Foreign versus Indigenous Innovation and Energy Intensity: Further Research across Chinese Regions

M.J. Herrerias[1]   A. Cuadros[2   D. Luo[3]

[1]University of Birmingham
Department of Economics

[2]Universitat Jaume I
Department of Economics & Institute of International Economics

[3]University of Nottingham
School of Contemporary Chinese Studies

1 September 2014

Abstract

The aim of this work is to analyze the role played by both foreign and indigenous innovation on energy intensity as well as the possible interactions between them across 30 Chinese regions. In addition, we disaggregate non-state investment into the different types of corporate ownership that operate in China, controlling for other relevant factors such as energy price and the share of industry. We examine not only total energy intensity, but also coal, crude oil, natural gas, and electricity in order to provide a complete picture of the energy sector in this country. The empirical model is estimated by panel-corrected standard errors over the period 2006-2010. Our findings indicate that the process of technological change through both foreign and indigenous innovation has been an important mechanism to improve the use of energy resources. However, the interaction between foreign and indigenous innovations is modest. We also observe that non-state investment plays a key role in reducing energy intensity, although both the specific type of ownership and the source of energy also matter. A closer look at regional differences among the transmission grids in China reveals the importance of accounting for the structure of investment and its geographical location.

Corresponding author: M.J. Herrerias, University of Birmingham, Department of Economics, Edgbaston, Birmingham, B15 2TT, United Kingdom.
E-mail address: m.j.herrerias@bham.ac.uk

[2] Email: cuadros@uji.es
[3] Email: d.luo@nottingham.ac.uk

Previous versions of this paper were running under the title: *Ownership Reform, Innovation and Energy Intensity: Further Research across Chinese Regions.*

1. Introduction

The fast process of industrialization has led the Chinese economy to consume a significant amount of energy resources, thereby becoming one of the most important consumers in the world today. However, the exceptional performance of this economy and the rate at which energy is consumed are not free of cost. China is currently facing a new scenario, where environmental pollution as well as problems in the supply of energy are the core of a debate taking place in this country due to their expected consequences on economic growth and the welfare of the population. Nonetheless, such concerns are a relatively recent phenomenon. Indeed, the 11th Five-Year Plan (2006-2010) was the first attempt to promote further reforms in the energy sector. This has been complemented by the 12th Five-Year Plan (FYP) (2011-2015), which set up several key targets to be reached by 2015, such as reducing pollutant emissions and energy consumption per unit of GDP by 17% and 16% respectively. Such a change in energy policies contrasts sharply with the previous period (before 2006) during which China paid little attention to achieving any environmental goals. This can be explained by the fact that energy-saving measures were seen by the Chinese government as a constraint on economic growth. However, relatively recent evidence shows that the Chinese economy can adopt energy-saving measures without interrupting the path toward economic growth (Herrerias et al., [1]). Thus, the key question to be answered is: What types of policies can be adopted by the government to improve energy efficiency and prevent global warming? This paper offers some new insights on this issue.

In the energy economics literature, one of the strongest debates has been focused on energy intensity. This is a simple measure of the degree of efficiency in the use of energy resources, and it is used as a key indicator to design energy policies among the

27   developed and developing countries. Changes in energy efficiency can be attributed to

28   technological progress and sectorial composition (Zhang, [2]; Fisher-Vanden et al., [3];

29   Fisher-Vanden et al., [4]; Liao et al., [5]; Ma and Stern, [6]; Herrerias et al., [12]). On

30   the one hand, there is an agreement in the literature on the role played by the

31   technological progress, however few works have disentangled the specific mechanisms

32   through which it may operate. On the other hand, the effect of the composition effect

33   would depend on the stage of economic development of different countries or regions

34   e.g. moving away from heavy industry sectors towards light industry or vice versa and

35   the shift from agriculture to industry. In this work, we focus on the technique effect,

36   where we distinguish foreign and indigenous innovations as key factors to improve

37   energy efficiency across Chinese regions. This distinction is important because

38   economic policies adopted by the government can affect the economy directly or

39   indirectly, modifying the incentives in the use of energy and stimulating the

40   technological innovation. In the case of the Chinese economy, the open-door policy has

41   increased the efficiency in the allocation of economic resources and enhanced the role

42   played by trade and foreign direct investment as mechanisms for knowledge transfer. In

43   addition, higher efforts towards the alleviation of pollution and improvement of energy

44   efficiency have been made since 2006 for its relevance on the sustainability of

45   economic growth. These policies influence the incentives to innovate through both

46   indigenous and foreign technology.

47   Despite the relevance of foreign and indigenous innovations as sources of

48   technological progress, their potential contribution to the advancement in energy

49   efficiency, as well as the interactions that may exist between them, they have been

50   ignored in the relevant literatures. In this paper, foreign technology is measured by

51   foreign direct investment (FDI) and imports, while indigenous innovations are captured

52　　by patents. On one hand, FDI has been found to be a suitable mechanism for technology

53　　transfer, which might affect productivity through spillover effects and also incorporates

54　　new technologies into the production process through the accumulation of physical

55　　capital. In addition, the presence of multinationals in the host economy may stimulate

56　　competition with local firms, encouraging them to use existing technologies more

57　　efficiently (Sjöholm and Lundin, [8]). In the international trade literatures, imports have

58　　been considered as an important channel for the international diffusion of knowledge

59　　due to the embodied technological progress in capital goods imports (Herrerias and

60　　Orts, [7]). On the other hand, indigenous innovation can emerge from the

61　　aforementioned competition effect and also from the implementation of innovation

62　　policies. They may stimulate the emergence of new discoveries or knowledge, thus

63　　improving efficiency and productivity. However, indigenous innovations could also be

64　　influenced by a country's characteristics, such as the structure of ownership investment,

65　　as it may condition the effectiveness of incentives.

66　　　　In the case of China, the transformation of the state sector and the emergence of new

67　　forms of investment ownership have been one of the fundamental keys to understand

68　　the process of China's transition from a planned to a market economy. The share-

69　　holding program initiated in the mid-1990s became the principal vehicle for

70　　implementing the ownership reform of the State-owned enterprises (SOEs) by the

71　　government (Jefferson and Su, [9]). This program was developed in response to the

72　　government's concerns about the benefits that could bring about by the multinationals

73　　and has consequently triggered the emergence of new forms of investment as well as

74　　international joint-ventures between foreign and Chinese firms in China. The private

75　　sector now accounts for more than half of the total industrial output, compared with

76　　barely more than a quarter of it in 1998, and it operates much more efficiently than the

public sector (Dougherty et al., [10]). However, in spite of the rapid growth in foreign and domestic non-state investment activities, the share of state ownership in physical capital still predominates in the Chinese economy

The net effect of technological progress might depend on the interaction between foreign and indigenous innovations as well as on economic geography. First, foreign and indigenous technology in an economy might interact with each other to create some positive spillovers, e.g., local firms can learn from foreign enterprises. However, competition coming from the presence of foreign companies can also lead to a crowding out effect, since the less productive domestic firms may exit from the market, only the most productive being the ones that survive. Secondly, recent contributions from the economic geography literatures have revealed that the location of economic activity as well as its degree of concentration in the same industry also matter in the process of accumulation of knowledge. Such knowledge spillovers would be higher if the firms are located close to each other and are operating within the same industry and region. Therefore, when explaining the process of knowledge transfer coming from foreign and indigenous innovation in China, geography may play a key role due to the higher concentration of economic activities along the coastal area at the expense of Western regions. Thus, the outcomes from the interaction between foreign and indigenous innovation are, a priori, unclear.

