INDUSTRY LOCATION IN CHINESE PROVINCES: DO ENERGY ENDOWMENTS MATTER?

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Abstract

We identify the driving factors of manufacturing activity across Chinese provinces with a particular focus on energy endowments. A model of production location is estimated, including both comparative advantage and economic geography determinants. The data set used consists of a panel of 28 Chinese provinces and 12 manufacturing industries over the period 1999-2009. Results confirm the relative importance of energy endowments. We find that larger energy endowments are significantly correlated with larger production of energy-intensive sectors. Disaggregating across energy sectors shows that coal exhibits the strongest impact. These results are robust across alternative specifications.

Key Words: China, industry location, energy endowments, economic geography

JEL Classification Numbers: F18, P2, Q4, R15

1. INTRODUCTION

Although energy resources have long been recognized as a crucial factor for long-run growth, their impact as a potential determinant of comparative advantage has received more attention only recently. The emerging evidence suggests that, along with other traditional determinants of comparative advantage and geographic concentration, energy endowments are significantly associated with specialization in energy-intensive products. This is verified both across nations (e.g. Gerlagh and Mathys, 2011) and across subnational entities (e.g. Michielsen, 2012, for the US). However, the evidence is still scant, and more studies are required to strengthen the empirical support, with a particular emphasis on country or regional studies like the present one, which allow for a better control of unobserved trade barriers, technological differences or heterogeneous preferences.

This paper tests the role of energy endowments in shaping the industrial specialization of Chinese provinces during the last decade. The Chinese case is interesting for at least four reasons. First, more than 30 years have passed since the pro-market reforms were launched at the end of the 70s, so it can be expected that the present locational decisions by firms are based on cost minimization, in particular energy costs in energy-intensive sectors. Second, China has overtaken Germany as the world's largest exporter in 2009 (WTO, 2010), thus structural change in China has been at least as impressive at its growth performance. Third, according to the estimates of the International Energy Agency, China may also have become the world's largest energy consumer (IEA, 2010). This is so because, in spite of government efforts and substantial improvements in energy efficiency, the Chinese production structure remains biased towards the heavy industries (54% of total energy consumption in 2006). Fourth, Chinese provinces differ widely in terms of energy sources (e.g. Yu, 2012), with energy-rich provinces mainly based in the North. Although the Chinese energy market is heavily regulated, this may allow energy-rich provinces to offer lower energy prices, in particular for those energy sources like coal (covering 70% of energy needs in 2005), which are characterized by large transport costs.

The empirical methodology is based on the previous analysis of the Chinese industrial structure by Batisse and Poncet (2004), who relied on the economic geography cum factor endowments model proposed by several recent studies in the field (e.g. Midelfart-Knarvik et al, 2001). We extend the existing literature by applying this model to Chinese provincial data over a reasonably long and recent time period (1999-2009) and by taking particular care of the relative importance of energy as a production factor. The following hypotheses are tested:

i) Is industrial location in China determined by both new economic geography mechanisms and comparative advantages? Is the activity of relatively energy intensive industries higher in relatively energy abundant provinces?

ii) Is the comparative advantage effect larger for immobile energy production factors that are subject to higher transport costs?

The next section outlines the literature review. The framework and methodological background are given in section 3. Section 4 exposes the data sources, variable definitions and some stylized facts. Section 5 presents and discusses estimation results and section 6 concludes.

2. LITERATURE REVIEW

We provide a brief review of the main existing empirical frameworks used to analyze industry location, than present those studies referring more specifically to the Chinese case.

2.1 Determinants of industrial location

There is an extensive literature illustrating how the predictions of the basic factor-endowment or Heckscher-Ohlin model (HO) can be improved by relaxing some key simplifying assumptions. Allowing for technological differences across countries, imperfect competition or transport costs substantially improves the explanatory power of the model. For example, Hakura (2001) shows that, by calculating a separate technological matrix for each of the four EU countries analyzed in 1970, the sign matches between factor endowments and trade orientation increase from 58 per cent to 94 per cent. By combining Krugman’s (1980) monopolistic competition model and transport costs with the HO framework, Romalis (2004) obtains a deviation from factor price equalisation which implies that locally abundant factors are relatively cheap. Therefore, relative industry output prices, which are built upon the interaction between industry and country characteristics (factor intensity and factor abundance) define a country’s share in total production.

By endogeneizing the locational choice of firms facing transport costs and increasing returns to scale, the New Economic Geography approach (NEG) initiated by Krugman (1991) allows analyzing industry agglomeration and thereby the pecuniary effects of supply and demand linkages. These NEG forces have been proved to be important factors in firms’ locational choices. Davis and Weinstein (1999) argue however that the downside of NEG is that it cannot include input composition and demand structure and that it therefore should be combined with determinants from the factor endowment theory. Hence, studies increasingly include both NEG and HO components. Of particular importance for the present study is the contribution of Midlefart-Knarvik et al (2001), who include both HO and NEG effects into a common framework. Their empirical application is based on a panel of industries in 14 EU countries over the period 1980-1997, letting both country and industry characteristics interact. They find that growing economic integration in the EU has given way to a larger impact of both NEG and HO determinants of industry location. Note that industrial location models tend to perform better when the analysis is limited to a given region or country as this limits the problems linked to technological differences or barriers to trade (see e.g. Hakura 2001 and Kim 1999).

Another frequent extension of the HO framework is to extend the number of factors considered. However, in spite of their economic, environmental and geopolitical importance, energy endowments have rarely been considered, and almost exclusively in the US case. Hillman and Bullard (1978) address the Leontief paradox by including energy as a production factor and not only as an intermediate input. The authors argue that the US is actually abundant in labour and capital but scarce in energy, which "distorts" the basic capital-labour trade-embodied calculations. Much later, using a combined HO-NEG framework Ellison and Glaeser (1999) include interaction variables on electricity, natural gas and coal endowments interacted with the corresponding intensities as determinants of employment shares. They find that the estimated energy interaction terms are quite large, explaining a substantial part of the total comparative advantage. Gustavsson et al (1999) find that energy-intensive sectors are more competitive in OECD countries with low energy prices, but the direction of causality remains unsettled. Gerlagh and Mathys (2011) assess the effects of energy endowments on trade using a panel of 14 OECD countries over the period 1970-1997. They find that energy-abundant countries have 7 to 10 per cent higher employment and 13 to 17 per cent point higher net exports per value added in energy-intensive sectors vis-à-vis otherwise comparable countries. Michielsen (2012) performs a country analysis on industry location in US regions, regressing value added on six different energy carrier interaction variables (electricity intensity with coal, natural gas and hydropower abundance and fuel intensity with oil and natural gas abundance) in addition to the usual factor endowment variables (labour, skilled labour and capital) and NEG interaction variables (market potential with economies of scale and intermediate input intensity). Energy endowments are found to play a significant role in determining US industry activity.

