Energy consumption and exports:

An analysis of high-tech firms in China

Abstract

Relying on a novel data set from a survey of high-tech manufacturing firms located in Hebei Province of China, this paper analyzes the effect of energy-intensive production on exports. It finds that firms' export propensity and intensity are positively related to the energy intensity of production, after controlling for several firm-specific characteristics. This result suggests that despite hosting several CDM (Clean Development Mechanism) projects aimed at reducing carbon emissions, and despite its leadership in the production and in the use of wind and solar photovoltaic technologies, China's exporting activities tend to involve less sustainable production activities compared to production activities aimed at the local market.

1. INTRODUCTION

The last quarter century has witnessed the emergence of China as a leading exporter of manufacturing products, reflecting the country's growing economic integration with the world economy (WDI, 2014). In 2012, the largest manufacturing economy in the world was responsible for 18 percent of manufactured exports (ahead of the US but just slightly behind the EU). The availability of a vast pool of workers—not only low skilled workers but even middle-range technicians—at relatively low wages has made China a very attractive place for large western companies to outsource production and assembly of even top-end products such as the i-phone (Nahm & Steinfeld, 2014; Zhou, 2008).

At the same time energy consumption in China has increased exponentially, and since the late 1990s, China is a net importer of energy (WDI, 2014). The rapid economic growth has brought along a proportionate growth in carbon emissions: carbon emissions per capita in China almost tripled, from 2.2 metric tons in 1990 to 6.2 in 2010 (WDI, 2014). In the realm of green energy production, however, China since the mid 2000s is the country with the largest renewable power capacity (with or without including hydro power) (REN21, 2010, 2014); Chinese firms have led the global market for wind turbines and solar photovoltaic technologies (PV) (Nahm & Steinfeld, 2014) ; and China is the largest host of the Kyoto mechanisms projects aimed at reducing carbon emissions (Bodas Freitas, Dantas & Iizuka, 2011). Despite these achievements, electricity production relies heavily on coal and oil (WDI, 2014); hence energy consumption in China represents a great deal of carbon emissions.

China's exports contribute to almost one quarter of its total emissions (Wang & Watson, 2008). Noting that more than 50% of exports are performed by foreign affiliates in China, some authors view this as reflecting the relocation of many carbon-intensive manufacturing activities from industrialized countries to China due to cost and environmental considerations (Pan, Phillips and Chen, 2008; Wang & Watson, 2008). Nevertheless, the available literature provides only an aggregated, macro view, and therefore there is still only a limited understanding of the association between energy intensity and exports. Specifically, a pertinent question that has so far been not explored is, are firms with higher energy intensity more likely to undertake exports and to export more of their final output compared to

firms with lower energy intensity? Answers to these questions are crucial for informed policy making in the realms of global development and environment.

In this paper, we examine the association between differences in energy consumption patterns and different degrees of export exposure of a sample of 471 high-tech firms located in the Hebei province of China. The objective of the paper is to uncover whether differences in the energy intensity of firms' production result in differences in their export propensity and intensity. We hypothesize that exporting firms are more likely to rely on energy intensive production technologies than firms that produce primarily for the domestic market, and that the degree of energy consumption is also larger among larger exporters. We use the Heckman full maximum likelihood procedure to examine the relationship between energy consumption and firms' propensity to and intensity of export. Controlling for industry effects, and a host of firm level factors such as capital intensity, technological competences, experience, size, and ownership, results demonstrate that energy-intensive firms are not only more likely to export but also to export a greater share of their production. This result raises questions about the ability of developing countries to escape the fatality of the Kuznets curve, which points to growing environmental deterioration with increases in economic growth at early stages of development. In particular, this challenges the potential efficacy of national policies in developing countries aimed to address and remedy pollution problems in the presence of strong external incentives for specialization in energy-intensive activities for exporting. More broadly, our findings bring to the fore the issue of lack of coordination on climate- and sustainability-related policies between developed and developing countries, such that the latter may specialize in production activities for global markets that are ineligible to be carried out in the former.

The paper is organized as follows. Section 2 reviews the literature on exports and energy consumption. Section 3 discusses the model, the methodology, and the data. Results are reported in Section 4 and Section 5 concludes.

2. EXPORTS AND ENERGY CONSUMPTION

A vast body of literature has documented the role of exports in fueling the process of industrialization and economic growth in developing countries (Amsden 1989; Westphal, et al 1984). Studies have also shown that the process by which exports contribute to the development of domestic industry or to the diffusion of more advanced technologies is not an easy, straightforward one (Lall & Albadejo, 2004; Mowery & Oxley 1997; Jacob & Szirmai 2007). In this respect, the literature highlights the importance of a variety of factors that are needed to profit from exporting such as national policies targeting the development of relevant institutions and resources (Bell & Pavitt, 1993; Bodas Freitas & Iizuka, 2012), the embeddedness of the export-oriented activities in local manufacturing (Poncet & Waldemar 2013), and the synergy between the upgrading of exporting activities and the growth of domestic market in similar or related products (Zhou, 2008). Although rich, this literature has not paid much attention to the energy content of exporting activities, and, in particular, to whether exporting activities are more or less energy consuming than production activities that are aimed at the local market. Answering this question is crucial for understanding the environmental effects of growing exporting activity, but it may also shed light on the economic effects of setting more stringent environmental standards.