In this context, the aim of this work is to provide new insights about three main questions. First, what is the differential role played by foreign and indigenous technology (as well as the interaction between them) on the diffusion of knowledge spillovers with an energy reducing effect? Second, since both location and geography proximity matter in the process of accumulation of knowledge: Are there significant differences in energy efficiency across Chinese regions? Third, is the structure of

102 corporate ownership a relevant factor to be considered in explaining the reduction in

103 energy intensity? We examine these issues for all sources of energy in the case of

104 Chinese regions over the period of 2006-2010.

105 The rest of the paper is organized as follows. Section 2 provides an overview of the

106 literature. Data and methodology are described in Section 3. Results are reported in

107 Section 4, while conclusions are drawn in Section 5.

108 **2. Literature Review**

109 Energy efficiency depends on both technological innovations and the accumulation

110 of physical capital. Technological innovations in an economy can come from outside of

111 the country through foreign direct investment and imports or from inside through

112 domestic innovation efforts. First, foreign direct investment plays a double role in the

113 process of energy efficiency improvement. On one hand, it is a potential source of

114 technology transfer and on the other hand it is investment from abroad, which

115 incorporates new technologies into the production process, both of which create

116 knowledge spillovers into the economy (Keller, [11]; Fisher-Vanden et al., [4];

117 Herrerias et al., [12]; Huber, **Error! Reference source not found.**; Hübler, [13]; Hübler

118 and Keller, [14]; Kumar, [15]; Ma and Stern, [6]; Perkins and Neumayer, [16]; Sahu

119 and Narayama, [17]). Imports can also affect energy efficiency by stimulating

120 competition between foreign and local firms (Amiti and Konings, [1]; Herrerias and Orts,

121 [7],). Second, domestic innovation depends, however, on different factors such as the

122 technological capabilities of the home country, investment ownership, the role played

123 by the government in gaining access to foreign technology, as well as local efforts to

124 promote the learning process coming from such technology, among other relevant

125 factors (Audretsch and Feldman, [29]). Thus, countries, especially the developing ones,

126 also have to rely on indigenous innovation efforts to promote economic development

127　(Fu and Gong, [20]). This capability for domestic innovation seems to play a central

128　role in mastering new technologies and adapting them to local conditions (Lall, [21]).[1]

129　In both sources of technology – foreign and indigenous – the interaction between them

130　and their geographical distribution are relevant factors that should be considered in

131　improving energy efficiency.

132　On the one hand, there are theoretical arguments and empirical evidences have

133　proved that indigenous and foreign innovation efforts can be complementary (Fu et al.,

134　[41]). Such an effect could arise if, for instance, the presence of a multinational can

135　bring knowledge transfer into local firms, which may stimulate both innovation activity

136　and absorptive capacity (Li, [22]; Fisher-Vanden et al., [4]). In addition, information

137　provided by local firms can be very useful as they are more familiar with the local

138　market and the potential of foreign technology (Zhou and Xin, [23]). Positive

139　interactions between foreign and local firms were found by Girma et al. [24], who

140　showed that multinationals played a significant role in restructuring Chinese state-

141　owned enterprises by introducing new technology and better managerial skills through

142　joint-ventures. While Harrison and Rodriguez-Clare [25] argued that firms with foreign

143　participation in China are of higher level of technology competence. In the case of

144　energy sector, Fu and Zhang [26] illustrated that the simultaneous adoption of both

145　technology transfer and indigenous innovation would be suitable for the technological

146　progress and the development of green technology sectors in developing countries.

147　More recently, however, Sjöholm and Lundin [8] did not find any positive impact of

148　FDI on R&D in domestically-owned firms, and Perkins and Neumayer [16] argued that

149　increased competitive pressures from multinationals may reduce the profitability of

150　domestic firms and delay their investments in more energy-efficient plants. Moreover,

---

[1] In China, there has been a change in the Chinese government's approach with greater emphasis on indigenous technology development and a more hesitant approach toward FDI (see Sjöholm and Lundin, [8]).

151 those domestic firms that are unable to compete on the basis of technology leadership,

152 they might pursue a cost minimization strategy and devote little resource in

153 environment-efficient designs.

154   In this paper, we argue that the mixed evidence about the interaction between foreign

155 and indigenous innovation can be explained by two factors. First, spillovers associated

156 with both foreign transactions and indigenous innovation capabilities might be

157 geographically localized (Jaffe et al., [27]). Second, empirical evidence indicates that

158 innovation capabilities seem to vary by type of ownership. In the case of China, Wang

159 and Lin [28] recently emphasized the need to account for both regional factors and firm-

160 level characteristics in order to analyze the dynamics of innovation.

161   On the other hand, the literature on knowledge spillovers and the geography of

162 innovation highlights the fact that geography matters in transmitting knowledge

163 (Audretsch and Feldman, [29]). Proximity enhances the ability of firms to exchange

164 ideas thereby allowing them to increase the accumulation of knowledge, and reducing

165 the uncertainty in the market where they operate. For these firms, being spatially

166 concentrated in areas where resources are abundant reduces the cost of scientific

167 discoveries and commercialization (Feldman, [30]). However, empirical evidence

168 suggests that these knowledge externalities are higher when firms are located in similar

169 industries and geographically concentrated areas (Audretsch and Feldman, [19], Xu and

170 Sheng, [31]; Girma and Gong, [32]; Girma et al., [24]; Ivarsson and Alvstam, [33];

171 Sjöholm and Lundin, [8]).

172   Regarding the implications of ownership structure, Du et al. [34] highlighted the

173 extraordinarily heterogeneous ownership structure in China[2] and argued that indigenous

174 Chinese firms of different ownership behaved differently with respect to imitation,

---

[2] See Figure 1.

7

175 innovation and competition, and displayed different technological capabilities for

176 knowledge absorption from the presence of foreign firms. Jefferson et al. [35] found

177 that ownership diversification during the period 1994-1999 led to the emergence of

178 high-intensity R&D performers that exhibited substantial innovation capabilities. They

179 further argued that foreign, private, and share-holding enterprises are the ones that made

180 the greatest innovation efforts in China. In similar terms, Girma et al. [42] concluded

181 that private and collectively-owned firms with foreign capital participation tended to

182 innovate more than other types of ownership. In the case of energy sector in China,

183 Fisher-Vanden et al. [3] found that ownership reform in the enterprise sector is one of

184 the principal drivers of China's declining energy intensity. Their results found that

185 foreign-invested firms were consistently more energy-efficient than their state-owned

186 counterparts. Sinton and Fridley [36] concluded that the shift from state-owned to

187 collective, private, and foreign-invested ownership has played an important role in

188 improving energy efficiency in China since 1996. Recently, Herrerias et al. [12] pointed

189 out that both foreign and non-state investments had played a leading role in the decline

190 of energy intensity across 28 Chinese regions, whereas no evidence of a positive

191 contribution of the state investment was identified. However, that work ignores

192 indigenous innovation and the different types of investment ownership that operate

193 through the transmission grids. This paper fills this gap in the relevant literature.