2.2 Industrial location in China

Few studies have so far investigated the determinants of industry location for Chinese provinces. On the one hand, this could be explained by important constraints regarding data availability (e.g. information that varies across time, industries and provinces) and reliability (e.g. consistency between national and provincial data). On the other hand, market forces have only recently developed their effects on industry location. After three decades of centrally planned economy, China generally reported a very weak degree of specialization across provinces, due to the central government's efforts to generate a widespread security of supply in case of foreign invasion. Young (2000) argues: “With material supplies only ensured when one actually produced them oneself, and with the central regime actively encouraging and funding the local development of industries, each province, county, city and locality tried to develop its own duplicate set of industries.” (p. 7) Herein lies the particular interest of a regional study on China; The opening reforms initiated in 1978 and which are still under development, have allowed market mechanisms to exercise a growing influence on economic activity. Nevertheless, as confirmed by the studies quoted below, the country continues to maintain high trade barriers at the international as well as the regional level, also impeding domestic trade. Protectionism not only limits geographic concentration and the benefits of specialization but also the free flow of goods across provinces, thus interfering with comparative advantage mechanisms.

Most closely related to the present study, Batisse and Poncet (2004) apply the economic geography augmented HO model to China, additionally accounting for regional protectionism. They criticize the indirect measure of protectionism used by Bai et al. (2003) and compute a variable based on a gravity equation using domestic trade flows (imports and exports to and from “the rest of China”). The authors show that both comparative advantage and economic geography play a significant role in the location of industries across provinces for the period 1992/1997 but that protectionist measures have increased at the same time, especially in less “outward-looking”, central provinces. Amiti and Javorcik (2008) assess internal impediments to trade in China by evaluating the effect of provincial internal and external components of demand and supply linkages (i.e. market potential and supplier access) on the entry of foreign firms. They find that the overall supplier access and market potential play an important role in determining entry of foreign firms, but that the internal linkages clearly dominate over the external linkages, indicating the existence of barriers to trade.

Regarding energy resources, in 2004 a national differential power pricing policy took effect, introducing specific tariffs with the objective to discourage further investment in energy intensive industries. Nevertheless, even accounting for these tariffs, the energy prices in China are, according to Lin and Liu (2010), lower than both the social and private equilibrium.

Additionally, the provinces have significant possibilities to intervene and counterturn the policies of the central government. As Lin and Liu (2010) argue, the heavy industry in some remote provinces is a major source of taxation and is an important consumer of other industrial products. Following the 2008 crisis, many regional governments lowered the tariffs for energy-intensive industries and gave other incentives through tax reductions and subsidies. Thus, Chinese resource prices do not just reflect the abundance of energy endowments, but are also the result of regional energy and fiscal policies.

In short, in line with the recent literature, we include both Heckscher-Ohlin (HO) and new economic geography (NEG) factors to analyze industry location in China. Moreover, following Gerlagh and Mathys (2011) and Michielsen (2012), we extend the work by Amiti and Javorcik (2008) and Batisse and Poncet (2004) by introducing energy sources as potentially important additional production factors.

3. METHODOLOGY

As outlined in the above section, the theoretical background is directly inspired from the recent literature on industry location. Firms produce differentiated goods under economies of scale and compete on markets which are partially segmented by transport costs and trade barriers. Locational decisions are based on factor costs, trade impediments, market potential and supplier access conditions. We borrow the basic specification from Midlefart-Knarvik et al (2001) and Batisse and Poncet (2004), where the left-hand side variable, a measure of relative output at the industry and province level, is explained by two groups of regressors, one related to HO effects, the other to NEG effects. As in Gerlagh and Mathys (2011) and Michielsen (2011), HO effects are captured by interaction terms obtained by the product between the relative factor endowment of the province and the relative factor intensity of the industry. The NEG effects are captured by indicators of demand linkages (market potential) and supply linkages (supplier access).

Using indices *k, p, t* to indicate the industrial sector, the province or respectively the year, the basic empirical specification is given by:

$$
\begin{aligned}
RY_{k,p,t} \quad = \quad & \alpha_1(SKL_{ab}^{p,t} * SKL_{in}^{k,t}) + \alpha_2(CAP_{ab}^{p,t} * CAP_{in}^{k,t}) + \alpha_3(ENG_{ab}^{p,t} * ENG_{in}^{k,t}) + \\
& \beta_1 MKTP_{ext}^{k,p} + \beta_2 MKTP_{int}^{k,p} + \beta_3 SUPA_{ext}^{k,p} + \beta_4 SUPA_{int}^{k,p} + \\
& \gamma_{k,t} + \delta_{p,t} + coast_p + \varepsilon_{k,p,t}
\end{aligned}
\qquad (1)
$$

The meanings and dimensions of each variable are summarized in table 1. The left-hand-side variable, *RY*, is the logarithm of relative output, defined as the ratio between output of industry *k* in province *p*, over the product of the share of province *p* in national output and the share of industry *k* in national output. This double standardisation allows for comparisons between industries and provinces which vary widely in size.[1]

The first line of equation (1) contains the HO variables, namely the interaction terms between factor abundance (*ab*) and factor intensity (*in*) for three primary factors i.e. skilled labour (*SKL*), capital (*CAP*) and total energy (*ENG*). All these terms are expressed in relative terms with respect to unskilled labour. For energy, we also consider an extension where *ENG* is replaced by three disaggregated energy sources: coal (*COAL*), petrol (*OIL*) and natural gas (*GAS*). This allows to controlling for the degree of mobility between these energy carriers, with larger expected coefficients for coal, because it is characterized by larger transport costs.

