central and Western regions. Over this period it is likely that any improvements in energy efficiency at the individual industry level were overwhelmed by a shift in the structure of China's economy towards more energy intensive industries The simple explanation would be that while the existing energy intensive industries in a prefecture-level city may well have improved their energy intensity, the overall structure of the city's economy had moved towards the relatively high energy intensive sector (output of these goods increased) and that more than offset industry specific intensity improvements from foreign investment and rising per capita incomes.

The rest of the paper is organized as follows: Section 2 provides a brief background review and Section 3 presents a description of the data and our empirical methodology. In Section 4 we present our empirical results and Section 5 concludes.

[6] See Rosen and Houser (2007) for an excellent discussion of these complex issues.

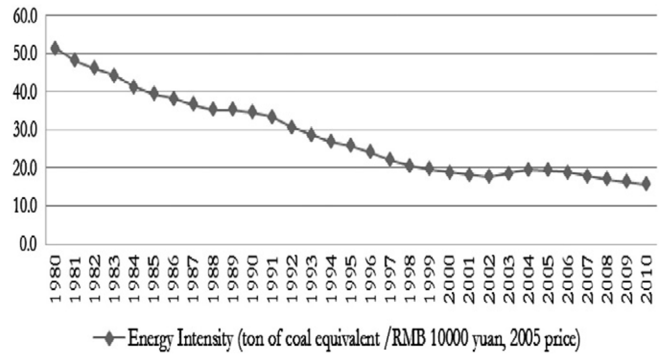

Fig. 1. Aggregate energy intensity in China (1980–2010).
Source: China Statistical Yearbook (2011).

2. Theoretical background

In studies that analyze the relationship between trade and the environment it is common to decompose the effects of economic activity into a scale, composition and technique effect (Grossman and Krueger, 1993). Such a distinction is made by Antweiler et al. (2001), Cole and Elliott (2003) and Copeland and Taylor (2003) looking at environmental pollutants and Cole (2006) and Hübler and Keller (2009) who apply the same criteria to energy consumption.

In the context of this paper, the scale effect represents an increase in total energy consumption. Since our focus is on energy intensity which is defined as energy consumption per unit of output, the scale effect is not central to our analysis. If we assume identical production technologies and constant returns to scale an economy can double in size without any change in the energy intensity of the economy. However, the composition effect (or structural effect in the decomposition literature) which captures changes in the industrial structure of the economy is something that we can measure with our data. Typically, an industrializing country experiences a transition from agriculture (primary) to industry (secondary) and finally to services (tertiary). This is suggestive of a rise and then a fall in energy intensity as a country develops holding technologies in those sectors constant (Stern, 2004) and matches the predictions of the EKC literature. The impact of foreign firms on this accepted pattern of energy intensity changes depends on two criteria. First, which are the sectors that foreign firms invest in and second, the type and efficiency of the technology employed as part of the foreign investment. The EKC inverted U relationship will be reinforced if foreign firms concentrate in sectors that require low energy inputs (primary and tertiary). If foreign firms use more advanced and more energy efficient technologies and displace domestic firms in the same industry and do not just increase the scale of production (by reducing average intensity) foreign firms may change the shape of the EKC curve and hence the turning point. One deficiency with Hübler and Keller (2009) is that the composition effect on energy intensity caused by FDI cannot be disentangled from technology transfer effects. Since we cannot get complete information of the industrial distribution of FDI for every city in our sample we include the gross industrial output by companies invested by domestic, foreign and Hong Kong, Taiwan, Macao firms respectively. This distinction enables us to capture the composition effect driven by investment from a specific group.

Finally, the technique effect captures the impact of new management practices and technology on energy use. If FDI is a channel by which technology is transferred from developed to developing countries a FDI-induced technique effect should reduce energy intensity through technological spillovers from foreign to domestic firms. The traditional definition of technological spillovers includes product and process innovations, improvements in the distribution channels and better marketing and management methods (Blomström and Kokko,

Table 1
Income, growth, FDI, population and energy in China's provincial capitals, 2005–2008.

City	Average GDP (US$ millions)	Average GDP per capita (US$)	Annual average GDP Growth (%)	Annual average FDI/GDP (%)	Average population (Million)	Average aggregate energy intensity (t/10,000 RMB)	Average industrial energy intensity (t/10,000 RMB)
Guangzhou	87,601	7110	13.74	3.58	7.67	0.73	1.16
Shanghai	47,208	6260	11.78	5.35	13.75	0.85	1.09
Beijing	24,598	5521	11.72	4.22	12.23	0.72	1.26
Hangzhou	13,336	5305	13.23	5.00	6.69	0.81	1.17
Nanjing	9546	4943	14.50	4.50	6.11	1.28	2.45
Tianjin	27,144	4358	15.23	7.80	9.54	1.04	1.33
Taiyuan[a]	23,566	3871	12.68	2.40	3.51	2.56	5.34
Jinan	114,013	3812	15.02	2.09	6.02	1.20	1.86
Hohhot[a]	29,959	3660	19.58	4.10	2.19	1.65	4.30
Changsha[a]	11,439	3159	15.20	4.81	6.34	0.96	1.09
Zhengzhou[a]	18,462	3145	15.01	2.73	6.99	1.28	2.44
Wuhan[a]	12,724	3126	15.05	5.46	8.20	1.23	2.06
Nanchang[a]	22,087	2797	15.58	6.67	4.86	0.91	0.78
Fuzhou	27,321	2755	12.50	3.08	6.26	0.71	1.00
Yinchuan[b]	20,417	2584	13.43	0.56	1.47	2.29	1.23
Shijiazhuang	65,095	2536	12.60	1.45	9.47	1.74	3.42
Chengdu	9452	2531	13.68	4.12	9.15	0.96	1.70
Harbin	38,936	2343	13.58	1.34	9.83	1.41	2.19
Haikou	6449.89	2138	12.03	9.66	2.46	0.81	0.24
Kunming[b]	13,175	2132	11.93	1.70	4.66	1.44	2.33
Xi'an	1103	1987	14.13	4.35	7.58	0.95	1.08
Nanning	3831	1407	15.38	1.23	6.77	0.88	1.64
Chongqing[b]	7443	1385	13.40	2.35	32.12	1.35	2.47

Source: China City Statistical Yearbook (2006, 2007, 2008 and 2009). Due to data limitations we exclude Shenyang, Changchun, Urumqi, Hefei, Lanzhou, Lasa, Xining and Guiyang (the capitals of Liaoning, Jilin, Xinjiang, Anhui, Gansu, Tibet, Qinghai and Guizhou respectively). US$ in 2005 prices.
[a] City in the Central region.
[b] City in the Western region.