194 **3. Data and Methodology**

195   **3.1 Data**

196   This paper investigates the role played by both foreign and indigenous innovation as

197 key mechanisms to reduce energy intensity as well as the structure of investment

198 ownership in China over the period of 2006-2010. In doing so, the foreign technology is

199 measured by foreign direct investment and imports, while indigenous innovations are

200 captured by patents. In addition, we disaggregate total investment in fixed assets into

201 state-owned, collectively-owned, cooperative, joint-venture, limited liability, share-

202 holding, private, self-employed, and foreign investment, which are measured as

203 percentages of GDP. This disaggregation provides a complete picture of this

204 phenomenon and its relevance to the study of energy intensity across 30 Chinese

205 regions. FDI, imports[3] and the number of patents have been included to separate the

206 effect of foreign innovation from that of domestic innovation. Patents can be regarded

207 as a good reflection of indigenous innovation efforts as they usually contain

208 technological improvements and/or innovative ideas that at least have to be new in the

209 country. Therefore, these variables are associated with the aforementioned technique

210 effect. We investigate not only total energy intensity (Total energy consumption/GDP),

211 but also other relevant sources of energy such as coal, electricity, petroleum, and natural

212 gas. These too are expressed in intensities.

213   To provide robust estimates, other control variables such as the share of industry[4]

214 (expressed as share of GDP) and energy prices (electricity and oil prices) are also

215 included. The share of industry is related to the composition effect, while an increase in

216 energy prices is an additional factor that may reduce energy intensity (Zhao et al., [37];

217 Wu, [38]). Since the progressive liberalization of the pricing system, the increase in

218 energy prices has led to a reduction in energy consumption, thereby improving the

219 energy intensity ratio (Fisher-Vanden et al., [3]; Herrerias et al., [12]). In the case of the

220 Chinese economy, information about energy prices is rather limited. To overcome this

221 problem, we use electricity price for total energy, coal, and natural gas intensity, while

222 oil price is used for oil intensity. We are aware of the drawbacks of this procedure but,

---

[3] We have introduced imports into the analysis since, on average, capital goods represented around 70% of the overall imports over the period 1962-2004. See Herrerias and Orts [7].

[4] Given the lack of data, we cannot disaggregate this variable in greater detail at the provincial level in China.

223 at the moment, it is the only information available in the Chinese statistics. The source

224 of data is from the National Bureau of Statistics of China (NBS).[5]

225 As been mentioned above, taking the Chinese regional dimension into account is

226 essential. In this paper, we employ two different approaches to deal with regional

227 heterogeneity. The first is based on the inclusion of a set of dummy variables in the case

228 of those provinces that belong to each of the six transmission grids that exist in China

229 (see Figure 3). We then make an interaction effect of this dummy variable with each of

230 the ownership structure considered in this work. This allows us to investigate the

231 differential effect by type of ownership across different transmission grids. The second

232 approach to overcome the heterogeneity of the Chinese provinces is to estimate the

233 model allowing for heteroskedasticity.

234 Tables 1 and 2 provide a summary of statistics of investment ownership and energy

235 intensity variables. From there, we can observe that state-ownership predominates over

236 other types of investment, even in a period that is characterized by a process of

237 liberalization. The period (2006-2010) was not chosen at random, but rather it attempts

238 to capture the period of time when most of the reforms took place. Moreover, since

239 2006 Chinese statistics offer a more detailed view of this investment structure, with

240 improved information coming from the NBS. Prior to 2006, part of the investment was

241 classified as "other types of investment", without knowing what type of investment it

242 belonged to. With this change, we have a clearer picture of each type of investment

243 ownership. In fact, there is a growing trend for domestic investment to take the form of

244 private and limited liability (10.3% and 15.1% respectively on average for the period

245 under consideration), and also share-holding investment reaches 27.9% in some regions,

---

[5] See Data Appendix for a detailed description of each variable.

246 even though on average it represents only 4% of the ownership.[6] This is not unusual,

247 given the aforementioned heterogeneity, as shown in Figure 1 (a-i). It plots each type of

248 investment ownership on a map of the Chinese regions in 2010. Table 2 shows

249 information about energy intensity for both total and each source of energy considered.

250 We can see that oil displays the highest percentage (16.4%), and it is relatively close to

251 the more traditional sources of energy used by China, like coal and electricity (14.1%

252 and 13.7%).

253 **3.2. Methodology**

254 Panel data methods were applied in order to consider the heterogeneity of Chinese

255 regions over time. Within the battery of estimators available, we selected the one

256 proposed by Beck and Katz [39], the so-called *panel-corrected standard errors*. The

257 attractiveness of this approach, according to these authors, is that common techniques

258 applied to time-series cross-section (TSCS) data produce incorrect results, in particular

259 with regard to the accuracy of the standard errors.

260 It is well-known that OLS becomes problematic in panel data techniques, when one

261 or more Markov assumptions are not satisfied. In the presence of temporal and spatial

262 correlation in the error term as well as heteroskedasticity, Parks [40] proposed a method

263 to deal with these problems based on GLS. However, the use of this method can lead to

264 dramatic underestimates of parameter variability in common research due to the

265 assumptions made about the structure of the error term, such as it is known. The

266 alternative often used by researchers is to apply the Feasible Generalized Least Squares

267 (FGLS), which relaxes the assumption of the known errors structure and uses estimates

---

[6] Another reason for considering this time period for the analysis is the fact that we aim to investigate the effect of both foreign and indigenous technology on energy intensity. However, the latter has become relevant since the People's Party Congress in 2006, where the focus of the Five-Year Plan relied on technology development. The ambition was to make the People's Republic of China an innovation-driven economy. We are aware of the short sample for the analysis, and therefore results should be interpreted with caution.

268 of the error process. However, when there are a large number of parameters to estimate,

269 FGLS causes estimates of the standard errors of the estimated coefficients to understate

270 their true variability by between 50% and 300%, according to Monte Carlo simulations

271 (Beck and Katz, [39]). To solve the apparent problem, Beck and Katz [39] suggested

272 correcting the formula for the sampling variability of the OLS estimates, which is given

273 by the square roots of the diagonal term.

274   Thus, the standard formulation of TSCS models under the assumption of poolability

275 is as follows:[7]

276     $$y_{it} = \boldsymbol{X}_{it}\beta + \lambda_i + \gamma_t + \epsilon_{ij} \quad i = 1, \dots N; t = 1 \dots T \qquad\qquad (1)$$

277     $$\epsilon_{i,t} = \rho_i \epsilon_{i,t-1} + \nu_{i,t} \qquad\qquad (2)$$

278 where $\boldsymbol{X}_{it}$ is a vector of k exogenous variables, and observations are indexed both by

279 unit (i) and by time (t).[8] y_{it} denotes the vector of observations on the dependent

280 variable, λ and γ are individual and time effects respectively and $\nu_{i,t}$ are variables that

281 are independently distributed over time. Thus, Parks' method, which is based on FGLS,

282 takes into account panel heteroskedasticity and unit-specific serial correlation (ρ_i).