The second line of equation (1) lists the NEG variables, which measure the proximity to both demand (market potential, *MKTP*) and suppliers of intermediate inputs (supplier access, *SUPA*). As mentioned in the literature review, China has large interior barriers to trade and exhibits quite a heterogeneous development across provinces. Therefore we split up the market potential into two components: an internal ($MKTP_{int}$) and an external ($MKTP_{out}$) effect, which allows accounting for trade restrictions between provinces. A similar distinction is

[1] The denominator can be interpreted as the "naïve" predictor of the particular industry-province output share, given the average importance of both the industry and the province.

TABLE 1: Variable Definitions and Dimensions

Variable		Definition	Dimension
Explained Variable	RY	Log of relative output measure: output of industry k in province p relative to the product of the share of industry k and the share of province p in total national output	province-industry-year
Abundance (ab) Variables (Country characteristics)	SKL_{ab}	log of university degree holders per worker	province-year
	CAP_{ab}	log of total capital stock per worker	province-year
	ENG_{ab}	log of total energy production per worker *(log of energy reserves per worker)*	province-year *(province)*
	$COAL_{ab}$	log of coal production per worker *(log of coal reserves per worker)*	province-year *(province)*
	OIL_{ab}	log of petrol production per worker	province-year
	GAS_{ab}	log of natural gas production per worker	province-year
Intensity (in) variables (Industry characteristics)	SKL_{in}	log of average wage rate per worker	industry
	CAP_{in}	log of industry capital stock per worker	industry-year
	ENG_{in}	log of total energy consumption per worker	industry-year
	$ELEC_{in}$	log of electricity consumption per worker	industry-year
	OIL_{in}	log of petrol consumption per worker	industry-year
	GAS_{in}	log of natural gas consumption per worker	industry-year
NEG Variables	$MKTP_{ext}$	log of market potential from all other provinces	province-industry
	$MKTP_{int}$	log of market potential within the province	province-industry
	$SUPA_{ext}$	log of supplier access from all other provinces	province-industry
	$SUPA_{int}$	log of supplier access within the province	province-industry

Note: Details on variable sources and construction are given in Appendix II.

applied between internal and external supplier access. The detailed construction of the NEG variables, which is based on input-output relationships, is given in Appendix II.B.

In the last line of equation (1), we find a white noise ($\varepsilon_{k,p,t}$) and three type of dummies to control for unobserved heterogeneity i.e. industry-year fixed effects ($\gamma_{k,t}$), province-year fixed effects ($\delta_{p,t}$), and a coastal dummy ($coast_p$). Alternative specifications will be considered as robustness tests. The fixed effects will be replaced by the individual elements of the interaction terms of the first line of equation (1), or complemented by province-industry fixed effects (in which case the NEG variables will have to be dropped as they have the same province-industry dimension). Autocorrelation issues will be addressed using clustered robust standard errors. Finally, instrumental variable estimates will also be proposed, as one may suspect reverse causality in the case of energy resources because factor abundance could actually be the result and not the cause of industry structure.

4. DATA

4.1 Data selection and preparation

Most of the data come from the China Industrial Economic Yearbooks, which include detailed annual information for all 31 provinces in 25 manufacturing industries, some of which had to be aggregated to correspond to the equivalent input-output (IO) table definitions (see Appendix II.A. for a description of sources and construction of intensity and factor abundance variables). National IO-tables are available for 2002 and 2007 while a regional table is available for 2002.

Following previous studies on industrial activity in China (e.g. Batisse and Poncet, 2004), we decided to exclude three provinces and two industrial sectors from the analysis. Tibet is excluded because of its specific political situation and incomplete data, Xinjiang for its strong reliance on petrol and Hainan for its low industrial activity. Further, mining and extraction industries, and petroleum processing have been excluded since their location is almost uniquely defined by the location of natural resources. Linearly interpolating 2004 values in case of missing values, the final aggregation procedure leads to a balanced panel data set covering 12 industries in 28 provinces over the 1999-2009 period (see table A1 for a list of the provinces and table A3 for a list of sectors).[2]

Factor intensity and factor abundance variables have, after taking the logs, additionally been standardized as standard scores per year over provinces (for abundance) and industries (for intensity), to facilitate the interpretation of the coefficients of the resulting interaction terms. Two particular cases are worthwhile mentioning and will be further discussed in the results' section. First, capital intensity is captured by the value of net fixed assets over the number of workers. This variable was preferred to gross capital formation per worker (as used e.g. by Batisse and Poncet, 2004), because the latter reflects short term capital needs rather than long term endowments. Second, as measure of energy abundance, instead of using natural energy reserves in each province as proposed in Michielsen (2012), we opted for using energy production per capita as this gives a better indication of actual availability of the factors and includes the effects of eventual distorting policies on abundance. Furthermore, we interact electricity intensity, not with electricity abundance - as this is more likely endogenous to the provincial industry structure and population[3]- but with coal production per capita, as 80% of the electricity in China is generated in coal power stations.

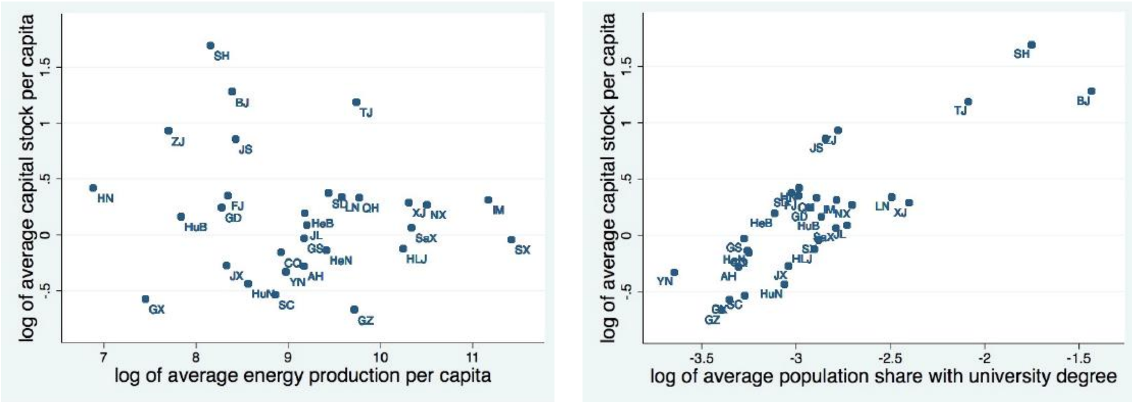
4.2 Descriptive Analysis

Regarding factor abundance we can see in Figure 1(a) that there is no strong correlation between capital and energy endowments. Capital-rich central provinces like Shaghai, Beijing or Tianjin, are not particularly well endowed in energy, while Northern provinces like Xinjiang or Inner Mongolia are among the largest energy producers although they are middle rank in terms of capital per capita. By contrast, Figure 1(b) shows that there is a strong and positive

[2] An alternative data set covering a longer time period but for fewer years (i.e. 1994, 1997, 2000, 2003, 2006 and 2009) has also been constructed and will be referred to in the robustness section.