1998; Fisher-Vanden and Jefferson, 2008; Yao and Wei, 2007). It can be argued that any technological advances in product development and manufacturing processes will also improve energy efficiency in certain sectors and hence through reduced input costs there should be a positive effect on productivity. FDI spillovers can be both horizontal and vertical. First, domestic firms can benefit from the presence of FDI in the same industry known as intra-industry or horizontal spillovers which arise through demonstration effects and the movement of workers between firms (foreign to domestic). Second, there may be spillovers from foreign firms operating in other industries known as inter-industry or vertical spillovers which are often associated with buyer–supplier linkages which can be upstream or downstream. For example, an upstream multinational firm may help a supplier improve their energy efficiency to raise the supplier's productivity and hence in the long run hope that this translates into lower unit prices for the multinational.[7]

To further understand how FDI can influence energy use we revisit the mechanism by which spillovers can take place. For domestic firms to benefit there must be a technological gap between the newly relocated foreign firms and their domestic counterparts. The larger the technological gap the greater the opportunities for domestic firms to improve their energy efficiency levels through the imitation of foreign firms (Findlay, 1978). If the technological gap is too small, MNEs will transmit few benefits to domestic firms (Kokko, 1994). However, if the gap is too large it can impair the absorptive capacity of cleaner and more efficient technologies from foreign firms as the costs and/or skills required to close the gap are just too large to bridge in the short term (Kinoishita, 2001; Wang and Blomström, 1992). The unbalanced nature of development across China means that the capacity of firms and hence to absorb clean technologies is likely to differ by region and be linked to a region's level of development.

[7] The technique effect can exceed the scale effect at high-income levels. In the EKC literature Cole (2006) argues that when the level of income reaches a given turning point, energy intensity falls as income continues to rise. The argument is that as per capita incomes increase, the public demands a clean environment which can then result in the adoption of more stringent environmental regulations to encourage firms to employ more energy-efficient technologies. The number of environmentally linked demonstrations in China in recent years is a good example of this income effect.

A second transmission mechanism is through vertical linkages, which in turn depends on the type of foreign investment. For example, the technological spillovers will be limited in the case where a foreign firm invests solely in a processing plant which assembles final goods from intermediate inputs for export or domestic sales. Such investment is more likely to occur in the coastal eastern region of China where it is easier and cheaper to import and export. The coast is where historically a large proportion of foreign investment has taken place.

3. Data and methodology

In this paper we use data for 206 Chinese cities across 19 provinces for the period 2005 to 2008. Each province has an independent Provincial Bureau of Statistics which provides separate data for each prefectural-level city within its borders including information on GDP, foreign investment and other economic indicators in the annual Yearbook of Provincial Bureau of Statistics. Since the beginning of the eleventh Five Year Plan the Provincial Statistical Bureaus are required to report the progress that has been made in reducing city-level energy intensity. By 2009 data was available for 19 provinces including two municipalities (Tianjin and Beijing) and two autonomous regions (Guangxi Zhuang Autonomous Region and Ningxia Hui Autonomous Region). Due to data limitations we were not able to obtain energy intensity information for Shanghai, Chongqing, Liaoning, Jiangxi, Anhui, Jilin, Guizhou, Gansu, Qinghai, Inner Mongolia, Xinjiang Uygur Autonomous Region and Tibet before 2008. Appendix 1 provides a full list of cities and their province of origin.

To investigate the impact of FDI on energy intensity we estimate Eq. (1) derived from our theoretical priors and the previous empirical evidence. We therefore estimate;

$$EI_{it} = \alpha_i + \beta_1 YPC_{it} + \beta_2 YPC_{it}^2 + \beta_3 FDI_{it} + \beta_4 GIPd_{it} + \beta_5 GIPh_{it} + \beta_6 GIPf_{it} + \varepsilon_{it} \quad (1)$$

where subscripts i and t represent city and year respectively. EI measures energy intensity which is measured in two ways, first aggregate energy intensity (ENTI) and second, industrial energy intensity (ENDI). We measure both aggregate energy intensities (calculated as

Table 2
FDI distribution of the top 20 and bottom 20 cities 2005–2008.

FDI inflows (US$ Million)				FDI/GDP (%)			
Top 20		Bottom 20		Top 20		Bottom 20	
City	FDI	City	FDI	City	FDI/GDP	City	FDI/GDP
Shanghai	7990	Tongchuan[b]	5.49	Shenyang	10.94	Guangyuan[b]	0.23
Suzhou	6629	Baoshan[b]	5.26	Nantong	10.55	Yibin[b]	0.22
Tianjin	5039	Hegang[a]	5.01	Zhaoqing	10.54	Anshun[b]	0.22
Beijing	4806	Zhangye[b]	5.00	Haikou	10.39	Zunyi[b]	0.18
Shenyang	4050	Pingliang[b]	5.00	Suzhou	10.25	Hanzhong[b]	0.16
Shenzhen	3482	Ziyang[b]	4.34	Sanya	9.99	Dazhou[b]	0.13
Qingdao	3440	Anshun[b]	3.65	Dalian	9.37	Ziyang[b]	0.10
Dalian	3354	Yulin[b]	2.97	Huizhou	9.37	Shizuishan[b]	0.09
Guangzhou	3120	Tianshui[b]	2.34	Ganzhou[a]	9.12	Tianshui[b]	0.09
Wuxi	2674	Guang'an[b]	2.15	Zhuhai	9.12	Wuwei[b]	0.08
Nantong	2540	Wuwei[b]	1.91	Qingdao	8.39	Dingxi[b]	0.07
Hangzhou	2520	Xinzhou[a]	1.67	Tianjin	8.32	Baiyin[b]	0.07
Ningbo	2446	Zhaotong[b]	1.43	Xiamen	7.67	Zhaotong[b]	0.06
Wuhan[a]	2141	Shizuishan[b]	1.35	Huzhou	7.63	Guangan[a]	0.06
Dongguan	2094	Baiyin[b]	1.34	Jiaxing	7.58	Qitaihe[a]	0.06
Nanjing	1817	Qingyang[b]	1.06	Lianyungang	7.57	Longnan[b]	0.06
Yantai	1733	Qitaihe[a]	1.06	Heyuan	7.36	Qingyang[b]	0.06
Chengdu[b]	1670	Longnan[b]	0.78	Nanchang[a]	7.22	Xinzhou[a]	0.05
Changchun[a]	1575	Dingxi[b]	0.63	Weihai	6.70	Yulin[b]	0.05
Changzhou	1464	Bazhong[b]	0.47	Changzhou	6.68	Bazhong[b]	0.02