China over the last 25 years has made considerable investment in energy production, in particular in 'clean' energy sources such as hydroelectric power stations in the late 1990s, in wind farms in the mid 2000s, and more recently in solar PV farms. However, rapid industrialization has meant that already by 1998 the demand for energy outstripped domestic supply and by 2010 energy import represented 10% of total energy used (WDI, 2014). Despite being the country with highest installed capacity to produce renewable energy, renewables and hydroelectric sources respectively accounted for only 0.4% and 14.8% of total electricity production in China in 2007, and 2.2% and 14.8% in 2011 (WDI, 2015). Hence, electricity from oil, gas and coal sources continue to represent circa 80% of total electricity production in the country (WDI, 2014). Thus, energy consumption in China arguably represents a great deal of carbon emissions.

China's focus on export-led growth has meant that environmental regulations governing export-oriented activities are relatively weak. While the State Environmental Protection Administration (SEPA) has proposed environmental protection plans, known as "China's 11th Five-Year Plan for Environmental Protection", such plans are rarely enforced (SEPA, 2006; Liu & Diamond, 2008). As stated by Liu and Diamond (2005, p.1181) "… although there has been much effort to control environmental degradation, economic development often takes priority at the local level and is still the main criterion for judging government officials' performance." While admitting the increase of carbon dioxide (CO_2) emissions in China, National Development and Reform Commission (2007) argues that the per capita CO_2 emissions in China is still low, "equivalent to only 87% of the world average and 33% of the level in Organization for Economic Co-operation and Development (OECD) countries" (National Development and Reform Commission, 2007, p.6). Thus, even though China's national-level policies have been emphasizing the need for transitioning towards energy efficient practices, local policymakers tend to view energy-intensive export activities as welfare enhancing, without paying sufficient attention to their negative impacts on the living conditions of the population (Economy, 2007). However, China is not an exception among developing countries who often tend to promote economic growth at the expense of spreading awareness of environmental issues among the population in general and the business organizations in particular (Stern, 2004).

There may indeed be counter-balancing factors that mitigate the above-discussed bias towards energy-intensive processes in export-oriented activities. According to the management and innovation literature, the market environment exerts a key influence on firms' behavior and strategies (Smith, 2014; MacGarvie, 2006). In this regard, compared to their peers that primarily produce for the local market, firms with a focus on exporting not only possess different competencies to produce, innovate and market, but also face greater competition and more demanding customers (Cooper & Kleinschmidt, 1985; Roper & Love, 2002). In particular, final consumers of middle and top-end products in high-income countries are likely to be more environmentally aware than domestic consumers and therefore may prefer products with low levels of environmental impact. Furthermore, the increasing presence of more sophisticated products in a developing country's export basket could

lead to a fall in the energy intensity of its exports. Newer technologies to produce relatively sophisticated products for high-income markets may be transferred from clients in industrialized countries where energy efficiency standards are more stringent. In addition, as domestic firms begin to export final products they may need to meet international environment standards, which potentially raises the energy efficiency of their manufacturing activities (Christmann and Taylor, 2001). This would create financial incentives for domestic firms to signal to consumers, investors and other partners their commitment to environmental protection (Zeng and Eastin, 2012). Exporting firms would thus be more concerned with environmental issues, and would use less polluting and more energy efficient practices and technologies.

However, the above scenario is unlikely to have emerged in China. Firstly, the industry structure and the export activities in developing countries are quite different from those in high-income industrialized countries. Entry into the global markets by firms from developing countries tend to occur in resource intensive activities and processing activities due to the relatively cheap and abundant availability of natural resources and labour (Sachs & Warner, 1999). In these countries, even firms which operate in otherwise high-technology industries tend to be engaged in technologically mundane and highly standardized activities (Ernst & Kim, 2002; Leamer, 2007). Exporting firms are primarily engaged in the production of intermediate products for which cost competitiveness is of paramount importance. It is therefore likely that they adopt production processes that are low cost, but at the same time are also highly energy intensive, polluting and carbon emitting. Consumers of final products in developed countries, even when they are environmentally conscious, can rarely trace back the processes underlying the production of intermediate inputs. All these suggest that the process of international standards adoption in developing countries is a long, slow process of infrastructure, institutional and capability building, requiring targeted governmental policies, and firms' own specific learning efforts (Aden, Hong &, Rock, 1999; Bodas Freitas & Iizuka, 2012). Moreover, even compliance with international environmental management standards, such as ISO14001, does not guarantee or oblige the use of the most clean or the most energy efficient technologies; instead it only requires compliance with national regulations (Boiral, 2007).

Second, while China exhibit increasing competences to produce and export more sophisticated products, increasingly stringent economic and environmental standards need to be adhered to in production processes in high-income countries. This has created what may be described as perverse incentives for the transfer of technologies associated with polluting industrial activities together with the relocation of these activities to developing countries where environmental regulation is often less stringent (Kuchler, 2010; Pan et al., 2008; Wang & Watson, 2008). The existence of high-polluting exporting activities in China was well illustrated when the Guangdong region experienced the closure of many exporting firms after the region implemented tougher environmental regulations (along with more stringent working conditions) (Sharif & Huang, 2012).