[3] Electricity production per capita is highly correlated with regional GDP per capita, implying that production is potentially linked to generally higher consumption in developed provinces.

correlation between capital endowment and the skill labour force, suggesting that skill people tend to locate in capital-abundant provinces.

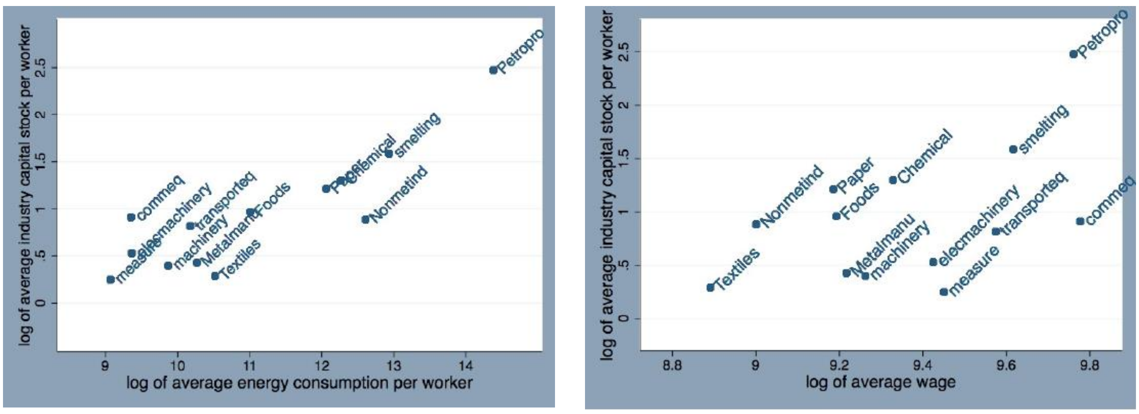


(a) capital - energy production (b) capital - skilled labour

Note: see table A1 for a list provinces including their two-digit code

FIGURE 1: Average factor abundance across provinces

Regarding factor intensities on the industry level, Figure 2(a) shows what one might expect: apart from the extreme case of petroleum products (excluded from the regressions), the paper, chemical, smelting and non-metallic mineral industries are the most intensive in energy use, and are also intensive in capital use and skill level (Figure 2(b), although the correlation is less strong than for abundance variables). Table A3 in the Appendix confirms that these four sectors are the more energy-intensive for all energy carriers.



(a) capital - energy consumption (b) capital - skilled labour

Note: see table A3 for a list sectors including their short name

FIGURE 2: Average factor intensities across industries

Generally, in the HO framework, factor intensities and endowments are considered constant through time and the issue is therefore often not further addressed in the statistical analysis. However, table A2 in the Appendix shows that for the time period between 1999 and 2009 the average abundance across provinces and the average intensity across industries are actually subject to important annual growth in China (with the exception of petroleum). This may seem contrary to other findings, in particular the decrease in energy intensity reported by Rosen and Houser (2007), but these later authors define energy intensity per unit of output instead of per worker, so the difference is mainly due to the large productivity increases experienced by China over the sample period.

Two additional stylized facts are in order. First, coal is the major energy carrier in China, where it represented 81(71) per cent of primary energy production (consumption) in 2006. Second, there is a clear division between provinces on the coast and those inland. Figure A1 in the Appendix exhibits that out of the 10 provinces with the highest GDP per capita, 9 are situated on the coast. Coastal provinces also trade substantially more with the rest of the world. This is not only due to the locational advantage, but also to economic policies of the Chinese government, in particular the establishment of the Special Economic Zones, since the 1970s (see e.g. Yueng, Lee and Kee, 2009).

5. RESULTS

5.1 Framework

Results for the basic estimations are reported in table 2. Each column corresponds to a two-way fixed-effects regression with industry-year and province-year fixed effects and a coastal dummy (their joint significance is always confirmed by a Wald test). Standard errors are clustered robust, allowing for autocorrelation within each province-industry group. The dependent variable is the log of relative output defined in table 1, although results are robust when using the log of industry output instead. Results are reported either for the basic specification without energy (column (1)), or with energy as a production factor, either total or disaggregated by energy sources, and whether energy endowments are measured in terms of production (columns (2) and (3)) or reserves (columns (4) and (5)).

The explanatory power of the model is quite good, with an R^2 of at least 65 per cent across columns, and significant results for the main regressors that will be commented in the next subsection. The choice between energy production or energy reserves deserves a brief discussion. At first sight, reserves seem more appropriate as an endowment measure. However, natural reserve data are based on estimated ensured reserves in 2005, and do not account for changes due to new discoveries made since then. Moreover, as for energy production, energy reserves might be suspected of endogeneity. The Chinese government has been encouraging the exploration of reserves, and newspaper articles reporting discoveries of large coal deposits have been published almost annually since 2005. In the end, we decided to keep reserves as an instrument in the robustness subsection, and focus our main discussion on results obtained when using energy production instead.

5.2 Validation of the Hypotheses

Hypothesis 1: *Comparative advantages and new economic geography mechanisms determine industry location across Chinese provinces. Consequently the activity of energy intensive industries will be higher in energy abundant regions.*

Results in table 2 demonstrate that skill, market potential, supplier access and the different specifications of energy abundance determine positively and significantly the location of production, as predicted by theory. This suggests that market forces are actually at work across Chinese provinces.

The hypothesis that energy intensive industries locate in energy abundant regions is clearly validated in all specifications in table 2, with special attention paid to total energy, which enters the regression significantly at the 1%-level and with a large coefficient. This positive and significant relationship has shown to be very robust throughout all estimations performed.