Source: China City Statistical Yearbook, 2006–2009. US$ in 2005 prices.
[a] City in the Central region.
[b] City in the Western region.

units of total energy consumed per unit of GDP) where a unit of energy consumed is measured in tons of coal equivalent and industrial energy intensity (calculated as units of energy consumed in industrial sector per unit of industrial value added). The traditional energy intensity variable (aggregate intensity) reflects the intensity of energy consumption in general, while the latter (industrial energy intensity) is associated with industrial production (hence more likely to be directly impacted by FDI). *YPC* measures per capita income. We also include a quadratic term as a direct test of the inverted U-shaped relationship between income and energy intensity. *FDI* represents foreign direct investment scaled by *GDP* to capture the effect of direct technology transfers attributed to foreign investment. α_i is the random effect term and ε is the error term. In order to better examine the role of foreign investment on energy intensity we also differentiate between ownership type classifying output by domestic industrial output (*GIPd*), industrial output of Hong Kong, Taiwan and Macao owned firms (*GIPh*) and industrial output from foreign firms (*GIPf*).[8] Eq. (1) is estimated using both fixed and random effects. All variables are expressed in logs.[9]

Evidence of a beneficial effect of FDI (and possible evidence for technology spillovers) would be revealed by a negative β_3 coefficient implying that FDI facilitates improved energy efficiency in recipient cities. The nonlinear income-energy relationship derived from EKC hypothesis predicts that $\beta_1 > 0$ and $\beta_2 < 0$.

A potential methodological concern is whether per capita income can be considered truly exogenous. The difficulty is that causality could move from energy intensity to income where a decrease in energy intensity improves profitability and hence per capita income perhaps through the health benefits experienced by workers which can then lead to improved firm productivity. We test the null of exogeneity of current income using the one-period lagged value of income per capita as an instrumental variable using a Hausman test. The null hypothesis of exogeneity is rejected for 35 of our 36 reported models. In Section 4 we therefore report the results from models in which income is treated as endogenous and for the case where the null of exogeneity is not rejected the results are replaced by those from their exogenous counterparts. We lag our per capita income variables by one year to mitigate endogeneity concerns. Appendix 2 provides detailed definitions of our variables and sources while Appendix 3 presents some simple summary statistics.

Before we present our econometric results we present some descriptive evidence. Fig. 1 provides an overview of the evolution of energy intensity for China as a whole (measured in tons of coal equivalent). There is a clear downward trend from 1980 until 2001 when this trend reversed before falling again albeit at a much slower rate. Aggregate energy intensity halved between 1985 and 2000 but made little progress in the subsequent decade.

Table 1 compares the average levels of population, income, growth, FDI and both aggregate energy intensity and industrial energy intensity between 2005 and 2008 ranked by per capita income for 23 provincial capitals. As expected, Eastern cities have generally higher income per capita levels than Central and Western cities, especially in the South-Eastern coastal provinces (Guangzhou in Guangdong and Hangzhou in Zhejiang). However, over the same period cities from central China appear to have grown faster (albeit from a low base) than the well developed coastal areas (suggesting a positive impact of recent central government policy). Column 2 in Table 1 shows that income per capita ranges from $1385 (Chongqing) to $7110 (Guangzhou) in 2005 US$ which is useful as a comparator when we calculate turning points. The high annual growth rates against an annual growth rate for China during the same period of around 11% is that as capital cities they have greater access to economic and political capital.[10]

Table 2 presents the distribution of foreign investment for our 206 cities and reveals large regional disparities. The major recipients of

[8] According to the Chinese Corporation Law, HTM and foreign investors are allowed to enter industrial production and service provision in mainland China through joint ventures, cooperative enterprises, sole investments, and limited liability enterprises. The share of foreign registered capital should be no less than 25% for a limited liability enterprise. These different ownership structures are included with our definitions of a foreign and HTM firm.

[9] It is argued that the quadratic log function provides a more realistic income–energy consumption relationship because of the symmetrical nature of the quadratic function. A symmetric quadratic function implies, first, that the level of energy intensity will fall at the same rate as it increases and that energy intensity will become negative, probably over a short period of time. In contrast, a quadratic log function falls away gradually once it passes the turning point as the curve asymptotically approaches zero.

[10] The large population of Chongqing is because of its status as a municipality like Shanghai, Beijing and Tianjin. The total area of Chongqing is 82,403 km^2 compared to an area of 6341 km^2 for Shanghai.

Table 3
Top 20 and bottom 20 cities for energy intensity, 2005–2008.

Average aggregate energy intensity (t/10,000 RMB)				Average industrial energy intensity (t/10,000 RMB)			
Top 20		Bottom 20		Top 20		Bottom 20	
City	Value	City	Value	City	Value	City	Value
Ningde	0.545	Xinyu[a]	2.753	Haikou	0.241	Shuozhou[a]	5.783
Shanwei	0.567	Loudi[a]	2.780	Zhongshan	0.451	Lijiang[b]	5.818
Shenzhen	0.568	Tangshan	2.797	Xiamen	0.500	Mudanjiang[a]	5.947
Taizhou	0.595	Jinzhong[a]	3.068	Shenzhen	0.564	Loudi[a]	6.000
Xiamen	0.625	Qitaihe[a]	3.231	Yan'an[b]	0.671	Handan	6.088
Zhuhai	0.632	Changzhi[a]	3.263	Putian	0.695	Laiwu	6.182
Shantou	0.658	Weinan[b]	3.322	Wenzhou	0.710	Zhangjiakou	6.244
Zhanjiang	0.698	Xinzhou[a]	3.513	Foshan	0.764	Lvliang[a]	6.295
Zhangzhou	0.703	Yuncheng[a]	3.515	Heyuan	0.797	Jiamusi[a]	6.430
Wenzhou	0.705	Anshun[b]	3.575	Zhoushan	0.810	Linfen[a]	6.453
Fuzhou	0.711	Panzhihua[b]	3.581	Guyuan	0.813	Qitaihe[a]	6.589
Zhongshan	0.723	Baise[b]	3.677	Taizhou	0.828	Hegang[a]	6.606
Beijing	0.724	Lvliang[a]	3.723	Dongying	0.839	Yuncheng[a]	6.898
Putian	0.728	Linfen[a]	4.068	Quanzhou	0.864	Xinzhou[a]	7.103
Guangzhou	0.730	Zhongwei[b]	4.300	Lishui	0.923	Weinan[b]	7.174
Yancheng	0.773	Laiwu	4.385	Suizhou[a]	0.938	Shuangyashan[a]	7.316
Lishui	0.778	Wuhai[a]	5.671	Yangjiang	0.940	Laibin[b]	7.578
Dongying	0.783	Wuzhong[b]	5.952	Weihai	0.949	Dazhou[b]	7.973
Nantong	0.786	Shizuishan[b]	7.651	Zhuhai	0.952	Heihe[a]	8.150
Yangjiang	0.791	Liupanshui[b]	8.691	Dongguan	0.975	Jixi[a]	10.391