In this regard, it is pertinent to note that exporting and domestic activities have distinctive structures of organization in China. Traditionally foreign affiliates, using imported technologies, performed most of China's exporting activities (Poncet and Waldemar, 2013, Huchet, 1997, Lemoine and Unal-Kesenci, 2004). These activities seldom led to the diffusion of technologies to local firms, prompting some authors to argue that technological development and exports upgrade observed during the 1990s and 2000s, especially in the mid-range activities, resulted mainly from the ability of domestic firms in enhancing existing technologies and commercializing new products (Thun and Brandt, 2010; Zhou, 2008). Furthermore, foreign firms that otherwise actively address environmental and energy concerns in their home countries are hesitant to do so in China due to laxer standards there, slowing down the diffusion of energy-saving technologies in China (Poncet and Waldemar, 2013, Huchet, 1997, Lemoine and Unal-Kesenci, 2004). On the contrary, differences in standards have meant that foreign firms carry out their highly energy consuming and polluting activities in China, away from their home country.[1] This suggests that exporting activities of even foreign firms, which are responsible for more than 50% of total exports in China, may be more energy intensive (even in middle and top-end industrial activities) and more polluting than their manufacturing activities that are aimed at the local market.

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[1] Although most foreign firms may comply with local environmental management standards, they do not guarantee or oblige the use of most clean or most energy efficient technologies.

Against the background outlined above, we aim to explore the question: to what extent are production activities aimed at exporting more energy intensive than those geared for the local market?

3. EMPIRICAL MODEL

(a) Econometric specification and estimation strategy

We adopt an econometric framework that links exports to a range of firm specific factors. Prior literature has well documented that not all firms export because exporting involves sunk cost so only firms with higher productivity would venture into exporting (for a review, see Greenaway & Kneller, 2007). Not correcting for this selection problem can result in biased estimates. We therefore follow the Heckman (1979) full maximum likelihood selection correction procedure in which we first estimate a selection model explaining the probability to export (export propensity) on a sample of all firms in our data set, followed by estimating a model explaining export intensity on a subsample of firms that export. One requirement of the Heckman procedure is that the selection model should include at least one variable that is not included in the second stage. The selection equation therefore consists of the full set of explanatory variables, including additional variables not in the export intensity equation, and is defined as follows:

$$Exports_i =$$

$$\alpha + \beta_1 productivity_i + \beta_2 age_i + \beta_3 asset\ intensity_i$$

$$+\beta_4 energy\ intensity_i + \beta_5 R\&D\ intensity_i + \beta_6 human\ capital_i$$

$$+\beta_7 size_i + \beta_8 state_i + \beta_9 foreign_i + \vartheta_i$$

in which *exports_i* represents export propensity and takes a value 1 for exporting firms and 0 for non-exporting firms. *Productivity_i* measures the labor productivity of firm *i*, measured as the logarithm of the ratio of the total sales revenue to the total number of employees. This variable is particularly noted

in the literature as a key factor explaining the firm's decision to export–higher productivity affords a firm a greater ability to gear itself to sell products in foreign markets (e.g. Clerides et al. 1998). Age_i is measured as the difference between the current year and the firm's year of inception. It is used to capture the effect of a firm's experience which is especially salient when competitive conditions are high (Klepper 2002) as is the case in foreign markets. *Capital intensity$_i$* is defined as the logarithm of the ratio of the firm's total fixed assets to total number of employees—the capital labor ratio. For a firm from an emerging economy, the relative prices of labor and capital favor the choice of more labor intensive production techniques. Such production techniques may be of particular importance in the context of exporting activities, given that cost competitiveness is the cornerstone of comparative advantage of emerging economy firms.

These three variables (productivity, age, and capital intensity) appear only in the selection equation that explains a firm's decision to export, and not in the second stage equation that explains the differences in the export intensity among firms. The remaining variables in the equation are expected to affect both export propensity and export intensity and therefore appear in both equations.

Energy intensity$_i$ is our main explanatory variable and is defined as the logarithm of the ratio of total energy use to total output. As we argued before, energy intensity is expected to have a positive impact on export performance, as well as on the decision to export. The remaining variables are control variables whose sign and significance are not of key interest to our study, but who may nevertheless have an impact on firms' exports. *R&D intensity$_i$* is defined as the logarithm of the ratio of total R&D expenses to total sales revenue. While a widely used measure of a firm's technological efforts, R&D may not fully capture innovation activities of firms in emerging economies where learning by doing are known to be a key source of innovation. Still, given that our focus is on high tech firms R&D may represent a good proxy for the innovative efforts of firms. *Human capital$_i$* is a dummy variable that takes the value 1 if firm has employees with a graduate degree or above, and 0 otherwise. This variable proxies the quality of the labor force–a key ingredient for absorbing knowledge which is characterized by a high level of tacitness (Polanyi 1958). *Size$_i$* is defined as the logarithm of the number of employees of the firm. A larger size allows a firm to reap the economies of scale, which is a

key advantage for firms from emerging economies that engage primarily in price competition. The last two variables represent the ownership categories of firms: *State$_i$* is a dummy variable which takes a value 1 for firms which are either state owned or collective owned and 0 for all others, and *foreign$_i$* is a dummy variable which takes a value 1 for firms which are foreign owned (by firms outside of mainland China: *HongKong-Taiwan-Macao firms* and by *other foreign-owned firms*).and 0 for all others. The reference category for both these variables is domestically-owned private firms. We expect that, in comparison with locally owned private firms, state/collective-owned firms are focused more on the domestic market while foreign firms might be focused more on foreign markets. Finally v_i is a composite error term [$v_i=\theta_i+\varepsilon_i$] consisting of industry dummies θ and the disturbance term ε_i.