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TABLE 2: Industry location in Chinese manufacturing industries 1999-2009
(Dependent variable = log of relative output)

		Without Energy	With Energy Production		With Energy Reserves	
		(1)	(2)	(3)	(4)	(5)
Comparative Advantage	$SKL_{ab}*SKL_{in}$	0.090** (0.036)	0.091** (0.036)	0.093* (0.043)	0.077** (0.036)	0.076* (0.037)
	$CAP_{ab}*CAP_{in}$	-0.251*** (0.068)	-0.244*** (0.070)	-0.246*** (0.081)	-0.198** (0.078)	-0.172** (0.087)
	$ENG_{ab}*ENG_{in}$		0.126*** (0.042)		0.066*** (0.032)	
	$COAL_{ab}*ELEC_{in}$			0.042 (0.026)		0.073** (0.035)
	$OIL_{ab}*OIL_{in}$			-0.031 (0.046)		-0.009 (0.041)
	$GAS_{ab}*GAS_{in}$			0.043 (0.044)		-0.005 (0.040)
Economic Geography Variables	$MKTP_{ext}$ (β_1)	-0.257 (0.591)	-0.521 (0.593)	-0.267 (0.591)	-0.352 (0.593)	-0.276 (0.596)
	$MKTP_{int}$ (β_2)	1.104*** (0.234)	1.151*** (0.236)	1.092*** (0.232)	1.104*** (0.234)	1.115*** (0.237)
	$SUPA_{ext}$ (β_3)	0.615 (0.577)	0.597 (0.547)	0.604 (0.573)	0.569 (0.572)	0.584 (0.562)
	$SUPA_{int}$ (β_4)	0.650*** (0.216)	0.555** (0.222)	0.638*** (0.215)	0.633*** (0.217)	0.617*** (0.219)
Wald test	$H_0: \beta_1/\beta_2<1$		p=.9977		p=.9982	p=.9908
	$H_0: \beta_3/\beta_4<1$		p=.4717		p=.4384	p=.5134
N-cluster		336	336	336	336	336
No obs		3865	3865	3865	3865	3865
R^2		0.686	0.693	0.688	0.688	0.689

*Note: Standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01. Clusters 336, No. of observations 3865. All regressions include fixed effects (per province-year and industry-year) plus a coastal dummy. See table 1 for explanatory variable definitions.*

Surprising are the significant, negative and relatively large coefficients for the capital interaction variable. This may be due to measurement errors affecting the estimates of the value of net fixed assets.[4] It may also be linked to the fact that capital and energy seem positively correlated across industrial sectors, but such a correlation is not present at the level of provinces, as an important share of energy production is concentrated in non-coastal capital-poor provinces.[5] As an alternative, we also contemplated the use of gross capital formation.

[4] See Appendix II.A for a description of the estimation procedure.

[5] A possible explanation of these contradictory results is the phenomenon put forward by Rosen and Houser (2007) and briefly mentioned above, stating that provincial governments, especially in relatively energy abundant and inland provinces, strongly intervene in the localization of heavy industry which is not only energy but also capital intensive, leading to a strong distortion of industry localisation. Hence, provinces relatively scarce in capital, actually attract capital-intensive industries and exhibit a larger than proportional activity in those industries. However

However, this indicator was discarded, because it is influenced by short term variations which are not relevant in the long-run HO approach. Moreover, it leads to a totally counter-intuitive ranking of industrial sectors, with industries such as petrol refining, smelting, and chemicals appearing among the least capital-intensive categories.

The impact of demand and supply linkages at the level of the province ($MKTP_{int}$ and $SUPA_{int}$) are significant and large, indicating that pecuniary spillover effects are important in determining industry location. The two external linkage effects ($MKTP_{ext}$ and $SUPA_{ext}$) are insignificant, suggesting that transport costs or protectionism between provinces prevent the full exploitation of the gains from geographical concentration.

Hence, not only comparative advantage and factor endowments but also market externalities condition firms' location choices, substantiating the predictions of both the HO model and NEG. Energy proves to be a driving force in determining industry location next to the two principle comparative advantage indicators, skilled labour and capital.

Hypothesis 2: *The comparative advantage effect is larger for immobile energy production factors that are subject to higher transport costs.*

In regressions (3) and (5), of the three included energy carriers, the coal x electricity interaction term's coefficient exceeds the other two clearly, and it is the only one to exhibit a significant sign.[6] This is in line with the theory's predictions, given that coal is considered relatively immobile and as the most important energy resource in China.[7] As will be confirmed in the next subsection, this result is robust to alternative specifications.

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this is only a presumption. While calling for further investigation, it exceeds the framework of the present paper, and will therefore not be subject to detailed discussion.

[6] Recall that the previous normalization of the variables allows for direct comparison of the resulting regression coefficients.

[7] The world coal association indicates that the transportation costs account for a large share of the delivered coal price (http://www.worldcoal.org/coal/market-amp-transportation/, 13.06.2012).

5.3 Robustness Tests

The above results may be affected by contemporaneous correlation issues, i.e. correlation between the clusters, as neighbouring provinces may share common factor abundance (e.g. in energy resources). Thus, we perform a robustness test with Discroll Kraay[8] standard errors, with results reported in columns (2) and (3) of table 3. Results are basically unchanged, apart from the coefficients for the different energy sources, which become significant. The coefficients for natural gas and oil remain inferior to the coefficient for coal, validating the larger impact of immobile factors on industrial activity.

In column (4) of table 3, we add province-industry fixed effects. The coefficients are expected to be lower, as we focus on the pure dynamics of the panel, and the economic geography indicators are dropped as they do not vary through time by construction. The R-squared jumps to 96.5 percent and the coefficients of the interaction variables are very much reduced, as expected. They keep the same signs, but remain significant only when additionally excluding the province Qinghai (which shows a very large variation of its relative abundance measure across the time period, therefore not complying with the long term perspective of the HO framework). This suggests that a large part of the explanatory power of factor abundance variables is linked to variation across provinces rather than over time.