Source: China City Statistical Yearbook, 2006–2009. US$ in 2005 prices.
[a] City in the Central region.
[b] City in the Western region.

absolute FDI levels and FDI scaled by GDP are almost always located in the Eastern provinces. The top five cities alone account for nearly a quarter of total FDI inflows. In contrast, the value of foreign investment received by the bottom 20 cities accounts for no more than 0.1% of the total FDI. One observation is that cities with the largest absolute levels are not necessarily those with the highest FDI scaled by GDP suggesting that FDI has a strategic dimension and is not just targeted at the most populous cities. For the large cities such as Shanghai the sheer economic size accounts for the difference. Export values reveal a similar pattern. Between 2005 and 2008 the East's average share of exports in total income is more than 70% compared to just less than 30% in the Central and Western regions. Following the market access commitments after WTO entry, an increasing fraction of foreign investment is in the form of wholly owned enterprises. The investment of single ownership companies accounts for an average of 60% of total FDI in the east of China between 1998 and 2006. The figures for the Central and Western regions are 39% and 44% respectively.

We now examine energy intensity more closely. Between 2006 and 2009 the national aggregate energy intensity of China fell by approximately 12%. Between 1990 and 2006 the aggregate energy intensity of China exceeded the world average by 80% although the extent that China exceeded the world average fell to 56% by 2007. Table 3 presents those cities with the lowest and highest energy-intensity levels (measured in aggregate energy intensity and industrial energy intensity) based upon 2005–2008 averages. The 20 cities with lowest levels of energy intensity (aggregate and industrial) are almost all in the eastern coastal provinces.

Table 4 presents a broad sectoral distribution of FDI by city. We also include data for 2009 and 2010 from the Chinese National Bureau of Statistics. The share of foreign investment in the tertiary industry (service sector) which is generally considered to be the least energy-intensive sector increased dramatically from 24.72% to 47.25% between 2005 and 2010 while the share of the most energy-intensive sector (the secondary industry) declined from 74.09% to 50.94%. However, absolute investment levels in the secondary sector remained fairly stable and continued by be the largest sector of investment. Although small in comparison foreign investment in the primary sector more than doubled between 2005 and 2010 and is probably the most energy intensive sector of all. The China Industry Economy Statistical Yearbook states that those industries in the manufacturing sector that attracted the most foreign capital in 2006 were Telecommunications, Computers and others; Transport Equipment; Electrical Equipment and Machinery; Raw Chemical Materials and Chemical Products; and the Textile Industry, whose industrial value added accounted for more than half of the total value added generated by foreign firms in the manufacturing sector, while the energy inputs in these five sectors represent only a quarter of the total energy inputs for the manufacturing sector. This suggests that in recent years foreign capital has targeted the manufacturing sector but has since moved into less energy intensive sectors.

Table 4
Industrial distribution of FDI inflows 2005–2010.

Year	FDI inflows by industry (US$ Million)			Share of FDI by industry (%)			Growth of FDI inflows by industry (%)		
	Primary industry	Secondary industry	Tertiary industry	Primary industry (%)	Secondary industry (%)	Tertiary industry (%)	Primary industry (%)	Secondary industry (%)	Tertiary industry (%)
2005	718	44,692	14,914	1.19%	74.09%	24.72%	–	–	–
2006	593	42,061	19,706	0.95%	67.45%	31.60%	−17.42%	−5.89%	32.13%
2007	895	41,494	29,995	1.24%	57.33%	41.44%	50.82%	−1.35%	52.21%
2008	1121	50,105	35,703	1.29%	57.64%	41.07%	25.26%	20.75%	19.03%
2009	1302	45,639	35,114	1.59%	55.62%	42.79%	16.21%	−8.91%	−1.65%
2010	1687	47,511	44,073	1.81%	50.94%	47.25%	29.52%	4.10%	25.51%

Source: China City Statistical Yearbooks (2006, 2007, 2008 and 2009). US$ in 2005 prices.

Table 5
Spearman correlation matrix.

	ENTI	*ENDD*	*Y*	*YPC*	*FDI*	*FDI/GDP*	*GIPd*	*GIPh*	*GIPf*
ENTI	1								
ENDD	0.8695[a]	1							
Y	−0.4251[a]	−0.4666[a]	1						
YPC	−0.3599[a]	−0.4755[a]	0.7399[a]	1					
FDI	−0.5121[a]	−0.5420[a]	0.8043[a]	0.7357[a]	1				
FDI/GDP	−0.4759[a]	−0.4841[a]	0.4898[a]	0.5768[a]	0.8998[a]	1			
GIPd	0.2202[a]	0.0483	0.3259[a]	0.4488[a]	0.1913[a]	0.0502	1		
GIPh	−0.5286[a]	−0.5280[a]	0.4681[a]	0.5301[a]	0.6788[a]	0.6967[a]	0.0068	1	
GIPf	−0.4744[a]	−0.5185[a]	0.6118[a]	0.6566[a]	0.7285[a]	0.6591[a]	0.0882[a]	0.5968[a]	1

Source: China City Statistical Yearbooks (2006, 2007, 2008 and 2009).
[a] Denotes statistical significance at 5% level.

Table 5 reports the Spearman rank correlations between energy intensity, FDI and other economic indicators. There is a high correlation between cities with high per capita incomes and those that receive the greatest volume of *FDI*. Energy intensity (both *ENTI* and *ENDD*) is also correlated with per capita income and the share of *FDI* in *GDP*. Finally, we find a negative and significant correlation between energy intensity and the output of foreign and firms from Hong Kong, Taiwan and Macao (*GIPf* and *GIPh* respectively). To allow for a visual representation of our date Appendices 4, 5 and 6 summarize the concentrations of FDI, income per capita and energy intensity respectively on a map of China.