An important aspect to note is that the Heckman model assumes that the dependent variable in the second stage follows normal distribution. However, export intensity variable is a fraction that lies between 0 and 1. We therefore made a following logit transformation of the export intensity variable:

$$log\left(\frac{export\ intensity}{1-export\ intensity}\right)$$

(b) Data

Our analysis focuses on high-tech firms located in the Hebei province of China. Hebei is an important region bordering five provinces and embracing two municipalities, Beijing (the capital of China) and Tianjin (the famous trading port in north China). The tight connection between Hebei and the important Tianjin trading port favours the development of export in Hebei. We use an original dataset entitled "Statistical report for enterprises in National high-tech industrial development zone (in Hebei Province)". This survey was conducted by the Ministry of Science and Technology of China (MSTC) and it is compulsory for all industrial enterprises which have been identified as high-tech enterprises by MSTC to answer the questions. Thus this survey provides a complete set of information of all the high- and new- technology enterprises (HNTEs) in Hebei province. According to the latest regulation effective from 2008, to qualify a HNTE, an enterprise must meet the required personnel structure and high spending on R&D, have registered in mainland of China for at least one year, own the proprietary intellectual property right of core technology in connection with the main products or services of the

enterprise. In particular, the products or services of the enterprise must be within the scope of the state-supported sectors (i.e. Electronic information technology; Biological and medical technology; Aviation and space technology; New materials technology; High-tech services; New energy and energy conservation technology; Resources and environmental technology; Transformation of traditional sectors through new high-tech) (see more details in Cao, 2008; Stender and Wang, 2008).

The survey was conducted in 2011 and the data collected in this survey reflects the situation of previous year (1 January 2010 to 31 December 2010).This survey covers 658 high-tech firms located in Hebei province. After excluding firms that did not provide information on energy consumption, and those in agriculture and service sectors, we identified a total of 471 high-tech manufacturing firms. These firms operate in 25 industries, ranging from Food manufacturing and Textile manufacturing to Measuring instruments and machinery (see Appendix Table 1). In terms of ownership, the investigated firms consist of five types –majority of the firms are domestically owned *private firms* (63%), while the next biggest category is *state-owned firms* (17%), followed by *collective firms* (7%), *HongKong-Taiwan-Macao firms* (3%), and *other foreign-owned firms* (5%) (see Appendix Table 2).[2] In the empirical analysis we treat all firms with ownership outside of mainland China as foreign owned firms (*HongKong-Taiwan-Macao firms* plus *other foreign-owned firms*).

(c) Descriptive statistics

Table 1 provides a summary of the variables used along with the correlation among them.

[Insert Table 1 about here]

About 46% of firms in our sample are exporters (216 of 468 firms). The average export intensity of the firms in our sample is about 25% (logit transformed value is -1.11) with a maximum export intensity of 85% (logit transformed value is 1.76). Energy intensity has a maximum of close to 9 (natural logarithm value is 2.18). Firms display considerable variability in terms of other variables too. Labor productivity ranges from a low of about 5 to a high of close to 1000 (natural logarithm values are respectively 1.67 and 6.90). Likewise, firms differ in their experience, with the sample consisting

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[2] The ownership structure of a small number (5%) of firms is unclear, however.

of firms as young as one year to as old as 55 years (natural logarithm values of respectively 0 and 4).

Firms in the sample tend to be innovative, with the average R&D intensity about 5%. Nearly 70% of

firms have employees with a graduate degree or above. Finally, the correlation matrix shows no

significant correlation between any pair of explanatory variables.

4. RESULTS

a) the effect of energy consumption on export propensity and export intensity

Table 2 reports the estimates of firm export propensity (regression 1-2) and export intensity

(regression 3-4) based on the Heckman two-stage selection model. We estimate all models with

cluster-robust standard errors to ensure that the estimates are robust to problems such as

heteroskedasticity and non-normality, and to account for potential correlation among observations that

belong to the same industry. The first set of regressions (regressions 1 and 3) are the baseline models

that include only the controls variables, and in the second set of regressions (regressions 2 and 4) we

include the key explanatory variable energy intensity. One of the requirements of the Heckman model

is that at least one variable that is present only in the selection model should be statistically significant.

The age variable is significant at the 1% level in both equations while labor productivity is significant

in the second equation. However, the Wald tests indicate no significant correlation between the two

stages, which appear to suggest that unbiased estimates could be obtained using just a single-stage

model. We compare these results with those from single stage models later in the robustness analysis.

[Insert Table 2 about here]

Results reported in Table 1 show that export propensity and export intensity are significantly

positively associated with the energy-intensive production processes. The positive sign of the

estimated coefficients in both the selection and the main regressions suggest respectively that the more

energy a firm consumes per unit of output, the more likely it is to export, and the higher is its export

intensity. This confirms our predictions that exporting activities in China is more energy intensive compared to manufacturing activities that are aimed at the domestic market.

In terms of the effects of the controls, R&D intensity has a significant positive effect on export intensity, but has no significant effect on export propensity. In other words, firms with higher technological efforts appear to be able to be more competitive in foreign markets, while such efforts have no discernible effect on being able to export in the first place. Firm size significantly explains both the propensity to export and export intensity. Larger firms are more likely to not only export but export a larger share of their output to foreign markets. This result, together with the positive effect of age on export propensity suggests that firms with larger resources and competences accumulated over time were able to enter international markets, and did not become locked in the domestic market. Industry fixed effects, which are not reported, are significant in explaining both export propensity and export intensity. State or collective ownership has a negatively significant effect on export intensity but no discernible effect on export propensity. This indicates that these firms, compared to private independent firms, are focused more on the local market than on the foreign market, but also may be less competitive.