Reverse causality may affect results on natural resource abundance measures, because abundance could actually be the consequence and not the cause of industry structure (e.g. a provincial government may subsidize energy production because its industry structure is biased towards energy-intensive products). To control for this endogeneity bias, we report in table 4 results for IV regressions on the basic specification given in table 2 as well as on an alternative specification including the linear variables (the components of the interaction terms) instead of fixed effects. We use self-sufficiency (indigenous provincial energy production divided by final

[8] Discroll Kraay standard errors account for heteroskedasticity, autocorrelation and contemporaneous correlation. However, the results should be interpreted with care, given that the estimator is based on asymptotic theory and the cross-section in this study is fairly large with respect to the relatively small number of years.

TABLE 3: Robustness tests with contemporaneous correlation or industry-province fixed effects (dependent variable = log of relative output)

	Basic	Discroll Kraay standard errors		Industry-province fe
	(1)	(2)	(3)	(4)
$SKL_{ab}*SKL_{in}$	0.091** (0.036)	0.091*** (0.010)	0.083*** (0.010)	0.036** (0.014)
$CAP_{ab}*CAP_{in}$	-0.244*** (0.070)	-0.244** (0.059)	-0.213*** (0.059)	-0.046** (0.020)
$ENG_{ab}*ENG_{in}$	0.126*** (0.042)	0.126*** (0.003)		0.038* (0.020)
$COAL_{ab}*ELEC_{in}$			0.042*** (0.013)	
$OIL_{ab}*OIL_{in}$			-0.031*** (0.011)	
$GAS_{ab}*GAS_{in}$			0.043** (0.017)	
$MKTP_{ext}$	-0.521 (0.593)	-0.521** (0.210)	-0.267 (0.202)	-
$MKTP_{int}$	1.151*** (0.236)	1.151*** (0.069)	1.092*** (0.064)	-
$SUPA_{ext}$	0.597 (0.547)	0.597*** (0.117)	0.604*** (0.125)	-
$SUPA_{int}$	0.555** (0.222)	0.555*** (0.028)	0.638*** (0.028)	-
Coast dummy	Ok	Ok	Ok	-
Industry-year fe (131)	Ok	Ok	Ok	Ok
Province-year fe (307)	Ok	Ok	Ok	Ok
Province-industry fe (324)	-	-	-	Ok
Clustered std. errors	Ok	Ok	Ok	-
N Cluster	336	336	336	308
N	3685	3685	3685	3556
R^2	0.693	0.693	0.688	0.965

*Note: Standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01. In column (4), the Qinghai province is excluded, as it exhibits a very large variation of its relative abundance measure across the time period. See table 1 for explanatory variable definitions.*

consumption on the provincial level in 2006) and the 2005 natural reserves level as instrumental variables. The exogeneity of the instrumented variables is rejected at the 90 percent confidence level. Columns (2) and (3) show that the IV coefficients' estimates for the energy-linked interaction terms are significant, and larger than in the basic specification. The elasticities of the other explanatory variables prove to be consistent, with the exception of the capital interaction term, which turns insignificant when the coal x electricity interaction is instrumentalized. An additional robustness exercise is performed in regressions (4) and (5), replacing the fixed effects by the linear variables entering the HO interaction terms. Results regarding energy endowments and intensities are unchanged.

TABLE 4: Robustness tests with IV regressions and linear terms
(dependent variable = log of relative output)

	Basic	IV regressions		IV regressions + linear terms	
	(1)	(2)	(3)	(4)	(5)
$SKL_{ab}*SKL_{in}$	0.091** (0.036)	0.078** (0.034)	0.062* (0.035)	0.141*** (0.035)	0.118*** (0.038)
$CAP_{ab}*CAP_{in}$	-0.244*** (0.070)	-0.203* (0.107)	-0.105 (0.129)	-0.345*** (0.129)	-0.202 (0.133)
$ENG_{ab}*ENG_{in}$	0.126*** (0.042)	0.203*** (0.071)		0.209*** (0.005)	
$COAL_{ab}*ELEC_{in}$			0.115*** (0.047)		0.203*** (0.058)
$OIL_{ab}*OIL_{in}$			0.036 (0.048)		0.070 (0.057)
$GAS_{ab}*GAS_{in}$			0.036 (0.052)		0.045 (0.059)
$MKTP_{ext}$	-0.521 (0.593)	-0.591 (0.553)	-0.312 (0.555)	0.115 (0.182)	0.118 (0.187)
$MKTP_{int}$	1.151*** (0.236)	1.200*** (0.228)	1.090*** (0.218)	0.663*** (0.105)	0.645*** (0.109)
$SUPA_{ext}$	0.597 (0.547)	0.597 (0.506)	0.542 (0.541)		
$SUPA_{int}$	0.555** (0.222)	0.504** (0.219)	0.634*** (0.200)		
Industry-year fe (131)	Ok	Ok	Ok	-	-
Province-year fe (307)	Ok	Ok	Ok	-	-
Population & year dummies	-	-	-	Ok	Ok
Linear terms	-	-	-	Ok	Ok
Underidentification (F)	-	98.7	103.20	84.46	100.65
Weak Instrument (F)	-	16.1	96.69	21.91	99.76
Hansen J (p-value)	-	0.11	0.24	0.10	0.19
Endog (p-value)	-	0.04	0.06	0.10	0.01
N Cluster	336	336	336	336	336
N	3685	3685	3685	3685	3685
R^2	0.693	0.323	0.309	0.557	0.525

*Note: Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regressions include a coast dummy and clustered standard errors. Energy interaction terms are instrumented using self-sufficiency and reserves as instruments. The linear terms are all the independent variables entering the interaction terms (plus the log of education). See table 1 for explanatory variable definitions.*

A final robustness test is performed applying the basic specification to a cross-section data set every three years across the 1994-2009 period. Detailed results are reported in table A4 in the Appendix (the corresponding IV regressions are not reported as the exogeneity of the instrumented variables could not be rejected). They confirm the above-commented pattern of results regarding the importance of energy as a determinant of industrial location in China.

6. CONCLUSION

In the context of the growing pressure on world energy resources, the consequences of China's exceptional growth performance on international energy markets have rightly received a lot of attention. What has been more neglected so far is the question of the role of energy resources within China, as a determinant of industrial location across Chinese provinces. If this role is important, then energy policy deserves to be considered at an equal footing with investment or education policies to address the challenges of structural change. The evidence reported in the present paper suggests that it is the case.