4. Results

In Table 6 we present the results from the estimation of Eq. (1) with two alternative dependent variables *ENTI* and *ENDD*. In Tables 7 and 8 we present the results after allocating each of our 206 cities to one of three distinct regions (East, Central and West) for *ENTI* (Table 7) and *ENDD* (Table 8) respectively. In Table 6, columns (1), (2), (7), and (8) provide linear and quadratic specifications to test the simple relationship between income per capita and energy intensity with no further controls. The quadratic specification (columns 2 and 8) provides a direct examination of the inverted-U relationship between per capita income and energy intensity. Columns (3), (4), (9) and (10) include an aggregate measure of FDI to examine the relationship between foreign capital inflows and energy intensity. In columns (5), (6), (11) and (12) we drop *FDI* and instead include the share of gross industrial production (*GIP*) by ownership type, domestic (*GIPd*), foreign (*GIPf*) and HTM (*GIPh*) to check whether a city's share of production differentiated by ownership influences a city's energy intensity.

Table 6
Linear and quadratic log estimation results with random effects for total energy intensity (ENTI) and industrial energy intensity (ENDD).

	Total energy intensity (ENTI)						Industrial energy intensity (ENDD)					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
YPC	−0.2527***	1.1633**	−0.2693***	1.5326***	−0.6432**	−0.1533	−0.3772***	2.8992**	−0.4552***	2.3817*	−1.1829*	0.6106
	(−6.44)	(2.36)	(−6.36)	(2.82)	(−2.34)	(−0.29)	(−5.79)	(2.44)	(−6.14)	(1.83)	(−1.67)	(0.44)
YPC^2		−0.0785***		−0.0970***		−0.0185		−0.1877***		−0.1584**		−0.0676
		(−2.9)		(−3.28)		(−0.69)		(−2.84)		(−2.21)		(−0.89)
FDI			−0.0197***	−0.0267***					−0.0309**	−0.0339**		
			(−3.24)	(−5.03)					(−2.16)	(−2.5)		
GIPd					0.1228***	0.0958***					0.2553**	0.1189
					(3.29)	(2.63)					(2.27)	(1.60)
GIPf					−0.0018	−0.0019					0.0183	−0.0116
					(−0.28)	(−0.31)					(0.95)	(−0.66)
GIPh					−0.0028	−0.0030					−0.0287*	−0.0537***
					(−0.49)	(−0.58)					(−1.74)	(−3.56)
Constant	2.5530***	−3.7885*	2.6564***	−5.6621**	5.4289**	2.6947	4.1697***	−10.0346*	4.8107***	−7.823	10.1614*	0.3428
	(7.36)	(−1.68)	(6.96)	(−2.27)	(2.36)	(1.00)	(7.24)	(−1.89)	(7.17)	(−1.33)	(1.72)	(0.05)
R2 (within)	0.5050	0.4587	0.5131	0.4300	0.3165	0.4369	0.3216	0.2587	0.3117	0.2731	0.2684	0.3160
R2 (overall)	0.1192	0.1499	0.1408	0.1933	0.1779	0.1848	0.2161	0.2574	0.2616	0.2860	0.2967	0.3396
Hausman for RE	1.47	1.79	2.85	3.44	8.21	26.52	1.33	2.58	2.82	0.37	16.15	1.12
(p-value)	(0.2254)	(0.4082)	(0.2402)	(0.3288)	(0.0841)	(0.0001)	(0.2496)	(0.2756)	(0.2437)	(0.9465)	(0.0237)	(0.9521)
Hausman for IV	17.67	5.53	9.82	7.04	15.13	23.55	13.92	10.02	9.58	7.02	12.58	25.29
(p-value)	(0.0000)	(0.0629)	(0.0074)	(0.0708)	(0.0044)	(0.0003)	(0.0002)	(0.0067)	(0.0083)	(0.0712)	(0.0135)	(0.0001)
Turning point (RMB)		1651.69		2697.28				2259.64		1840.86		
Observations	756	756	747	747	708	708	743	743	730	730	693	693

Acceptance of the null hypothesis (p-value > 0.1) means that the Hausman test for RE indicates that the Random Effect model is more efficient than the Fixed Effects model.
Rejection of the null hypothesis (p-value < 0.1) means that the Hausman test for IV indicates endogeneity of the variable (income per capita) should be considered and the IV employed is qualified.
The turning points reported in this table have been transformed into income values (RMB). The original value is calculated from natural logarithm of the estimation values which are 7.41 and 7.90 for regressions (2) and (4) in the ENTI analysis (with a standard deviation of 0.35), and 7.72 and 7.52 for regressions (8) and (10) in the ENDD analysis (with a standard deviation of 0.14).
* Indicates significance at 10% level.
** Indicates significance at 5% level.
*** Indicates significance at 1% level.

Table 7
Linear and quadratic log estimation results with random effects for total energy intensity (ENTI).