In order to better understand these results, next we carry out separate analyses for subsamples of young vs old firms, and low innovative vs high innovative firms, and firms active in low and in high tech industrial activities as OECD classification (Peneder, 2003; OECD, 2005).

b) effects by firm age

Due to the recent developments in terms of energy efficient technologies, and of environmental concerns, the effect of energy consumption on export propensity and export intensity may be different for new ventures and more established firms. We therefore, split our sample into two groups: firms that are 10 years or younger, and firms that are older than 10 years. Results for each sub-sample of firms are reported in Table 3.

[Insert Table 3 about here]

Results confirm the positive effect of energy consumption on export intensity. Energy intensity explains export intensity for both young and older firms. However, for young firms in our sample energy intensity is not a decisive factor in explaining the decision to export. Propensity to export among young ventures depends mainly on achieving a size scale, and export intensity on the energy intensity of their activities. This may reflect the fact that young ventures were born with international market orientation because they were founded when China was already a big exporter. Among the remaining variables, firm size continues to exert a significant positive effect on export propensity for both types of firms, but on export intensity only for older firms.

c) effects by firm innovation

The effect of energy consumption on export propensity and export intensity may have different effects across firms with low and high levels of innovativeness. In order to examine this, we dropped the 14 observations relative to non-innovative firms, and we split our sample into two groups: firms with an innovative intensity (share of revenue from innovative products in total sales revenue) that is below the median value for the whole sample (low innovative), and firms with an innovative intensity that is above the median value (high innovative). Results for each sub-sample of firms are reported in Table 4.

[Insert Table 4 about here]

For both types of firms, energy intensity has a positive effect on export propensity, but has no significant effect on export intensity. Capital intensity and productivity are particularly important in the decision to export of low innovative firms. In other words, among low innovative firms, those with a labor intensive production structure and that are more efficient turns out to be more likely to export than those with a capital intensive production structure and that are less efficient. Among the low-innovative firms, large firms and firms that are part of foreign groups are more likely to export. Export

intensity among the low-innovative firms depends mainly on size. Among the high-innovative firms, besides energy intensity, size explains significantly export propensity, while only the variable foreign explains significant export intensity.

These results suggest that export propensity in high and low innovative firms depend on different factors, hinting at that they face different type of competition in international markets. Additionally, results suggest that export intensity in low-innovative and high-innovative firms is significantly different, once with the slip sample export intensity is mainly explained by firms size and capital ownership.

d) effects by firm industrial activity

Finally, we check if there are different dynamics at work for firms operating in high tech industries, compared to those in low tech industries. As the degree of product maturity and level of reliance on new sources and technological inputs differ greatly between low and high tech industries, the products, their production and innovative processes as well as the competitive challenges faced by firms are different in low and high tech industries (Gereffi & Korzeniewicz, 1994; Gereffi, Garcia-Johnson & Sasser, 2001). We adopt the OECD classification in which high tech industries include pharmaceuticals, electronics, instruments and manufacture of aerospace and other equipment and we split our sample into two groups (Peneder, 2003; OECD, 2005). Results reported in Table 5 indicate that energy intensity has a significant positive effect on export propensity in the low tech sample and on export intensity in the high tech sample.

[Insert Table 5 about here]

In high tech sample, export propensity is higher for high productive and large firms, while export intensity is higher for large firms, for R&D intensive firms and for energy intensive firms. In the low tech sample, export propensity is higher for older, less capital intensive, energy intensive, state and

collaborative owned firms and for larger firms. Export intensity is higher in large firms, with high share of skilled employees, in firms that are not part of state or collaborative groups.

d) Robustness checks

As noted before, Wald statistics showed that the Heckman procedure would not be necessary for our sample in order to derive unbiased estimates. To confirm this we estimated the export propensity and export intensity equations separately, using Probit and OLS estimators respectively. Results for the full sample, reported in Table 6, show remarkable similarity with those reported in Table 2 derived using the Heckman procedure.

[Insert Table 6 about here]

Next, we explored if potential endogeneity of the energy intensity variable could bias the results; this could arise if energy intensity may itself be affected by firm specific factors. We therefore adopted a two-stage least squares estimator in which energy intensity was instrumented with three variables— number of trade marks (in logarithms), labour productivity (difference between the logarithms of revenue and number of employees), and capital intensity (in logarithms)—while the first variable provides an indication of the quality of a firm's product portfolio, the last two variables may capture the firm's production processes. Results are reported in the last column of Table 6 (regression 5). Coefficient of energy intensity continues to remain positively significant. This result suggests that we can rule out any bias in the results due to potential endogeneity of the energy intensity variable.

5. CONCLUSIONS

This paper has analyzed the energy content of exports from China at the firm level. Using a novel survey data spanning 471 high-tech firms located in the Hebei province of China, it examined the effect of firms' energy consumption per unit of output on their propensity to and intensity of export. Findings from this study suggest that firms that are engaged in exporting activities typically consume higher levels of energy per unit of output than firms that produce for domestic market. These results

are consistent when we carry out separate analyses for subsamples of young vs old firms, low innovative vs high innovative firms, and low-tech vs high-tech industries. The analyses of the subsamples provide some additional insights on the factors influencing propensity to and intensity of exports, and in particular on their relationship with energy intensity.