We have analyzed the determinants of industrial location in China during the 1999-2009 period using a state-of-the-art empirical specification based on both traditional factor endowment motives and new economic geography determinants of locational choice, including proxies for energy endowment and intensities. In spite of some caveats regarding data quality, in particular estimates of the capital stock per sector and province, the explanatory power of the model has been satisfactory and several robust results have emerged. First, both comparative advantage variables and supply and demand linkages are significant determinants of industrial output per region and sector. Second, within-province linkages effects are larger than between-provinces linkages, suggesting internal trade is subject to transport cost or other trade barriers. Third, total energy endowment is significant and of similar magnitude, if not larger, than traditional factors of comparative advantage such as capital or skilled labour. Fourth, when relying on a disaggregated specification, the coefficient on coal appears as the largest and most significant one among alternative energy sources, which is probably linked to the relatively important transport costs of coal with respect to more footloose alternatives like petroleum. This set of results is consistent with, and strengthens to the emerging literature on the importance of energy endowments as a source of comparative advantage.

It is fair to recognize that the conditions specific to China cast certain doubts upon the precise interpretation of results, given that neither free flow of goods, nor identical technology matrices are confirmed in the Chinese context. As the applied specification does not include estimates of regional and international protectionist measures, room is left for a more profound analysis of interregional trade. With the continuing improvement and expansion of statistics published by the Chinese government, an extension of the model to different technology matrices would potentially be possible. Taking care of the specific role of state-owned enterprises (SOEs) in energy markets and heavy industries is also a promising research avenue.

Finally, note that the abovementioned findings could have an important impact on current and future Chinese environmental policies in two ways. On the one hand, having energy intensive industries concentrating in regions where energy endowments are abundant will most likely weaken the effects of national environmental policies directed towards energy consumption reduction, as the share of energy in production costs increases, thereby exerting a larger influence on firms' location decisions. On the other hand, the important influence and interventionist tendency of local governments, fostering and protecting certain industries, subsidizing heavy industry at which environmental policies are directed, prevents efficiency gains due to specialization and makes policy implementation more difficult. A better understanding of these politico-economic forces is warranted for China to cope with its huge environmental challenges.

APPENDIX

I. Additional Tables and Figures

TABLE A1: Coast-center regional division and province abbreviations

Coast		Center			
Beijing	BJ	Shanxi	SX	Guangxi	GX
Tianjin	TJ	Hebei	HeB	Chongqing	CQ
Liaoning	LN	Inner Mongolia	IM	Sichuan	SC
Shanghai	SH	Jilin	JL	Guizhou	GZ
Jiangsu	JS	Heilongjiang	HLJ	Yunnan	YN
Zhejiang	ZJ	Anhui	AH	Shaanxi	SaX
Fujian	FJ	Jiangxi	JX	Gansu	GS
Shandong	SD	Henan	HeN	Qinghai	QH
Guangdong	GD	Hubei	HuB	Ningxia	NX
Hainan	HN	Hunan	HuN	Xinjiang	XJ

TABLE A2: Average annual growth of industry intensity and provincial abundance in percentages

	Intensity	Abundance
Capital	9.57	9.03
Skilled labour	NA	7.95
Energy	8.09	12.43
Electricity	8.99	10.80
Coal	8.54	12.26
Petroleum	-0.89	1.96
Natural Gas	10.02	16.78
Industry Output	20.45	

TABLE A3*:* Average factor intensities per industry per labour*

	Capital	Skill	Electricity	Coal	Petrol	Natural Gas	Total Energy
Measuring instruments (*measure*)	0.883	12’720	0.508	0.378	0.191	0.096	8.727
Electrical machinery (*elecmachinery*)	1.171	12’405	0.608	0.611	0.222	0.398	11.723
Communication equipment (*commeq*)	1.687	17’636	0.731	0.303	0.251	1.437	11.668
Machinery (*machinery*)	1.009	10’537	0.778	1.454	0.245	0.721	19.478
Transport equipment (*transporteq*)	1.521	14’409	0.869	2.230	0.287	1.210	26.455
Food (manufacture/process.) (*Foods*)	1.841	9’842	1.026	6.931	0.381	0.324	60.858
Textile (*Textiles*)	0.977	7’268	1.264	3.517	0.230	0.170	37.248
Metal products (*Metalmanu*)	1.033	10’075	1.923	1.314	0.382	0.459	28.888
Paper (*Paper*)	2.005	9’766	2.722	21.015	0.485	0.352	174.17
Non-metallic mineral products (*Nonmetlind*)	1.553	8’123	2.985	36.75	1.604	3.845	300.42
Chemical industry (*Chemical*)	2.453	11’275	4.327	23.691	1.293	0.243	213.84
Petro-processing (*Petropro*)	7.353	17’357	4.744	232.11	8.263	27.042	1767.3
Smelting (*smelting*)	3.311	15’032	8.761	47.571	1.281	2.407	418.34

**For construction and unit specification of the variables see Appendix II. Sorted from least to most electricity-intensive industry. Natural gas per labour is multiplied by 100. Energy is expressed in toe.*

TABLE A4: Industry location using the cross-section data set
(dependent variable=log of relative output)

	Pooled 1994-2009	1994	1997	2000	2003	2006	2009
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$SKL_{ab}*SKL_{in}$	0.098*** (0.038)	0.074** (0.034)	0.113*** (0.038)	0.134*** (0.046)	0.105** (0.052)	0.122** (0.047)	0.094** (0.046)
$CAP_{ab}*CAP_{in}$	-0.195*** (0.038)	-0.086 (0.076)	-0.315*** (0.113)	-0.213*** (0.041)	-0.326*** (0.086)	-0.527*** (0.104)	-0.143*** (0.042)
$ENG_{ab}*ENG_{in}$	0.195*** (0.043)	0.176*** (0.039)	0.137*** (0.039)	0.208*** (0.057)	0.233*** (0.063)	0.168*** (0.047)	0.225*** (0.063)
$MKTP_{ext}$	-0.406 (0.490)	-0.468 (0.475)	-0.298 (0.485)	-0.958* (0.577)	-0.455 (0.629)	-0.403 (0.597)	-0.149 (0.634)
$MKTP_{int}$	1.372*** (0.164)	0.983*** (0.156)	1.165*** (0.169)	1.347*** (0.191)	1.547*** (0.184)	1.600*** (0.181)	1.513*** (0.172)
industry-year fe (131)	Ok	-	-	-	-	-	-
province-year fe (307)	Ok	-	-	-	-	-	-
province (27)	-	Ok	Ok	Ok	Ok	Ok	Ok
industry (11)	-	Ok	Ok	Ok	Ok	Ok	Ok
Coast	Ok	Ok	Ok	Ok	Ok	Ok	Ok
Std. errors	clustered	Huber-White	Huber-White	Huber-White	Huber-White	Huber-White	Huber-White
N Cluster	336						
N	2014	336	336	336	336	334	336
R^2	0.703	0.542	0.579	0.619	0.659	0.669	0.655

