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# Sectoral Changes, Energy Consumption, and the Role of Foreign Firm Ownership: The Case of Chinese Cities

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## **Abstract**

This paper decomposes the changes in energy consumption for the industrial sector among a set of 327 Chinese cities over the years 1998 to 2013, taking into that energy consumption can be generally reduced via the scale, the technique and the composition effect. In a second step, it estimates the impact of foreign firm ownership on the industrial shift across sectors, thus, on the composition effect. My findings indicate that both the technique and the composition effect contributed on average to a decline in energy intensity, with the technique effect playing the dominant role. A higher share in foreign firm ownership appears to shift the economy towards relatively more energy intensive sectors, however, only the share of fully foreign owned enterprises from non-ethnically Chinese origins remains statistical significant across different specifications. When considering the changes in the foreign ownership structure instead of the initial values, findings at first suggest a contribution towards relatively cleaner industries. However, they are not stable across different definitions of “foreign ownership”. Further research is necessary to resolve potential endogeneity concerns.

Keywords: Energy Decomposition, Composition Effect, Foreign Firm Ownership, Pollution Haven Hypothesis, China

JEL classification: F21, Q40, Q55

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# Contents

- 1. Introduction ..... 1**
- 2. Related Literature ..... 3**
- 3. Identification Strategy ..... 6**
  - 3.1. The Decomposition Analysis ..... 6*
  - 3.2. The Econometric Analysis ..... 7*
    - 3.2.1. Baseline OLS ..... 7*
    - 3.2.2. Changes in Foreign Ownership Structure ..... 9*
    - 3.2.3. Alternative Measures ..... 10*
- 4. Data and Descriptive Statistics ..... 10**
  - 4.1. Decomposition and Dependent Variable: The Composition Index ..... 10*
  - 4.2. Explanatory Variables and Controls ..... 12*
  - 4.3. Descriptive Statistics ..... 13*
- 5. Results ..... 14**
  - 5.1. The Decomposition Results ..... 14*
  - 5.2. The Econometric Results ..... 19*
    - 5.2.1. Baseline OLS ..... 19*
    - 5.2.2. Changes in Foreign Ownership Structure ..... 21*
    - 5.2.3. Alternative Measures ..... 23*
- 6. Robustness Checks ..... 26**
- 7. Conclusion ..... 28**
- References ..... IV**
- Appendix ..... VI**
  - i. Sector Overview ..... VI*
  - ii. Detailed Variables Description ..... VII*
  - iii. Decomposition results: Alternative Specifications ..... VIII*
  - iv. Further Regression Tables ..... IX*

# 1. Introduction

Over the past decades, China experienced a phase of rapid and outstanding economic development, with annual GDP growth rates exceeding regularly 8%. Along with the economic takeoff, the central government implemented market orientated economic reforms that attracted foreign investors, making China the world largest recipient of Foreign Direct Investment (FDI) (OECD, 2004). In line with that, energy consumption among the Chinese industrial sector rose dramatically. Just in 2009, the country overtook the USA to be the number one consumer of energy worldwide (Yang et al. 2016).

Nevertheless, such phenomenal economic expansion and integration in the world economy were accompanied by increasing pollution intensities and environmental problems. For example, Beijing reported levels of air pollution 40 times higher than those considered as safe by the WHO in late 2015.<sup>1</sup>

Since energy consumption is closely related to air pollution emissions (Cole et al. 2005), policies that target a decline in energy use play an important role for both local and central governments in China. However, to design such policies effectively, it is important to understand the channels through which emissions can be reduced (Voigt et al. 2014). In general, a city's energy consumption can be altered by three major effects, which were originally named by Grossman and Krueger (1993): First, via technological change, meaning a reduction of energy needed to produce one unit of output (henceforth: *technique* effect) and second via structural change, referring to a shift of output towards less polluting industries (henceforth: *composition* effect). Furthermore, a decline of production in absolute terms also leads to less energy consumption (henceforth: *scale* effect).

One theory often emphasized in the literature that contributes to a change in energy consumption via the *composition* effect is the so called "pollution haven" hypothesis.<sup>2</sup> Multinationals may relocate the relatively energy intensive parts of their production towards countries with weaker environmental standards (typically developing or emerging economies) and thus, increasing the share of relatively dirty industries at the place of destination (Eskeland and Harrison 2003).

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<sup>1</sup> See *The Guardian*, December 7, 2015: Beijing issues first pollution red alert as smog engulfs capital. <http://www.theguardian.com/environment/2015/dec/07/beijing-pollution-red-alert-smog-engulfs-capital> [Accessed Feb 01, 2016].

<sup>2</sup> See Copeland and Taylor (2003) for an overview of the classical pollution haven model.