Energy intensity was found to explain significantly export propensity and intensity of old, established firms and export intensity of young ventures. Young firms, despite their newness, appear to be responding to a specific incentive structure that encourages the adoption of energy-intensity techniques or activities in catering to external demand. In addition, energy intensity was found to explain significantly export propensity of both low and high innovative firms, but not their export intensity. Finally, energy intensity was found to have a significantly positive effect on export propensity in the low tech sample and on export intensity in the high tech sample. This suggests that energy intensity along with R&D intensity are fundamental to successfully competing in global markets in high tech industries, while in labour intensive activities firms employing energy-intensive techniques are more likely to export than only produce for domestic market.

Thus while China is rapidly achieving the capability to produce and export technologically sophisticated products, a combination of local policies that emphasize export-led growth and environmental policies in developed countries that are getting ever more stringent appear to have incentivized the adoption of energy-intensive, and potentially environmentally damaging, techniques by high technology manufacturing firms in China.

Overall, these results raise questions about the ability of developing countries to escape the fatality of the kuznet curve. Some authors argue that developing countries can and in many cases were implementing policies to address and remedy pollution problems, and in this way they could somehow escape the dire predictions underlying the Kuznet curve (Stern, 2004). For instance, Sharif & Huang (2012) pointed out that many exporting firms in the Guangdong region of China closed down when the region implemented tougher environmental regulations (along with more stringent working conditions). In contrast, our findings suggest that unlike developed countries in which more stringent

environmental standards have been shown to be drivers of innovation and exports (Constantini & Mazzanti, 2012), developing countries may not have the institutional and/or the technological capabilities to explore the win-win potential effects of environmental regulation. More broadly, our findings stress the lack of coordination on climate- and sustainability-related policies between developed and developing countries, such that the latter may specialize in production activities for global markets that are ineligible to be carried out in the former.

Future research focusing on manufacturing activities in a family of products could provide more in-depth clues about the differences in the characteristics of products produced for exports and for the domestic market in China, but also differences in the production processes underlying the same product family in other world locations. Also future research involving more qualitative research methods could aim at exploring the elasticity of international demand for Chinese manufacturing products in case more stringent environmental standards were introduced in China. That would offer further insights for policy makers in China in regard to reshaping their policies.

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Table 1. Descriptive statistics and correlation matrix

No	Variables	Obs	Mean	SD	Min	Max	Correlation matrix									
							1	2	3	4	5	6	7	8	9	10
1	Export propensity	468	0.46	0.50	0.00	1.00	1									
2	Export Intensity	468	-1.11	1.89	-9.92	1.76	-0.63									
3	Productivity	468	4.46	0.88	1.67	6.91	0.15	-0.13								
4	Age	468	2.14	0.58	0.00	4.01	0.15	-0.12	0.01							
5	Capital intensity	468	4.76	1.26	-0.93	8.66	0.11	0.02	0.42	-0.07						
6	Energy intensity	468	-5.47	1.81	-13.31	2.18	0.15	0.03	-0.07	0	0.27					
7	R&D intensity	468	-2.99	1.05	-11.44	-0.14	-0.17	0.15	-0.36	-0.03	-0.2	-0.05				
8	Human capital	468	0.71	0.46	0.00	1.00	0.09	-0.04	0.06	0.05	0.03	-0.04	0.01			
9	Firm Size	468	5.53	1.18	2.56	9.77	0.4	-0.18	0.17	0.17	0.24	0.19	-0.27	0.11		
10	State/Collective	468	0.18	0.38	0.00	1.00	0.13	-0.14	0.18	0.1	0.1	0.06	-0.07	0.25	0.25	
11	Foreign	468	0.08	0.27	0.00	1.00	0.13	-0.07	0.19	-0.01	0.16	-0.03	-0.22	0.12	0.18	-0.13

Table 2. Heckman Maximum Likelihood estimator – full sample

Variables	Dependent variable: Export Propensity		Dependent variable: Export Intensity	
	(1)	(2)	(3)	(4)
Age	0.3156***	0.3321***		
	(0.1204)	(0.1227)		
Productivity	0.1413	0.1961*		
	(0.1113)	(0.1132)		
Capital intensity	0.0015	-0.0360		
	(0.0454)	(0.0452)		
Energy intensity		0.1079**		0.2564***
		(0.0422)		(0.0972)
R&D intensity	-0.0427	-0.0396	0.2726***	0.2425**
	(0.0708)	(0.0730)	(0.1041)	(0.0974)
Human capital	0.0915	0.1175	0.3324	0.3814
	(0.1228)	(0.1269)	(0.2404)	(0.2644)
Firm Size	0.4550***	0.4378***	0.4104***	0.3108***
	(0.0763)	(0.0795)	(0.0982)	(0.1033)
State/Collective	0.1620	0.1484	-0.7242*	-0.7190*
	(0.2332)	(0.2361)	(0.3859)	(0.3858)
Foreign	0.4081	0.4524	0.2068	0.2387
	(0.4509)	(0.4211)	(0.3813)	(0.3589)
Industry dummies	Yes	Yes	Yes	Yes
Constant	-9.6503***	-9.3131***	-3.6955***	-1.5977**
	(0.5175)	(0.5631)	(0.7609)	(0.8054)
Observations	468	468	216	216
Rho	0.148	0.128	0.148	0.128
Log-Psuedolikelihood	-718.7	-711.6	-718.7	-711.6
Wald test of indep. eqns: Chi-square	0.819	0.584	0.819	0.584
Significance comparison	0.365	0.445	0.365	0.445