283 **4   Results**

284   In Table 3, we present the results for each type of investment ownership as well as

285 for imported technology, and their effects on energy intensity for both total energy and

286 the different sources of energy considered in this work. In Table 4, besides the structure

287 of investment, we also account for the effect of indigenous innovation. Tables 5 and 6

288 present the results of the relationship between foreign and indigenous innovation on

289 energy intensity. Finally, Table 7 shows a summary of the results coming from the

---

[7] Given the small sample in our data, the issue of heterogeneity in the beta coefficient is not considered. In addition and for the same reason, we only contemplate the static version of the panel data.

[8] We tested for endogeneity in all our estimated models. However, we did not find any symptoms of this problem, thereby making the application of instrumental variables unnecessary. Furthermore, due to the small sample and unbalanced panel, panel cointegration techniques were not applied. This method requires a longer period to obtain robust estimates.

290 spatial dimension.[9] The first four columns of these tables report the results for "Total

291 Energy Intensity", while the others show the findings for "Coal", "Electricity", "Gas",

292 and "Oil" intensity.

293   Recall that the technique effect is captured by both foreign and indigenous

294 innovation. The foreign technology is comprised with FDI and imports, while

295 indigenous innovations are represented by patents. According to our results (Table 3

296 and 4), both foreign and indigenous technology matter in the process of energy

297 efficiency improvement. However, this effect could be influenced by the source of

298 energy under consideration in the case of foreign technology. On the one hand, our

299 findings show that foreign investment[10] could reduce total energy intensity and coal

300 intensity. This is explained by the fact that China is coal dependent and also because the

301 coal industry was among the first energy sectors opened up for foreign entry with the

302 aim of bringing in advanced expertise and technology. On the other hand, imports

303 improve total energy efficiency in China as well as for the electricity sector. The

304 knowledge transfer through openness seems to play an important role in this industry. In

305 addition, the electric power cuts in the majority of regions during the summer period,

306 and the need to import energy from abroad, can partially explain these results.

307   The effect of indigenous innovation is reported in Table 4. As can be observed,

308 patents are always significant and with a negative sign.[11] These findings indicate that

309 compared with technology transfer via FDI and imports, domestic innovation seems to

310 play a more significant role in the diffusion of energy-saving technologies. This is

311 consistent with the finding of Fu and Gong [20] that indigenous technology may result

---

[9] Appendix A reports the complete statistical results for each type of investment ownership.

[10] We are aware that other types of ownership might contain some foreign participation Jointly with the domestic one. However, we are not able to distinguish the percentage of foreign participation due the lack of data. Thus, for the sake of simplicity we attribute the technique effect to foreign investment and imports.

[11] We have to keep in mind that most of the patents still come from the state sector (see Fu and Gong, 2011; Li, 2011).

312 in higher efficiency gains in certain sectors. Li [22] further argues that to use foreign

313 technology better, China should enhance its absorptive capacity through its own R&D

314 activities.

315 An interesting hypothesis to be tested is the relationship between foreign and

316 indigenous technology, and energy intensity. In doing so, we define an interaction effect

317 that is the product of foreign direct investment and patents (Table 5), and then we define

318 another one that is the product of imports and patents (Table 6). This empirical strategy

319 allows us to distinguish the two components of our foreign technical effects and their

320 relation with indigenous innovation. Our results show that the combination of foreign

321 and domestic technology as drivers of energy-saving measures only matters with regard

322 to total and coal intensity. By contrast, it seems that foreign and indigenous innovations

323 have a crowding-out effect on oil energy intensity. The limited impact of the interaction

324 between foreign and domestic technology in China is also found in Sjöholm and Lundin,

325 [8]. One of the possible explanations for this outcome is the long adaption process of

326 foreign technology by domestic firms and the lack of coordination among the different

327 stakeholders (Karplus, [42]). In addition, as previously mentioned, the spillovers can

328 have certain effect within the same industry or region, but no effect across regions.

329 As can be observed in Tables 3 and 4, when it comes to explain the evolution of

330 energy intensity across Chinese regions, the type of investment ownership matters.

331 Empirical results from Tables 3 and 4 show that state investment does not seem to help

332 in the reduction of energy intensity in any case since, as whenever significant, it shows

333 a positive sign. This effect is more evident among the Northern and Central provinces in

334 China in the case of coal and electricity intensity (Table 7). These results are similar to

335 the ones obtained by Sinton and Fridley [36] and Herrerias et al. [12] for China. These

336 studies confirm that a shift from state-owned investment plays a key role in improving

14

energy efficiency in this country. Among non-state investments, there are notable differences for each type of investment, geographical transmission grid and source of energy. We find that both self-employed and foreign investments[12] are beneficial to improve total energy efficiency (Tables 3 and 4). However, only the latter shows a significant effect in the East, North and South of China (Table 7). In the case of coal, in addition to foreign investment, share-holding investment is also found to play a significant role in reducing coal intensity, especially in the Southern provinces (Table 7). The role played by share-holding investment on coal intensity is robust to different specifications (Table 4) and can be explained by its significant participation in this industry. For electricity intensity, we find that only private investment has a significant negative influence. Once the economic geography is taken into account, we observe that this phenomenon is concentrated in the North-East of China (Table 7). This result can be explained by the dominant presence of the state sector in the electricity market. In the case of gas and oil intensity, cooperative, self-employed, joint-ventures, and private investments are useful conduits for the improvement of gas efficiency resources (Tables 3 and 4). Cooperative investment has a major impact in the North-East of China, while self-employed, joint-ventures and private investments seem to be more significant in the North-East, East and South of China (Table 7). However, in the case of oil intensity, cooperative investment appears to be significant in Central regions, while the effects for self-employed, joint-ventures and private investments predominate more in the North, Central and South, except in private investments that are also relevant in the Eastern area.

These results could be explained by the fact that the National Development and Reform Commission (NDRC) is making all-out efforts to encourage private investment

---

[12] Kumar [15] and Sahu and Narayama [17] for India and Fisher-Vanden et al. [3][4] for China confirm that foreign companies are more efficient in the use of energy resources than their domestic counterparts.

361 in more heavily state-controlled and monopolized sectors, such as electricity, oil, and

362 natural gas, in order to make the economy more dynamic and to reduce the presence of

363 the state sector. Moreover, in recent years, the Chinese government has invited foreign

364 joint-ventures to bid for shale gas exploration licenses to develop China's potential

365 reserves and to mitigate its dependence on imported coal and oil. Relatively recent

366 infrastructure projects like the West-East Electricity Transfer Project that aims to

367 increase the generation capacity in Northern and Central provinces and the "West-to-

368 East Gas Transmission Pipe Line" in the Southern and Eastern areas would help to

369 improve the efficiency of energy resources. This strategy can allow China to become

370 more self-sufficient in energy.

371 The above-mentioned results give support to the so-called technical effect, and

372 highlight the importance of the reforms in the structure of investment ownership as well

373 as the need to strength both domestic and foreign innovation in order to improve energy

374 efficiency in China. In all the specifications, the composition effect, captured by the

375 share of the secondary sector over GDP, shows the expected sign, namely, in all the

376 cases where it is significant, industry has a positive sign, except in gas intensity. This

377 result indicates that further improvements in energy intensity can be achieved through

378 sectoral decomposition, for example by shifting toward less energy-intensive sectors.