The objective of this paper is therefore to provide additional insight on the impact of foreign firm ownership on sectoral changes. Thereby, I follow McMillan et al. (2014) and apply a two-stage identification strategy. First, I decompose the energy consumption among 327 Chinese cities for the years 1998 until 2013 into the *technique*, *composition* and *scale* effect combining data on energy consumption taken from the China Statistical Yearbook (henceforth: CSY) with data on industrial output from the “Annual Survey of Industrial Firms in China” (henceforth: ASIF).

In a second step, I use the constructed measure of the *composition* effect as the dependent variable to estimate the impact of foreign firm ownership on sectoral changes, whereas I distinguish between Joint Ventures and fully foreign owned enterprises coming from Hong Kong, Macao or Taiwan (henceforth: HMT) as well as from non-ethnically Chinese origins. This differentiation is important, since several studies point out that foreign investors from HMT behave differently with regard to pollution intensity than those from the rest of the world (e.g. Cole et al. 2011; Dean et al. 2009). Moreover, I do not only examine the relation between the *composition* effect and foreign firm ownership per se, but also look at the *changes* in foreign firm ownership, thus, if the output share of foreign owned firms in a respective city is growing or decreasing over time.

If the pollution haven hypothesis were true, a higher share of foreign owned firms should contribute to a growing share of energy intensive sectors, and thus, increasing the overall energy consumption. However, there exists empirical evidence that indeed the opposite may be the case. For example, Dean and Lovely (2010) find in a sample for the Chinese industrial sector over the years 1995 until 2006 that the enhanced presence of foreign invested enterprises tends to move the economy towards relatively less polluting industries.

My findings suggest that, although the *scale* effect plays the most prominent role of all three effects, both the *technique* as well as the *composition* effect contributed on average to a decline in energy consumption, with the *technique* effect being the major force. Thereby, the impact of foreign firm ownership appears to be weak. Only the share of fully foreign owned enterprises from non-ethnically Chinese origins remains statistical significant across different specifications: An increase in such share tends to shift the industry towards relatively dirtier sectors, which is in line with the “pollution haven” hypothesis. Regarding the case of *changes* in foreign ownership shares, I find that the effects at first point in the direction of a contribution towards relatively cleaner industries. However, they are not stable across

different measures of defining “foreign ownership”, especially for the case of foreign owned firms coming from HMT. In general, my results should not be regarded as the ultimate answer to the relation between foreign firm ownership and compositional changes, but rather as a first see-through the data, which needs to be consolidated by further research.

The paper contributes to the literature in mainly two ways. First, most decomposition analyses on energy intensity in China are limited to the country as a whole, neglecting regional differences. However, local Chinese governments play a crucial role for the enforcement of environmental policies (Wu et al. 2016), highlighting the importance of heterogeneity across cities. To the best of my knowledge, this study will be one of the first decomposing energy consumption at the city level, enabling me to account for such differences in a very accurate manner. Additionally, the paper combines both the decomposition analysis and an empirical assessment of determinants that drive compositional changes. As pointed out by Yang et al. (2016), most studies focus either on the decomposition or on the regression analysis. Thus, by setting up the described identification strategy, I am able to directly link changes in foreign ownership shares to compositional changes on city-level without having to rely on proxies for either variable. At the same time, I keep enough variation in the sample for obtaining reliable results that account for intraprovincial differences.

The remainder of the paper is structured as follows. In the next part, I give a short overview of the major literature, Section 3 explains the empirical strategy for the decomposition as well as the empirical analysis, whereas Section 4 introduces the data and provides some descriptive statistics. Section 5 discusses the results from both the decomposition analysis and the empirical part. Section 6 presents alternative specifications to underpin the robustness of my results and Section 7 concludes.

## **2. Related Literature**

In general, there exists a vast literature on both pollution and energy decomposition into the three above-mentioned channels. In the following, I first present a short overview of the most important literature for the worldwide case, before turning to studies focusing especially on China.

One of the earliest to decompose pollution measures in *technique*, *composition* and *scale* effect were Grossman and Krueger (1993), who examined the possible impact of the North

American Free Trade Agreement (NAFTA) on several air pollutants for the U.S. and Mexico. They argue that, by liberalizing trade between the two countries, Mexico most likely specializes in its comparative advantage of labor-intensive and agricultural sectors that are typically less energy consuming and thus, contributing to a decrease in pollution via the *composition* effect.

However, their work is limited to a very specific case of further market integration. Therefore, Antweiler et al. (2001) provide a more general theoretical and empirical decomposition framework to estimate the effect of increased openness on the air pollutant SO<sub>2</sub> for 108 cities in 42 countries from 1971 to 1996. According to their results, trade liberalization accounting for 1% of GDP growth reduces pollution by 1%, whereas the largest impact is due to the *technique* rather than the *composition* effect. In line with that, Levinson (2009) decomposes SO<sub>2</sub> emissions for the U.S. manufacturing sector from 1987 to 2001 and shows that trade leads to a reduction of emissions mainly due to increased technological progress.