	East				Central				West			
	A(1)	A(2)	A(3)	A(4)	B(1)	B(2)	B(3)	B(4)	C(1)	C(2)	C(3)	C(4)
YPC	−0.3770***	0.6841*	−0.5340***	−0.3064	0.1978***	3.9294***	−0.1449	0.4258	0.1582	0.8687	0.0528	−0.0559
	(−8.86)	(1.76)	(−7.98)	(−0.44)	(4.17)	(2.79)	(−0.95)	(0.33)	(1.12)	(0.23)	(0.39)	(−0.88)
*YPC*²		−0.0554***		−0.0081		−0.2189***		−0.0457		−0.0386		0.6606
		(−2.75)		(−0.23)		(−2.73)		(−0.63)		(−0.17)		(0.62)
FDI	−0.0014	−0.0043			−0.0884***	−0.0523***			−0.0458***	−0.0517***		
	(−0.31)	(−1.01)			(−5.07)	(−4.55)			(−3.49)	(−4.19)		
GIPd			0.1938***	0.1599**			0.1475*	0.1933**			0.2386***	0.0032
			(4.3)	(2.45)			(1.78)	(2.26)			(2.69)	(0.04)
GIPf			0.0063	−0.0017			−0.0250	−0.0034			−0.0360*	−0.0070
			(0.67)	(−0.20)			(−1.46)	(−0.30)			(−1.91)	(−0.49)
GIPh			0.0176*	0.0095			−0.0343**	−0.0184*			−0.0322**	0.0091
			(1.68)	(0.93)			(−2.54)	(−1.89)			(−1.96)	(0.75)
Constant	3.5913***	−1.4642	4.1155***	2.8943	−1.4083***	−17.1639***	1.1572	−0.5936	−0.9434	−4.1864	−0.9011	−1.1002
	(9.06)	(−0.78)	(9.86)	(0.91)	(−3.3)	(−2.78)	(1.11)	(−0.11)	(−0.79)	(−0.27)	(−0.85)	(−0.25)
R^2 (within)	0.7423	0.7459	0.7197	0.7295	0.0003	0.000	0.2239	0.3704	0.0015	0.0004	0.0292	0.1804
R^2 (overall)	0.1004	0.1138	0.1555	0.1665	0.0596	0.1002	0.1018	0.0425	0.0644	0.0634	0.2637	0.0037
Hausman for RE	4.32	4.05	7.73	8.28	0.05	5.98	2.46	1.29	3.99	2.93	8.51	26.08
(p-value)	(0.1155)	(0.2563)	(0.3568)	(0.4067)	(0.9763)	(0.4258)	(0.6521)	(0.9355)	(0.1357)	(0.4029)	(0.2901)	(0.0001)
Hausman for IV	87.33	157.28	10.41	50.45	112.91	16.6	37.68	1188.68	6.6	16.09	13.37	6.81
(p-value)	(0.0000)	(0.0000)	(0.0340)	(0.0000)	(0.0000)	(0.0009)	(0.0000)	(0.0000)	(0.0369)	(0.0011)	(0.0096)	(0.2355)
Observations	372	372	372	372	347	347	320	320	208	208	180	180

Acceptance of the null hypothesis (p-value > 0.1) means that the Hausman test for RE indicates that the Random Effect model is more efficient than the Fixed Effects model.
Rejection of the null hypothesis (p-value < 0.1) means that the Hausman test for IV indicates endogeneity of the variable (income per capita) should be considered and the IV employed is qualified.
* Indicates significance at 10% level.
** Indicates significance at 5% level.
*** Indicates significance at 1% level.

The Hausman tests suggest that the null hypothesis of the exogeneity of income is rejected across all specifications. The Hausman test for the efficiency of the random effects model finds that except for columns (5) and (6) for *ENTI* and column (11) for *ENDD*, the null hypothesis that fixed effects are preferable is rejected. Hence, we employ a 2-stage least square (2SLS) random effects estimation for all other specifications. Columns (5), (6) and (11) use ordinary least squares (panel OLS) fixed effects estimators.[11]

The first observation is that the results from columns (2) and (4) and (8) and (10) suggest that energy intensity increases with income per capita but at a decreasing rate as indicated by the significant positive and negative coefficients on *YPC* and *YPC*². This confirms the inverted U-shape relationship between income per capita and either aggregate energy intensity or industrial energy intensity. The results from columns (2) and (4), in which the quadratic term is significant, allow us to calculate the turning point for aggregate energy intensity which is estimated to be between RMB 1651 (US$345 estimated using the average 2005–2008 exchange rate between the RMB and the US$) and RMB 2697 (US$564.23) and between RMB 1841 (US$385) and RMB 2260 (US$473) for industrial energy intensity.[12] Cities with income levels below this value can expect the energy intensity of firms to increase as the process of industrialization continues. Cities with income levels higher than $473 can expect energy intensity to fall as income per capita rises. If we consider aggregate energy intensity, 181 cities out of sample of 206 cities had higher income levels for the period 2005–2008. For industrial energy intensity the number of cities above $473 was 196 out of 206. Our results suggest that the majority of Chinese cities are located on the downward facing slope of the inverted-U curve. To better illustrate the relationship of income and energy intensity in China, in Figs. 2, 3, 4 and 5 we plot the income per capita and energy intensity of the cities studied along with the inverted-U curve estimated in regressions (2), (4), (8) and (10) respectively.

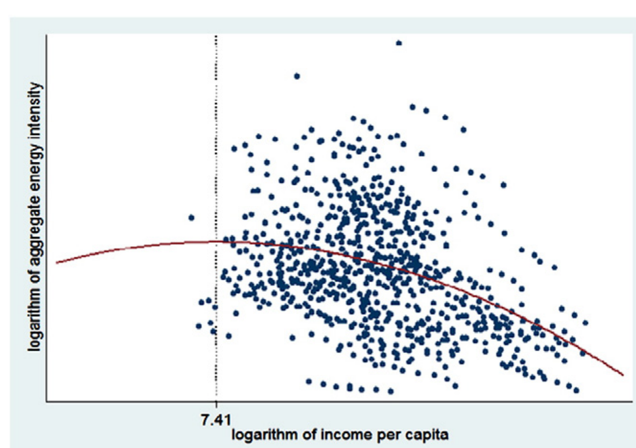

Fig. 2. Income per capita against aggregate energy intensity estimated from regression (2). *Logarithm of turning point estimated to be 7.41 (RMB) which is equivalent to US $345.

[11] We employ Baltagi's EC2SLS random effects estimator. Baltagi and Long (2009) show that for estimating a single equation in a simultaneous panel data model, EC2SLS has more instruments than G2SLS. Based on the results of tests for the appropriateness of IV estimators we report the random estimators with IV. In specification C (4) for the *ENTI* regression we report OLS fixed effect results. We are not able to perform a stationarity test on the data due to the short time period.

[12] We calculate turning points for the regressions where the quadratic term is included and its coefficient is statistically significant. Turning points are not calculated in the region-specific regressions since the existence of a non-linear relationship between energy intensity and income per capita is derived from the fact that income levels differ across Eastern, Central and Western regions in China.

Table 8
Linear and quadratic log estimation results with random effects for industrial energy intensity (ENDD).