379 The Chinese economy depends on industrial performance which consumes a significant

380 amount of coal. The increasing relevance of the service sector is a challenge to balance

381 the economy for the sustainability of regional growth and a better use of energy

382 resources.

383 Finally, Chinese energy prices are found to be an additional source of improvement

384 in the use of energy resources per unit of output across regions in the case of total

385 energy intensity, gas, and coal intensity when imports are included in the model as a

386 source of technological transfer (Table 3), and total energy intensity and coal intensity

387 when domestic innovations are considered (Table 4). However, we found that in oil

388 intensity, oil prices are not significant (Tables 3 and 4) and in electricity intensity its

389 price has a positive sign. These unexpected findings might indicate that a liberalization

390 of energy prices in China could improve energy efficiency, and therefore further

391 reforms are required in this sector.[13]

392 **4. Conclusions**

393 Suitable policies for the improvement of energy efficiency in China have received

394 considerable attention among economists and policy-makers owing to their significant

395 implications for climate change and environmental protection. Changes in energy

396 intensity can be attributed to both technological progress and industrial composition.

397 However, a limited number of studies have identified the precise channels through

398 which these effects may operate.

399 In this paper, we argue that both indigenous and foreign innovations play an

400 important role in the diffusion of knowledge spillovers with an energy-reducing effect

401 in this country. However, this externality may vary depending on both of the structure

402 of the investment as well as its geographical location. Our findings corroborate the

403 importance of accounting for these two factors when analyzing the dynamics of energy

404 intensity in China. The fact that geography matters in the process of transmission of

405 knowledge is not surprising due to the high level of heterogeneity in the regional

406 distribution of economic activity and the uneven distribution of the different types of

407 firms across China. To the best of our knowledge, this is the first paper to address this

408 question.

---

[13] See Herrerias et al. [12], where it is found that international crude oil price is an additional factor in reducing energy intensity with different specifications.

409   Our empirical analysis is performed across 30 Chinese regions over the period of

410   2006-2010 by using panel data techniques. The results obtained suggest, on one hand,

411   that both domestic and foreign technology play an important role in improving the use

412   of energy resources. However, the former seems to play a leading role in such process.

413   In addition, the interaction between foreign and domestic technology to improve energy

414   efficiency is quiet modest, indicating the need to promote not only both foreign and

415   indigenous technology, but also to create the mechanisms in domestic firms that can

416   facilitate the assimilation and implementation of foreign technology in their production

417   process. On the other hand, our estimates indicate that the specific type of investment

418   ownership matters when it comes to explain the reduction in energy intensity. We find

419   that state investment plays a minor role in reducing any source of energy intensity in

420   China. Non-state investment is, by far, a more important element. More specifically, we

421   find that private investment plays an important role in this process in all sources of

422   energy except in coal intensity. Cooperative and joint-ventures seem to be significant in

423   reducing gas and oil intensity, while share-holding investment reduces mainly coal

424   intensity. Foreign investment seems to be relevant for total and coal energy intensity.

425   However, once we consider the regional heterogeneity and we estimate the differential

426   effect of investment ownership, we observe that most of the non-state investment has

427   greater effects in the Eastern and Southern provinces when compared with the Central

428   and Western ones. For the vast North and Western regions, limited progress has been

429   made in improving all sources of energy efficiency among various ownership structures.

430   This is partially because of the state's dominant position in these regions and partially

431   because of their relatively affluent reserves of resources. Hence, according to our

432   results, what matters in reducing energy intensity is not only the type of investment

433   ownership, but also its geographical location.

434   Finally, the share of industry (which captures the composition effect) is mainly

435   positive, thereby indicating that there is much room for improvement in the use of

436   energy resources by promoting changes in the sectorial composition. We also find that,

437   in most of the cases, increases in energy prices reduce energy intensity.

438   To sum up, energy policies that aim to promote foreign and domestic innovations as

439   well as an increase in the presence of the non-state sector across the Chinese provinces

440   may improve energy efficiency, thereby contributing to environmental protection both

441   in China and worldwide.

442   **References**
443

444   [1]   Herrerias, M.J., Joyeux, R. and Girardin, E. Short- and Long-run Causality

445   Between Energy Consumption and Economic Growth: Evidence Across Regions

446   in China. *Applied Energy* 2013b:112:1483-1492.

447   [2]   Zhang, Z. Why did the energy intensity fall in China's industrial sector in the

448   1990s? The relative importance of structural change and intensity change, *Energy*

449   *Economics* 2003:25:625-638

450   [3]   Fisher-Vanden, K., Jefferson, G. Liu, H. and Tao, Q. What is driving China's

451   decline in energy intensity? *Resource and Energy Economics* 2004:26:77-97.

452   [4]   Fisher-Vanden, K., Jefferson, M. Jingkui, and Jianyi, X. Technology development

453   and energy productivity in China, *Energy Economics* 2006:28:690-705.

454   [5]   Liao, H., Fan, Y. and Wei, Y. What induced China's energy intensity to fluctuate:

455   1997-2006*? Energy Policy* 2007:35:4640-4649

456   [6]   Ma, C. and Stern, D. China's Changing Energy Intensity Trend: a Decomposition

457   Analysis. *Energy Economics* 2008:30:1037-1053

458   [7]   Herrerias M.J. and Orts, V. Imports and Growth in China. *Economic Modeling*

459   2011:28:2811-2819

460   [8]   Sjöholm, F. and Lundin, N. Foreign Firms and Indigenous Technology

461   Development in the People's Republic of China. *Asian Development Review*

462   2013:30:49-75.

463   [9]   Jefferson, G. and Su, J. Privatization and Restructuring in China: Evidence from

464   Shareholding Ownership, 1995-2001. *Journal of Comparative Economics*

465   2006:34:146-166.

466   [10]   Dougherty, S., Herd, R. and He, P. Has a private sector emerged in China's

467   industry? Evidence from a quarter of a million Chinese firms, *China Economic*

468   *Review* 2007:18:309-334.

469   [11]   Keller, W. International Technology Diffusion. *Journal of Economic Literature*

470   *XLII*, 2004:752-782.

471   [12]   Herrerias, M.J., Cuadros, A. and Orts, V. Energy Intensity and Investment

472   ownership across Chinese Provinces. *Energy Economics* 2013a:36:286-298

473   [13]   Hübler, M. Technology Diffusion under Contraction and Convergence: A CGE

474   Analysis of China. *Energy Economics* 2011:33:131-142.

475   [14]   Hübler, M. and Keller, A. Energy Savings via FDI? Empirical Evidence from

476   Developing Countries. *Environment and Development Economics* 2010:15:59-80.

477   [15]   Kumar, A. Energy Intensity: A Quantitative Exploration for Indian

478   Manufacturing. Indira Gandhi Institute of Development Research, Mumbai

479   2003:65

480   [16]   Perkins, R. and Neumayer, E. Transnational Linkages and the Spillover of

481   Environment-Efficiency into Developing Countries. *Global Environment Change*

482   2009:19:375-383.