Robust standard errors, adjusted for clustering within two-digit industries, in parentheses
*** $p<0.01$
** $p<0.05$
* $p<0.1$

Table 3. Heckman Maximum Likelihood estimator – comparison between young and old firms

VARIABLES	Young firms (10 years or younger)		Old firms (older than10 years)	
	Export Propensity (1)	Export Intensity (2)	Export Propensity (3)	Export Intensity (4)
Age	0.2540		0.6383	
	(0.2054)		(0.3975)	
Productivity	0.1761		0.2857*	
	(0.1668)		(0.1576)	
Capital intensity	-0.0293		-0.0586*	
	(0.0725)		(0.0348)	
Energy intensity	0.0605	0.2995**	0.1922***	0.2483***
	(0.0507)	(0.1316)	(0.0659)	(0.0702)
R&D intensity	-0.0172	0.2145	-0.0941	0.2050
	(0.0954)	(0.2121)	(0.0899)	(0.1261)
Human capital	0.1881	0.7097	0.1056	0.2157
	(0.1760)	(0.5499)	(0.2245)	(0.5084)
Firm Size	0.4650***	0.0687	0.4656***	0.3330*
	(0.0914)	(0.1423)	(0.1040)	(0.1896)
State/Collective	0.2047	0.2215	-0.0161	-1.2534**
	(0.1358)	(0.5164)	(0.4767)	(0.5286)
Foreign	0.2556	-0.0655	0.5240	0.5653
	(0.4458)	(0.7326)	(0.6733)	(0.4743)
Industry dummies	Yes	Yes	Yes	Yes
Constant	-9.2028***	0.5949	-10.3068***	-2.7071*
	(0.5506)	(1.0843)	(1.4649)	(1.5631)
Observations	290	118	178	98
Rho	0.114	0.114	-0.0555	-0.0555
Log-Psuedolikelihood	-403.2	-403.2	-285.7	-285.7
Wald test of indep. eqns: Chi-square	0.216	0.216	0.0937	0.0937
Significance comparison	0.642	0.642	0.760	0.760

Robust standard errors, adjusted for clustering within two-digit industries, in parentheses
*** p<0.01
** p<0.05
* p<0.1

Table 4. Heckman Maximum Likelihood estimator – comparison between low and high innovative firms

VARIABLES	Low innovative: (Share of innovative products below median)		High innovative (Share of innovative products equal to or above median)	
	Export Propensity (1)	Export Intensity (2)	Export Propensity (3)	Export Intensity (4)
Age	0.1998		0.4048	
	(0.1690)		(0.2712)	
Productivity	0.3506**		0.1631	
	(0.1599)		(0.1599)	
Capital intensity	-0.2023*		0.1469	
	(0.1176)		(0.1164)	
Energy intensity	0.1169*	0.1322	0.1410**	0.3107
	(0.0633)	(0.1364)	(0.0627)	(0.2884)
R&D intensity	0.0879	0.5446	-0.2428	0.2209
	(0.1981)	(0.4706)	(0.2153)	(0.2448)
Human capital	0.2568	0.2316	0.2399	0.4694
	(0.2252)	(0.6373)	(0.1890)	(0.6161)
Firm Size	0.5107***	0.2508*	0.3485***	0.1313
	(0.0890)	(0.1317)	(0.1274)	(0.3672)
State/Collective	-0.2486	-0.5350	0.4231	-0.1512
	(0.3435)	(0.6234)	(0.3342)	(0.8816)
Foreign	0.8673**	0.1433	-0.2865	1.4514*
	(0.4145)	(0.4701)	(0.6534)	(0.8509)
Industry dummies	Yes	Yes	Yes	Yes
Constant	-3.2293***	2.1705***	-9.4544***	0.9223
	(0.9558)	(0.7968)	(0.3685)	(3.1193)
Observations	197	108	198	84
Rho	0.0983	0.0983	0.000884	0.000884
Log-Psuedolikelihood	-328.3	-328.3	-271.3	-271.3
Wald test of indep. eqns: Chi-square	0.364	0.364	9.16e-07	9.16e-07
Significance comparison	0.546	0.546	0.999	0.999

Robust standard errors, adjusted for clustering within two-digit industries, in parentheses
*** $p<0.01$
** $p<0.05$
* $p<0.1$

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Table 5. Heckman Maximum Likelihood estimator – comparison between high-tech and low-tech industries

	High-tech industries		Low-tech industries	
	Export Propensity (1)	Export Intensity (2)	Export Propensity (3)	Export Intensity (4)
Age	0.1775		0.5249***	
	(0.1151)		(0.1605)	
Productivity	0.3655***		0.1736	
	(0.1393)		(0.1711)	
Capital intensity	0.0305		-0.1230***	
	(0.0528)		(0.0408)	
Energy intensity	0.0693	0.6119***	0.1385***	0.0771
	(0.0959)	(0.2102)	(0.0445)	(0.0759)
R&D intensity	-0.0270	0.0860*	-0.0060	0.6080
	(0.0451)	(0.0449)	(0.1915)	(0.4034)
Human capital	-0.1335	-0.5368	0.2143	0.5024***
	(0.2634)	(0.4111)	(0.1420)	(0.1939)
Firm Size	0.6216***	0.3522***	0.3721***	0.3147**
	(0.1005)	(0.0975)	(0.1021)	(0.1310)
State/Collective	-0.2214	0.4065	0.3708*	-1.5292***
	(0.5176)	(0.3243)	(0.1950)	(0.4301)
Foreign	0.3793	0.4601	0.4304	-0.0312
	(0.2589)	(0.6329)	(0.6719)	(0.3968)
Constant	-5.0231***	-0.3095	-8.5055***	-1.7744
	(0.8575)	(2.2299)	(0.5533)	(1.4839)
Observations	175	75	293	141
Rho	0.439	0.439	-0.219	-0.219
Log-Psuedolikelihood	-246.4	-246.4	-449.5	-449.5
Wald test - Chi-square	1.731	1.731	0.432	0.432
Sig comparison	0.188	0.188	0.511	0.511