Although all of the described studies examine the impact of further market integration on pollution intensity through the *technique*, *scale* and *composition* effect, none of them directly focuses on the role of foreign firm ownership or, closely related, FDI. Eskeland and Harrison (2003) were one of the first to empirically test the pollution haven hypothesis for FDI inflows into four developing countries: Côte d'Ivoire, Morocco, Mexico and Venezuela. Even though they do not find robust evidence that multinationals strategically outsource the production of relatively dirtier sectors (*composition* effect), they do show that foreign plants are on average less energy intensive than local ones. Thus, they provide empirical evidence for the *technique* effect through the channel of FDI inflows.

Arguably, one cannot simply transfer those results to the case of China. The tremendous economic take off and rapid integration into the world economy were historically unique for such as large emerging country. Thus, a direct look at the Chinese energy decomposition and its relation to foreign ownership shares is necessary.

Yang et al. (2016) provide a recent overview of studies focusing on the decomposition of energy consumption in China. For example, Song and Zheng's (2012) findings suggest that over the years 1995 until 2009, the energy intensity among Chinese provinces for the overall economy declined by 34%, with the *technique* effect outweighing the *composition* effect. With regard to SO<sub>2</sub> emissions, He (2010) analyzes the decompositional structure of 13 industrial sectors at the province level. Again, she finds the *technique* effect to be the major

driving force behind the decline in pollution intensity. In line with that, Zhang et al. (2009) look at the decomposition of CO<sub>2</sub> emissions in China that are directly related to energy consumption. According to their results, structural changes have a small but positive effect on overall CO<sub>2</sub> reductions, although they are mainly resulting from a decline of emissions in the agricultural sector.

Regarding the relation between foreign investment and pollution intensity in China, He (2006) estimates how FDI affects SO<sub>2</sub> emissions through the *technique*, *composition* and *scale* effect on a panel of 29 Chinese provinces over the years 1994 until 2001. She finds an overall rather small impact: An increase of the FDI capital stock by 1% also raises the SO<sub>2</sub> emissions by 0.098%, of which she attributes 0.123% to the *scale* effect, a decline of 0.061% to the *technique* effect and an overall 0.036% *increase* to the composition of sectors. Thereby, she argues that most of this increase is related to the “pollution haven” hypothesis, thus, to the outsourcing of relatively dirty industries from industrialized countries to China.

Contrarily, Dean et al. (2009) do not find empirical support for the pollution haven hypothesis with respect to investors from high-income countries. They directly study the location choice of equity joint ventures among the Chinese manufacturing sector for the years 1993 to 1996 and argue that Joint Ventures from non-ethnically Chinese sources are not attracted by weak environmental standards and do not systematically shift their relatively more pollution intensive sectors to China. However, they do find evidence for the pollution haven hypothesis with regard to Joint Ventures funded by Hong Kong, Macau or Taiwan based enterprises in highly polluting sectors.

Moreover, there exist various papers examining the impact of firm ownership in China on the absolute level of pollution intensity directly (rather than on its compositional changes) with most of them finding state own enterprises (SOEs) tend to be generally more pollution intensive (e.g. Jiang et al. 2014; Wang and Jin 2002).

Again, Cole et al. (2011) emphasize on the importance to distinguish between non-ethnically Chinese and HMT origins when looking at the effects of foreign ownership on the pollution intensity in China: They relate an increase in the output share of domestic and non-ethnically Chinese enterprises to higher emission intensity, whereas the output share of HMT enterprises is more likely related to lower pollution levels.

This brief overview points out that although the energy intensity among Chinese industries declined over the past decades, the relationship between foreign ownership and sectoral shifts is not yet resolved. This paper aims to shed light on that question by directly linking the structure of firm ownership on compositional changes on the city-level in China.

### 3. Identification Strategy

#### 3.1. The Decomposition Analysis

As outlined in Section 1, the change in energy consumption of a city generally results from either the *technique*, the *composition* or the *scale* effect. Mathematically, those effects can be expressed in the following formula (Levinson 2009):

$$\begin{aligned} \Delta Energy_{ct} = & \sum_{s=1}^n \Delta Energy\ intensity_{st} * \theta_{sc1998} * y_{sc1998} \\ & + \sum_{s=1}^n Energy\ intensity_{s1998} * \Delta \theta_{sct} * y_{sc1998} \\ & + \sum_{s=1}^n Energy\ intensity_{s1998} * \theta_{sc1998} * \Delta y_{sct} \end{aligned} \quad (1)$$

In this formula,  $\Delta Energy_{ct}$  stands for the total change in energy consumption in city  $c$  between the year  $t$  and the base year of the analysis (1998).  $\theta$  refers to each sector's share of total output in city  $c$  at time  $t$  and *Energy intensity* to the sector-specific ( $s$ ) amount of energy needed to produce one unit of output in year  $t$ .  $y_{sct}$  denotes the absolute output of sector  $s$  in city  $c$  at time  $t$ .