	East				Central				West			
	A(1)	A(2)	A(3)	A(4)	B(1)	B(2)	B(3)	B(4)	C(1)	C(2)	C(3)	C(4)
YPC	−0.4178***	6.4257*	0.0236	0.3819	−0.0288	3.5690*	−0.3560*	1.0862	−0.3236*	−6.1219	−0.3604*	−12.9629**
	(−2.81)	(1.94)	(0.09)	(0.16)	(−0.22)	(1.65)	(−1.68)	(0.57)	(−1.82)	(−1.23)	(−1.73)	(−2.21)
YPC^2		−0.3714**		−0.056		−0.2106*		−0.0926		0.3532		0.7370**
		(−2.12)		(−0.44)		(−1.7)		(−0.86)		(1.19)		(2.13)
FDI	−0.0426	−0.0443			−0.0548***	−0.0484***			−0.0204	−0.0295*		
	(−1.59)	(−1.62)			(−2.89)	(−2.87)			(−1.26)	(−1.84)		
GIPd			0.3154***	0.2528**			−0.0765	−0.0552			−0.0091	0.1729
			(2.86)	(2.25)			(−0.63)	(−0.45)			(−0.08)	(1.06)
GIPf			−0.1307**	0.0026			−0.0206	−0.0030			−0.0226	−0.0315
			(−2.15)	(0.07)			(−0.63)	(−0.17)			(−1.11)	(−1.33)
GIPh			−0.1419***	−0.1002***			−0.0369**	−0.0258			−0.0369**	−0.0032
			(−3.64)	(−3.09)			(−1.95)	(−1.70)			(−2.15)	(−0.14)
Constant	4.3537***	−27.0479*	−0.4454	0.8908	1.2633**	−14.0245	4.6002***	−1.0496	3.7355**	27.4077	4.1875***	57.0678**
	(3.13)	(−1.72)	(−0.20)	(0.08)	(1.11)	(−1.48)	(3.21)	(−0.13)	(2.48)	(1.32)	(2.75)	(2.34)
R^2 (within)	0.2149	0.1303	0.0032	0.2413	0.0950	0.1178	0.5671	0.5889	0.3786	0.1489	0.4115	0.1741
R^2 (overall)	0.2198	0.2307	0.2873	0.3225	0.0469	0.0701	0.0330	0.0347	0.0511	0.0371	0.0782	0.1252
Hausman for RE	5.54	1.63	2.57	6.37	0.76	1.19	1.65	0.68	1.66	0.25	4.16	4.12
(p-value)	(0.3535)	(0.6522)	(0.6318)	(0.2717)	(0.6852)	(0.9776)	(0.9767)	(0.9838)	(0.4366)	(0.9684)	(0.3849)	(0.5318)
Hausman for IV	13.82	34.94	9.70	10.07	22.35	15.01	26.00	15.82	6.02	8.05	27.19	188.91
(p-value)	(0.0010)	(0.0000)	(0.0458)	(0.0733)	(0.0000)	(0.0018)	(0.0000)	(0.0074)	(0.0493)	(0.0450)	(0.0000)	(0.0000)
Observations	362	362	360	360	336	336	311	311	212	212	183	183

Acceptance of the null hypothesis (p-value > 0.1) means that the Hausman test for RE indicates that the Random Effects model is more efficient than the Fixed Effects model. Rejection of the null hypothesis (p-value <0.1) means the Hausman test for IV indicates endogeneity of the variable (income per capita) should be considered and the IV employed is qualified.

* Indicates significance at 10% level.
** Indicates significance at 5% level.
*** Indicates significance at 1% level.

When we consider the coefficient on *FDI* variable we find that it is significant and negative in the four specifications where *FDI* is included in Table 6 (columns 3 and 4 for *ENTI* and 9 and 10 for *ENDD*). This suggests that FDI reduces energy intensity in the host city. This contrasts with Hübler and Keller (2009) who find no significant FDI effect. The elasticity is between −0.02 and −0.027 for ENTI which means that a 10% increase in FDI will lead to an average 0.23% reduction in energy intensity. The equivalent value for industrial energy intensity is slightly higher and estimated to be between −0.31 and −0.34% and not surprisingly, this result suggests that the majority of the positive impact of FDI on energy savings comes from the industrial sector. Although we find a negative effect the economic significance is relatively small but a priori we believe it to be intuitively plausible.

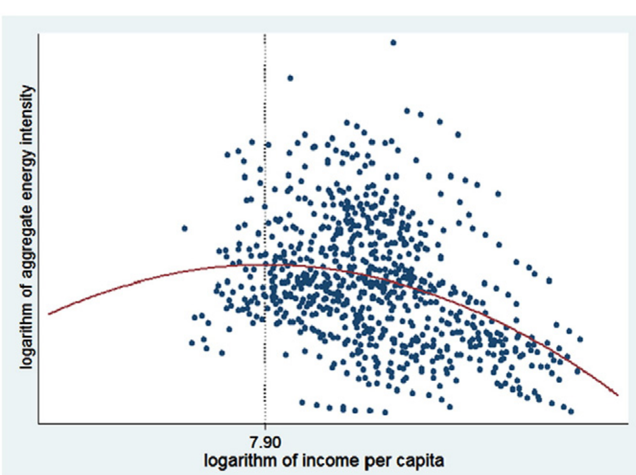

Fig. 3. Income per capita against aggregate energy intensity estimated from regression (4). *Logarithm of turning point estimated to be 7.90 (RMB) which is equivalent to US $564.23.

The next step is to introduce industrial output from foreign-sourced, HTM-sourced and domestic firms to examine the relationship between energy intensity and these variables. We drop FDI due to the high correlation between foreign-owned output and FDI. Our results show that domestic capital is positively related to both energy intensity variables. For *ENTI* the elasticity of domestic industrial output is estimated to be 0.1228, indicating that a 10% increase in domestic industrial output induce a 1.2% increase in energy intensity. For *ENDD* this elasticity is slightly higher, with an average value of 0.255. In contrast, industrial output of HTM firms seems to improve industrial energy intensity (but not at the aggregate level) (with elasticities in columns 11 and 12 of approximately −0.03 and −0.05 respectively). These coefficients on *GIPf* are not significant statistically. The differences between the results for *GIPd*, *GIPh* and *GIPf* suggest that HTM, foreign and domestic firms are investing in different industries and/or using different technologies. This suggests that domestic firms are relatively more concentrated in energy intensity industries.

One possibility is that HTM firms have continued to invest in light manufacturing and the more traditional labor intensive sectors such as textiles. Considering the significant coefficient on FDI, the insignificant result for industrial output from foreign-invested companies can be explained by a positive technology effect being canceled out by a negative composition effect (with some foreign firms targeting energy intensive sectors). It would appear therefore that where energy intensity is the variable of interest investment from Hong Kong, Taiwan and

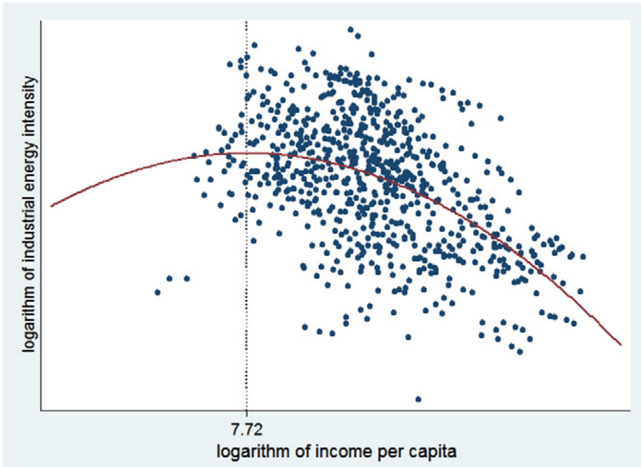

Fig. 4. Income per capita against aggregate energy intensity estimated from regression (8). *Logarithm of turning point estimated to be 7.72 (RMB) which is equivalent to US $385.