*Standard errors in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01. See Table 1 for a definition of the variables.*

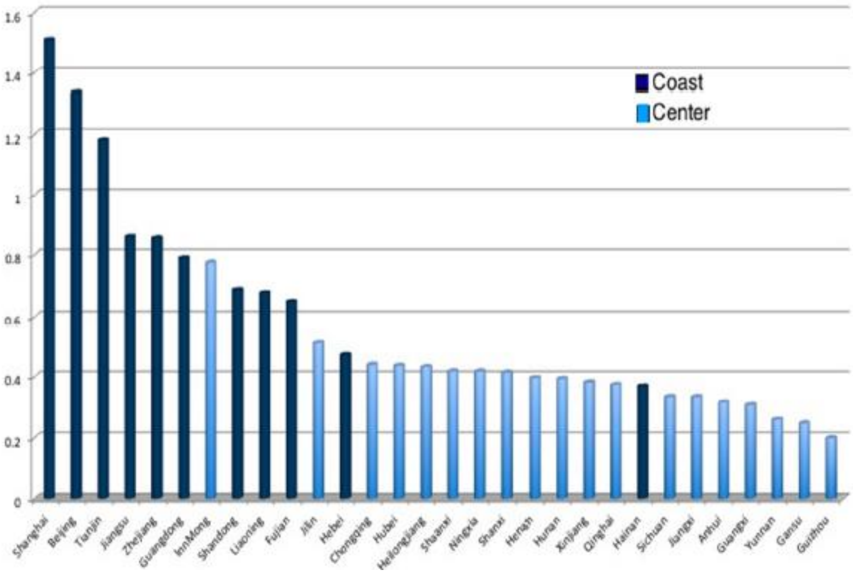

FIGURE A1: GDP per capita in 2009 (thousand RMB)

II. Variable Construction

II.A Factor endowments and intensity variables

All monetary values are in 100 million RMB and deflated with respect to 1971. In the regressions, we have taken the log and then standardized all variables per year over province and industry. Thus, abundance and intensity measures have means of 0 and variance of 1.

Dependent variable: China Industrial Statistical Yearbook.
Output per industry and per province relative to the share of industry *k* and province *p* in total national output.

Energy: China Energy Statistical Yearbook.
Energy abundance is defined as coal (in 10'000 tons), petrol (in 10'000 tons), natural gas (100 million cubic meters) and electricity (in 100 million kwh) production per province expressed relative to the province's population (in 10'000). The energy intensity is defined as consumption per industry expressed relative to the number of workers (in 10'000) per industry. Total energy is the aggregate of abovementioned coal, electricity, petrol and natural gas values converted to toe (ton per oil equivalent, using the standard conversion factors given on www.iea.org/stats/unit.asp) and expressed relative to population for abundance and workers for intensity respectively (both in 10'000).

Capital: China Industrial Statistical Yearbook, China Statistical Yearbook and Wu (2009).
Provincial capital stock values are taken from Wu (2009) and complemented according to the perpetual inventory method using the depreciation rates given in his paper and provincial gross capital formation from the China Statistical Yearbook. Capital intensity is the value of net fixed assets per industry and province divided by the number of workers (in 10'000) taken from the China Industrial Statistical Yearbook.

Skill: China Statistical Yearbook and Banister (2005).
Skill intensity per industry is proxied by the average urban wage in RMB in 2001 per industry, given in Banister (2005). The abundance is measured by the share of the population older than 6[9], with college level or higher educational attainment.

[9] As defined in The China Statistical Yearbook.

II.B Market Potential/Supplier Access

Internal market potential: $$MKTP_{int}^{k,p} = \frac{\sum_{k'=1}^{K} b_p^{kk'} \partial_p^{k'} + b_p^k \lambda_p}{\sqrt{\frac{Area_p}{\pi}}} \quad [A1]$$

External market potential: $$MKTP_{ext}^{k,p} = \sum_{m \neq p}^{R} \frac{\sum_{k'=1}^{K} b_m^{kk'} \partial_m^{k'} + b_m^k \lambda_m}{distance_{mp}} \quad [A2]$$

Internal supplier access: $$SUPA_{int}^{k,p} = \frac{\sum_{k'=1}^{K} a_p^{kk'} \partial_p^{k'}}{\sqrt{\frac{Area_p}{\pi}}} \quad [A3]$$

External supplier access: $$SUPA_{ext}^{k,p} = \sum_{m \neq p}^{R} \frac{\sum_{k'=1}^{K} a_m^{kk'} \partial_m^{k'}}{distance_{mp}} \quad [A4]$$

$b^{kk'}$: Share of industry k output absorbed by industry k'

b^k : Share of industry k output absorbed by final demand so that $b^k + \sum_{k'=1}^{K} b^{kk'} = 1$

$a^{kk'}$: Share of industry k' in the intermediate input of industry k

$\partial_p^{k'} = \frac{Y_p^{k'}}{Y_{China}^{k'}}$: Share of industry k' in province p's output relative to the national output of industry k'

$\lambda_p = \frac{GDP_p}{GDP_{China}}$

$Area_p$: Province size in km^2

$distance_{mp}$: Road distance from province's p capital to province's m capital

The formulas are derived from Midelfart-Knarvik et al (2001), with an elasticity with respect to distance equal to -1, which corresponds to market potential estimates from gravity models of trade. Data used is provided in the 2002 China provincial Input-Output tables. Distances between provinces were measured as the quickest route between provincial capitals on Google maps.

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