483   [17]   Sahu, S. and Narayanan, K. Determinants of Energy Intensity: A preliminary

484   investigation of Indian manufacturing. MPRA Paper No. 16606, August 2009

485   [18]   Amiti, M. and Konings, J. Trade liberalization, intermediate inputs and
486   productivity: evidence from Indonesia. *The American Economic Review* 2007:97:
487   1611–1638

488   [19]   Audretsch, D. and Feldman, M. R&D Spillovers and the Geography of Innovation
489   and Production. *American Economic Review* 1996:86:(4):253-273.

490   [20]   Fu, X. and Gong, Y. Indigenous and Foreign Innovation Efforts and Drivers of
491   Technological Upgrading: Evidence from China. *World Development* 2011:39:
492   1213-1225

493   [21]   Lall, S. Technological Capabilities and Industrialization. *World Development*
494   1992:20:165-186.

495   [22]   Li, X. Sources of External Technology, Absorptive Capacity, and Innovation
496   Capability in Chinese-Owned High-Tech Enterprises. *World Development*
497   2011:39:1240-1248.

498   [23]   Zhou, Y. and Xin, T. An Innovative Region in China: Interaction Between
499   Multinational Corporations and Local Firms in a High-Tech Cluster In Beijing.
500   *Economic Geography* 2003:79:129-152.

501   [24]   Girma, S., Gong, Y. and Görg, H. What Determines Innovation Activity in
502   Chinese State-owned Enterprises? The Role of Foreign Direct Investment. *World*
503   *Development* 2009:37:866-873.

504   [25]   Harrison, A. and Rodriguez-Clare, A. Trade, FDI and Industrial Policy for
505   Developing Countries. *Handbook of Development Economics vol. 5, Chapter 63*
506   2010:4039-4124.

507   [26]   Fu, X. and Zhang, J. Technology Transfer, Indigenous Innovation and
508   Leapfrogging in Green Technology: the Solar-PV Industry in China and India.
509   *Journal of Chinese Economic and Business Studies* 2011:9:329-347.

510   [27] Jaffe, A., Trajtenberg, M. and Henderson, R. Geographic Localization of
511   Knowledge Spillovers as Evidenced by Patent Citations. *Quarterly Journal of*
512   *Economics* 1993:63:577-598.

513   [28] Wang, C. and Lin, G. Dynamics of Innovation in a Globalizing China: Regional
514   Environment, Inter-Firm Relations and Firm Attributes. *Journal of Economic*
515   *Geography* 2013:13:397-418.

516   [29] Audretsch, D. and Feldman, M. Knowledge Spillovers and the Geography of
517   Innovation. *Handbook of Regional and Urban Economics, vol. 4. Elsevier* 2004.

518   [30] Feldman, M. The Geography of Innovation. Kluwer Academic, Boston 1994.

519   [31] Xu, X. and Sheng, Y. Are FDI Spillovers Regional? Firm-Level Evidence from
520   China. *Journal of Asian Economics* 2012:23:244-258.

521   [32] Girma, S. and Gong, Y. FDI, Linkages and the efficiency of State Owned
522   Enterprises in China. *Journal of Development Studies* 2008:44:728-749.

523   [33] Ivarsson, I. and Alvstam, C. The Effects of Spatial Proximity on Technology
524   Transfer from TNCs to Local Suppliers in Developing Countries: The Case of AB
525   Volvo in Asia and Latin America. *Economic Geography* 2005:81:83-111.

526   [34] Du, L., Harrison, A. and Jefferson, G. Do Institutions Matter for FDI Spillovers?
527   The Implications of China's Special Characteristics. *Working Paper 16767,*
528   *National Bureau of Economic Research* 2011.

529   [35] Jefferson, G., Hu, A., Guan, X. and Yu, X. Ownership, Performance and
530   Innovation in China's Large-and Medium Size Industrial Enterprise Sector. *China*
531   *Economic Review* 2003:14:89-113.

532   [36] Sinton, J. and Fridley, D. What Goes Up: Recent Trend in China's Energy
533   Consumption. *Energy Policy* 2000:28:671-687.

534   [37] Zhao, X., Ma, C. and Hong, D. Why Did China's Energy Intensity Increase

535   During 1998-2006: Decomposition and Policy Analysis. *Energy Policy*

536   2010:38:1379-1388.

537   [38] Wu, Y. Energy Intensity and Its Determinants in China's Regional Economies,

538   *Energy Policy* 2012:41:703-711

539   [39] Beck, N. and Katz, J. (). What to do and not to do with Time-Series Cross-Section

540   Data, *The American Political Science Review* 1995:89:634-647.

541   [40] Parks, R. Efficient Estimation of a System of Regression Equations When

542   Disturbances Are Both Serially and Contemporaneously Correlated. *Journal of*

543   *American Statistical Association* 1967:62:500-509.

544   [41] Fu, X., Pietrobelli, C. and Soete, L. The Role of Foreign Technology and

545   Indigenous Innovation in the Emerging Economies: Technology Change and

546   Catching Up. *World Development* 2011:39:1204-1212.

547   [42] Karplus, V. J. (), Innovation in China's energy sector, Working Paper for the

548   program on energy and Sustainable Development, Centre for Environmental

549   Science and Policy, Stanford University 2007.

550

551

552 **Data Appendix**

553 **GDP:** Gross Regional Product (100 Million Yuan). This refers to the final products
554 at market prices produced by all resident units within a country (or a region) over a
555 certain period of time.

556 **Industry:** Secondary Industry/GDP. This refers to mining and quarrying,
557 manufacturing, production and supply of electricity, water and gas, and construction.

558 **Energy Intensity Total**: This refers to the total energy consumption in each region
559 divided by GDP.

560 **Energy Intensity Coal:** This refers to coal consumption divided by GDP.

561 **Energy Intensity Electricity:** This refers to electricity consumption divided by
562 GDP.

563 **Energy Intensity Petroleum:** This refers to oil consumption divided by GDP.

564 **Energy Intensity Natural Gas:** This refers to natural gas consumption divided by
565 GDP.

566 **Patent (Number of Applications Accepted and Granted**): This is an abbreviation
567 for the patent right and refers to the exclusive right of ownership by the inventors or
568 designers of the creation or inventions, which is issued by the patents office after the
569 due process of assessment and approval in accordance with Patent Law. Patents are
570 granted for inventions, utility models, and designs. This indicator reflects the
571 achievements of S&T and design with independent intellectual property.

572 **Imports (IMP/GDP):** This refers to the real value of commodities imported across
573 the borders of China. They include the actual imports through foreign trade, goods
574 imported for the processing and assembly trades, and materials, supplies and gifts as aid
575 given gratis between both governments and the United Nations and other international
576 organizations, as well as contributions donated by overseas Chinese, compatriots in
577 Hong Kong and Macao and Chinese with foreign citizenship, leasing commodities
578 owned by tenants on expiry of the leasing period, imported commodities processed with
579 imported materials, commodities trading in border areas (excluding mutual exchange
580 goods), the imported commodities and articles for public use of the Sino-foreign Joint
581 ventures, cooperative enterprises, and ventures with sole foreign investment. The
582 indicator of the total imports at customs can be used to observe the total size of external
583 trade in a country. In accordance with the stipulation of the Chinese government,
584 imports are calculated CIF. We divided imports by GDP.