Macao makes the most significant contribution to energy intensity reductions and certainly more so than investment from other foreign firms.

Given the geographical concentration of certain sectors (for example heavy industry and coal in the Center and West and HTM firms in the East) in Tables 7 and 8 we run separate regressions for the regions of the East, Central and West for aggregate and industry energy intensity respectively. Although less robust, the non-linear relationship between energy intensity and *YPC* and YPC^2 is confirmed for the East and the Central regions but not for the West although when we control for industrial output the significance disappears for the central region. For cities in the East, the estimated coefficients of *YPC* in the *ENTI* regressions (columns A(1) and A(3) in Table 7) are all significant and negative with values between −0.377 and −0.534 and confirm an income-induced improvement in energy intensity in eastern cities, since an increase in income reduces aggregate energy intensity. More specifically, our results suggest that a 10% increase in income per capita in the East will improve energy intensity on average by more than 4%.

In Table 8, for *ENDD* the coefficients for *YPC* are negative and significant for four out of the six linear regressions across the three regions supporting the argument that rising per capita incomes reduces industrial energy intensity. To investigate further we compare the level of GDP per capita of cities in each region with the turning point estimated in Table 6 and find that all eastern region cities in our sample are distributed on the right hand half of the inverted U-shape relationship between energy intensity (ENTI and ENDD) and income. For *ENDD* the majority of cities in the central and western regions have a higher level of income than the turning point of RMB 2260 (US$473). This ratio is lower for *ENTI*. Therefore, a significant positive relationship remains between income and aggregate energy intensity for some cities in the West and Central regions of China.

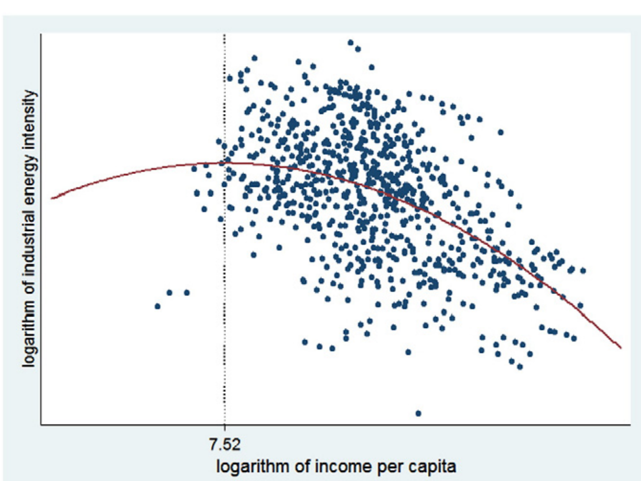

Fig. 5. Income per capita against aggregate energy intensity estimated from regression (10). *Logarithm of turning point estimated to be 7.52 (RMB) which is equivalent to US $473.

Comparing FDI coefficients across these three groups reveals some interesting insights. First, Tables 7 and 8 show no significant relationship between FDI and energy intensity (neither *ENTI* nor *ENDD*) for the cities in the East in our sample. This result might be due to the existing high level of technological adoption in the East (equivalent to saying that there is a relatively small technological gap between domestic and foreign firms), the export-orientation of local production and the structure of production in the East. For the other two regions the coefficients on *FDI* are negative and significant suggesting this is where foreign capital is making a difference to city level energy intensity. For *ENTI* the average elasticity on foreign investment is between −0.05 and −0.09 in the Central region and around −0.05 in the West. For ENDD the corresponding figures are −0.05 and −0.02 respectively. The larger technological gap between foreign and domestic investment in these regions might explain the positive FDI effect in the West and Central regions. Domestic firms in these regions are more able to absorb technological transfers and hence benefit from environmental spillovers from MNEs.[13]

5. Conclusions

In this paper we explore the relationship between growth in per capita incomes, FDI and energy intensity employing a unique panel of 206 Chinese prefectural-level cities between 2005 and 2008. This was a period of rapid economic growth and structural change in China. Our empirical results confirm an inverted-U relationship between per-capita income and energy intensity which suggests that the impact of an increase in income differs with the level of regional development. The location of a large majority of our cities for the period 2005 to 2008 is on the downward sloping part of the inverted-U curve which means rising income per capita has the effect of reducing energy intensity. We also find a significant and negative relationship between FDI and energy intensity which our regional studies show is stronger for the West and the Central region. This suggests that the beneficial FDI effect on energy intensity is not uniform across China. The differences across regions are of interest for regional policy makers who are striving to develop the central provinces in the West as part of the Twelfth-Five Year Plan. It is important to link energy policy and policies to attract new overseas investment.

While foreign investment appears to have a positive energy intensity reducing effect, the economic significance is relatively small. One reason may be the increasing investment by foreign firms in energy intensive sectors which may be linked to the competition between cities and provinces within China to have national champions in key strategic sectors such as iron and steel and aluminum. The local financing of regional state-owned enterprises, which allows firms to borrow at beneficial rates, has also encouraged the growth of energy intensive sectors in spite of China's relative comparative advantage in labor-intensive products. Finally, the local allocation of land can be used by local government to encourage high profile energy intensive investment that can pay high taxes and allow further local growth.

In summary, while foreign investment can have a beneficial effect on energy intensity and alleviate pressure on the energy consumption in

[13] For details on the role of absorptive capacity and the role of environmental spillovers see Albornoz et al. (2009).

China via technology spillovers the result is not as clear cut as one might expect. More promising is our evidence which suggests that increasing income helps enhance the energy efficiency once a city passes a certain level of income. There is a lot that China can do to meet its 2020 targets but the implementation is complicated by the complex mix of central policies, local incentives, market forces and the enforcements of environmental regulations. A closer investigation of these issues is left for future research.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.eneco.2013.08.004.

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