Robust standard errors, adjusted for clustering within two-digit industries, in parentheses
*** $p < 0.01$
** $p < 0.05$
* $p < 0.1$

Table 6. Robustness Analysis
Probit analysis of export propensity and OLS and 2SLS analyses of export intensity– full

	Export Propensity		Export intensity		
	Probit	Probit	OLS	OLS	2SLS[!]
	(1)	(2)	(3)	(4)	(5)
Age	0.3092**	0.3269***			
	(0.1234)	(0.1250)			
Productivity	0.1333	0.1919*			
	(0.1050)	(0.1094)			
Capital intensity	0.0092	-0.0331			
	(0.0507)	(0.0482)			
Energy intensity		0.1075**		0.2468**	0.5742**
		(0.0422)		(0.0978)	(0.2273)
R&D intensity	-0.0432	-0.0395	0.2935**	0.2606**	0.2169**
	(0.0686)	(0.0715)	(0.1090)	(0.1039)	(0.0940)
Human capital	0.0905	0.1171	0.3016	0.3578	0.4323
	(0.1244)	(0.1283)	(0.2377)	(0.2682)	(0.2891)
Firm Size	0.4534***	0.4370***	0.3249***	0.2467**	0.1429
	(0.0755)	(0.0792)	(0.0744)	(0.0838)	(0.1131)
State/Collective	0.1699	0.1574	-0.7493*	-0.7487*	-0.7478**
	(0.2293)	(0.2309)	(0.3700)	(0.3636)	(0.3388)
Foreign	0.4122	0.4559	0.1683	0.1924	0.2243
	(0.4507)	(0.4200)	(0.4056)	(0.3955)	(0.3737)
Constant	-4.1082***	-3.4507***	-1.7473***	-0.9309	1.4812
	(0.4673)	(0.5152)	(0.5444)	(0.6237)	(1.6912)
Observations	454	454	219	219	
Log Likelihood	-259.9	-256.3	-464.3	-460.6	
R-squared			0.1102	0.1399	0.0876
Adj-R-squared			0.0301	0.0578	0.000451

Robust standard errors, adjusted for clustering within two-digit industries, in parentheses
*** p<0.01
** p<0.05
* p<0.1
[!]2SLS – 2 stage least squares estimator is an instrumental variable estimator using which we instrument energy intensity with the variables Age, productivity, and Capital intensity that appear only in the selection model.

Appendix tables

Table 1: summary of industry categories

industry_category	Freq.	Percent	Cum.
C13_Processing of agricultural and sideline products	3	0.64	0.64
C14_food manufacuturing	5	1.06	1.7
C17_textile manufacturing	4	0.85	2.55
C18_Manufacture of Textile Wearing Apparel, Footware and Caps	1	0.21	2.76
C19_Manufacture of Leather, Fur, Feather and Related Products	2	0.42	3.18
C20_Processing of Timber, Manufacture of Wood, Bamboo, Rattan,Palm and Straw Products	1	0.21	3.4
C22_facture of Paper and Paper Products	1	0.21	3.61
C23_Printing,Reproduction of Recording Media	5	1.06	4.67
C25_Processing of Petroleum, Coking, Processing of Nuclear Fuel	1	0.21	4.88
C26_Manufacture of Raw Chemical Materials and Chemical Products	52	11.04	15.92
C27_Medical and pharmaceutical products	52	11.04	26.96
C28_Chemical Fibers manufacturing	2	0.42	27.39
C29_Rubber and Plastics products	19	4.03	31.42
C30_Manufacture of Non-metallic Mineral Products	20	4.25	35.67
C31_Smelting and Pressing of Ferrous Metals	4	0.85	36.52
C32_Smelting and Pressing of Non-ferrous Metals	10	2.12	38.64
C33_ Manufacture of Metal Products	26	5.52	44.16
C34_Manufacture of General Purpose Machinery	31	6.58	50.74
C35_Manufacture of Special Purpose Machinery	79	16.77	67.52
C36_Manufacture of Automobiles	24	5.1	72.61
C37_Manufacture of Railway, Ship, Aerospace and Other Transport	7	1.49	74.1
C38_Manufacture of Electrical Machinery and Apparatus	43	9.13	83.23
C39_Manufacture of Computers, Communication and Other Electronic Equipment	52	11.04	94.27
C40_Manufacture of Measuring Instruments and Machinery	20	4.25	98.51
C41_Other Manufacture	7	1.49	100
Total	471	100	100

Table 2: summary of ownership categories

ownership	Freq.	Percent	Cum.
State-owned enterprises	83	17.62	17.62
Collective enterprises	34	7.22	24.84
Private enterprises	297	63.06	87.9
Hongkong-Taiwan-Macao enterprises	12	2.55	90.45
Foreign enterprises	24	5.1	95.54
Others	21	4.46	100
Total	471	100	100