585 **Price:** We use electricity price (for Industry 35kV and above, RMB/KWH) and Oil
586 price (RMB/Ton), which is the only information available. In the case of total energy
587 consumption, coal consumption, and natural gas, we use electricity price as a proxy
588 variable.

589

590 **Investment Ownership: (Investment ownership / GDP)**

591 **State-owned:** This refers to non-corporation economic units where the entire assets
592 are owned by the State and which have registered in accordance with the Regulation of
593 the People's Republic of China on the Management of Registration of Corporate

Enterprises. Excluded from this category are sole state-funded corporations in the limited liability corporations.

Collective-owned: This refers to economic units where the assets are owned collectively, and which have registered in accordance with the Regulation of the People's Republic of China on the Management of Registration of Corporate Enterprises.

Cooperative: This refers to a form of collective economic units (enterprises) where capitals come mainly from employees as their shares, with a certain proportion of capital from the outside, where production is organized on the basis of independent operation, independent accounting for profits and losses, Joint work, democratic management, and a distribution system that integrates remuneration according to work with a dividend according to capital share.

Joint-Venture: This refers to economic units established by two or more corporate enterprises or corporate institutions of the same or different ownership, through Joint investment on the basis of equality, voluntary participation, and mutual benefits. They include state Joint-ownership enterprises, collective Joint-ownership enterprises, Joint state-collective enterprises, and other Joint-ownership enterprises.

Limited Liability: This refers to economic units established with investment from 2-50 investors and registered in accordance with the Regulation of the People's Republic of China on the Management of Registration of Corporations, each investor bearing limited liability to the corporation depending on its share of investment, and the corporation bearing liability to its debt to the maximum of its total assets. Limited liability corporations include exclusive state-funded limited liability corporations and other limited liability corporations.

Share-holding: This refers to economic units registered in accordance with the Regulation of the People's Republic of China on the Management of Registration of Corporations, with total registered capitals divided into equal shares and raised through issuing stocks. Each investor bears limited liability to the corporation depending on the holding of shares, and the corporation bears liability to its debt to the maximum of its total assets.

Private: This refers to profit-making economic units invested and established by natural persons, or controlled by natural persons using employed labor. Included in this category are private limited liability corporations, private share-holding corporations Ltd., private partnership enterprises, and private-funded enterprises registered in accordance with the Corporation Law, Partnership Enterprises Law, and Interim Regulations on Private Enterprises.

Self-employed Individual: This refers to domestic-funded economic individuals other than those mentioned above.

Foreign Funded: This refers to enterprises established in the mainland of China with exclusive investment from foreign investors in accordance with the Law of the People's Republic of China on Foreign-Funded Enterprises and other relevant laws.

Source: All definitions come from the National Bureau of Statistics of China in their original form.

List of Tables

Table 1: Summary of Statistics, Investment Ownership / GDP. (2006-2010)

Variable	Obs.	Mean	Std. Dev.	Min	Max
State	150	0.193	0.077	0.064	0.409
Collective	150	0.015	0.013	0.000	0.061
Cooperative	150	0.003	0.002	0.000	0.010
Joint	150	0.002	0.002	0.000	0.010
Limited	150	0.151	0.057	0.056	0.334
Share-holding	150	0.044	0.023	0.009	0.145
Private	150	0.103	0.057	0.017	0.279
Self-employed	150	0.025	0.012	0.000	0.067
Foreign	150	0.020	0.014	0.003	0.058

Table 2: Summary of Statistics, Energy Consumption / GDP (2006-2010)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Total Energy	120	0.134	0.064	0.054	0.398
Coal Energy	120	0.141	0.110	0.022	0.602
Electricity Energy	120	0.137	0.082	0.062	0.532
Oil Energy	112	0.164	0.160	0.000	0.667
Natural Gas Energy	120	0.005	0.006	0.000	0.023

Table 3: Investment Ownership, imported technology, and energy intensity

	Total	Coal	Electricity	Gas	Oil
State	0.3550***	0.9030	0.1780*	0.0052	-0.1040
Collective	0.4374	0.4227	0.3440	0.0518	0.1550
Cooperative	0.2131	0.6070**	0.3917*	-0.2750*	-0.7700**
Joint	0.1938	0.8604**	0.9180	-0.1920*	-0.1449***
Limited	0.5850	0.5366***	0.0941	0.0172	0.2420
Share-holding	0.2435*	-0.6232***	0.3140	0.1050***	0.3872***
Private	-0.1797**	-0.1010	-0.3050***	-0.0374***	-0.1192***
Self-employed	-0.6551***	-0.1084	-0.3520	-0.0495	-0.1825**
Foreign	-0.6905**	-0.1902***	0.0175	0.0174	0.2285
Industry	0.2223***	0.4814***	0.3190***	-0.0165*	0.1810
Imports	-0.3650***	-0.1580	-0.0314*	-0.0002	0.0769
Electricity Price	-0.8650***	-0.3025***	0.0279**	-0.0068**	
Oil Price					-0.0605
No observations	120	120	120	120	112
R^2	0.9592	0.9287	0.9646	0.8493	0.8843
Individual Effects	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes

Note: * $p<.10$, ** $p<.05$, *** $p<.01$

Table 4: Investment Ownership, domestic innovation, and energy intensity

	Total	Coal	Electricity	Gas	Oil
State	0.2812***	0.7460	0.2140**	0.0144**	-0.1540
Collective	0.3861	0.5747	0.3030	0.0192	0.1130
Cooperative	0.1976	0.4914**	0.5121***	-0.3140**	-0.8483**
Joint	0.1315	0.7926**	0.0063	-0.0975	-0.1289***
Limited	0.2570	0.4847***	-0.0175	0.0036	-0.0066
Share-holding	0.2680	-0.5945**	0.0919	0.0899***	0.3601***
Private	-0.9180	-0.0782	-0.1630	-0.0259**	-0.1031***
Self-Employed	-0.5491**	-0.1317	-0.4040	-0.0933**	-0.1893**
Foreign	-0.7527**	-0.1756***	0.0808	0.0441	0.3314**
Industry	0.3522***	0.5479***	0.4160***	-0.0104	0.2200
Patents	-0.1560***	-0.1010*	-0.0207***	-0.0020***	-0.0302**
Electricity Price	-0.7070***	-0.2603***	0.0456	-0.0032	
Oil Price					0.0079
No Observations	120	120	120	120	112
R^2	0.9751	0.9292	0.9699	0.8516	0.8865
Individual Effects	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes

Note: * p<.10, **p<.05, *** p<.01

Table 5: Relationship between FDI and domestic Innovation

	Total	Coal	Electricity	Gas	Oil
State	0.2014***	0.431	0.217**	0.0088	0.184
Collective	0.5015**	0.6807	0.307	0.0538*	-0.297
Cooperative	0.2181	0.4922**	0.4990***	-0.282**	-0.8968**
Joint	0.9648	0.7643**	-0.0283	-0.135	-0.1534***
Limited	0.1523**	0.4878***	-0.0272	0.0016	-0.396*
Share-holding	0.469	-0.5352**	0.0875	0.0802***	0.3355***
Private	-0.2052***	-0.882	-0.154	-0.0261**	-0.698**
Self-Employed	-0.3401	0.587	-0.417	-0.0712*	-0.3576***
Foreign	**-0.5420***	**-0.3219**	**0.47**	**-0.251**	**0.2468***
Industry	0.2636***	0.5062***	0.414***	-0.0088	0.311*
Patents	-0.238***	-0.13	-0.0203***	-0.0031***	0.0245
Electricity Price	-0.772***	-0.2552***	0.0447	-0.0034	
Foreign x Patents	**0.4982***	**0.1636**	**-0.0401**	**0.0316**	**-0.2276***
Oil Price					-0.0884
No Observations	120	120	120	120	112
R^2	0.9614	0.9359	0.9698	0.8629	0.9076
Individual Effects	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes

Note: * p<.10, ** p<.05, *** p<.01

Table 6: Relationship between Imports and Domestic Innovation

	Total	Coal	Electricity	Gas	Oil
State	0.1780***	0.355	0.219**	0.0114*	0.163
Collective	0.7338***	0.7473	0.322	0.0309	-0.999
Cooperative	0.2378	0.3963	0.4858***	-0.272**	-0.6500**
Joint	0.1387	0.8394**	0.132	-0.127	-0.1373***
Limited	0.1438**	0.5273***	-0.0245	0.0029	-0.108
Share-Holding	0.0873	-0.6934***	0.0831	0.0910***	0.2911***
Private	-0.1530**	-0.476	-0.175	-0.0249**	-0.633
Self-Employed	-0.3452	-0.554	-0.403	-0.0740*	-0.3059***
Foreign	-0.3011	-0.1418**	0.137	0.0050	0.1023
Imports	**-0.4949***	**-0.4279***	**-0.109**	**0.0243**	**0.1922***
Industry	0.2144***	0.4545***	0.417***	-0.0062	0.481***
Patents	-0.268***	-0.225***	-0.0215***	-0.0013	0.0079
Electricity Price	-0.770***	-0.2689***	0.0506*	-0.0045	
Imports x Patents	**0.467***	**0.408***	**0.0096**	**-0.0021**	**-0.183**
Oil Price					-0.0817
No Observations	120	120	120	120	112
R^2	0.9681	0.9346	0.9703	0.8562	0.8987
Time Effects	Yes	Yes	Yes	Yes	Yes
Individual Effects	Yes	Yes	Yes	Yes	Yes
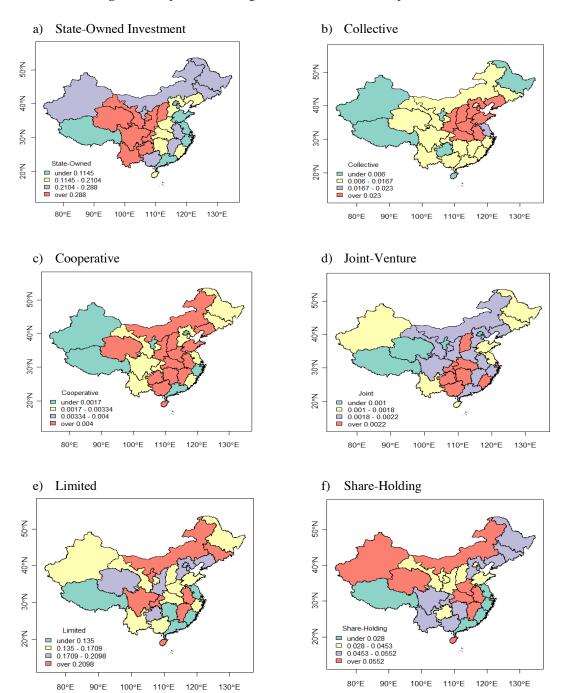
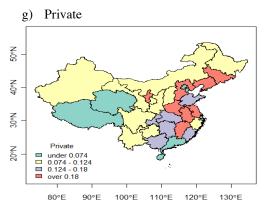**Table 7:** Summary of the Results, Investment Ownership and Regional Dimension

|	Total	Coal	Electricity	Gas	Oil
State	North, Central, North-Western (+)	North-East, North, East, Central, South, North-Western (+)	North-East (-); North, North-Western (+)	North, East (-)	Central, South, North-Western (-)
Collective	South (-)	North-East, North, North-Western (+)	North (+)	North-East, North (-)	South (-)
Cooperative	East, South (-); North-Western (+)	North-East, North, North-Western (+)	North, North-Western (+); East (-)	North-East, North, East (-)	Central (-)
Joint- venture	North-East, South (-); North, North-Western (+)	North, North-Western (+); South (-)	North-East, East, Central, South (-)	North-East, North, South (-); North-Western (+)	North, Central, South (-)
Limited Liability		North (+)	North-East (-); North, North-Western (+)	North (-)	North, East, Central (-)
Share-Holding	South (-)	South (-)	North-East (-); North, North-Western (+)	East (-); Central, South, North-Western (+)	North-East, North-Western (+)
Private		South (-)	North-East (-); North-Western (+)	North-East, South (-); Central (+)	North, East, Central, South (-)
Self- Employed	North, Central, North-Western (+)	North-East, North, North-Western (+)	North, North-Western (+)	North-East, North, East, South (-); North-Western (+)	North-East, North-Western (+); East, Central, South (-)
Foreign	North, East, South (-); North-Western (+)	East, Central, South (-)	North-Western (+)		Central (-); South, North-Western (+)
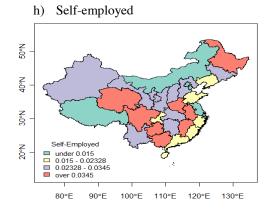
Note: We include in the table those results, which are robust to different specifications. A complete statistical analysis is available upon request by the authors. The sign of the effects appears in brackets.

657
658 **Figure 1:** Map of Chinese regions, Investment Ownership / GDP in 2010
659

a) State-Owned Investment

b) Collective

c) Cooperative

d) Joint-Venture

e) Limited

f) Share-Holding

g) Private

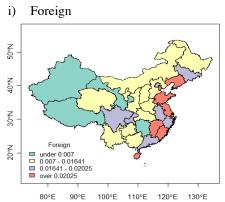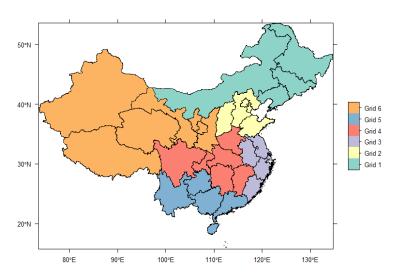h) Self-employed

i) Foreign

Figure 2: Map of the Transmission Grid

Source: Herrerias et al. (2013a)

Grid 1: North-East = 1 for Heilongjiang, Jilin, Liaoning and Inner Mongolia;
0 otherwise
Grid 2: North = 1 for Beijing, Tianjin, Hebei, Shanxi and Shandong;
0 otherwise
Grid 3: East = 1 for Shanghai, Zhejiang, Anhui, Jiangsu and Fujian;
0 otherwise
Grid 4: Central = 1 for Jiangxi, Henan, Hubei, Hunan, Chongqing and Sichuan;
0 otherwise
Grid 5: South = 1 for Guangdong, Hainan, Guangxi, Yunnan and Guizhou;
0 otherwise
Grid 6: North-Western = 1 for Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang;
0 otherwise