The first term of equation (1) is the *technique* effect, which shows the part of changes in energy consumption that arises from more energy efficient production (energy intensity), with both the composition of sectors and the absolute output remaining on 1998 levels. Similar, the *composition* effect (2<sup>nd</sup> term) accounts for changes in energy consumption due to the mix of sectors, holding the output level and the energy intensity constant. The third term refers to the *scale* effect, capturing the change in energy consumption that can be explained by an expansion in absolute output with both the composition and technique fixed on their 1998 values (Levinson 2009).

To obtain percentage changes, one simply needs to divide both sides of equation (1) by the energy consumption of city  $c$  in the base year ( $Energy_{c1998}$ ). Moreover, it is important to

mention that equation (1) represents changes in overall energy *consumption*. However, when interested in estimating changes in citywide energy *intensity* (energy consumption per unit of output), the third term of equation (1) (*scale effect*) necessarily drops and the first two terms have to be divided by the city output of 1998 ( $y_{sc1998}$ ).

### 3.2. The Econometric Analysis

Before proceeding to the empirical strategy in greater detail, it is noteworthy that two modifications were applied to equation (1) when including its second term as dependent variable in the regression analysis:

First, changes in energy intensity due to sectoral shifts (*composition*) are not constructed with respect to the base year 1998 but with respect to t-1. Arguably, the *composition* effect would be larger for the year 2013 than for the year 1999 if only changes in energy consumption with respect to 1998 would be considered. Clearly, that would bias the regression results. I therefore estimate changes in the mix of sectors by continuously using the preceding period (t-1) as base and holding both the sectoral energy intensity and output values fixed on their 1998 levels. Put differently, the  $\Delta$  in the second part of equation (1) now refers to changes from t-1 to t instead of 1998 to t. Second, I do not use annual data on compositional changes, but averages over four years, reducing the number of years included in the regression to four points in time, namely 1998, 2001, 2005 and 2009.<sup>3</sup> In this way, I account for short-term volatilities that are likely to impact the composition of industries (e.g. exogenous shocks affecting only specific sectors such as a drop in commodity prices).

#### 3.2.1. Baseline OLS

To estimate the relationship between a city's output share stemming from foreign invested firms and the compositional shift across sectors, I use the following panel OLS regression equation:

$$\begin{aligned} \Delta Comp_{ct} = & \alpha_0 + \beta_1 JointVenture_{ct} + \beta_2 ForeignOwned_{ct} + \beta_3 SOE_{ct} + \gamma Controls_{ct} + \delta_c \\ & + \delta_t + \varepsilon_{c,t} \end{aligned} \tag{2}$$

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<sup>3</sup> Thereby, 1998 refers to the average annual change from 1998-2001, 2001 to 2001-2005 and so on. The first period (1998-2001) only includes three years, due to the uneven number of years in the analysis.

where  $\Delta Comp_{ct}$  stands for the average annual change in energy *intensity* in city  $c$  from time  $t$  to  $t+1$  (e.g. the average yearly change between 1998 and 2001) that is due to sectoral shifts (*composition effect*).  $Controls_{ct}$  refers to a set of control variables that can vary across cities ( $c$ ) and time ( $t$ ). City fixed effects ( $\delta_c$ ) and year fixed effects ( $\delta_t$ ) account for time invariant city and year characteristics,  $\varepsilon_{ct}$  denotes the idiosyncratic error term and  $\alpha_0$  the intercept.

The coefficients of interest in my analysis are  $\beta_1$  and  $\beta_2$ , capturing the impact of different types of foreign ownership on the dependent variable. Thereby,  $JointVenture_{ct}$  refers to the output share of city  $c$  in time  $t$  that is coming from either foreign equity joint ventures or foreign cooperative joint ventures, whereas  $ForeignOwned_{ct}$  is the output share generated by fully foreign owned enterprises, foreign invested cooperations or other foreign invested enterprises. Additionally, I control for the output share of state owned enterprises (SOEs, including state cooperative enterprises, state and collective enterprises and state-owned limited liabilities) in city  $c$  at year  $t$ , indicated by  $SOE_{ct}$ , to account for the fact that SOEs are in general more energy intensive than other type of firms (Jiang et al. 2014).

However, as outlined in Section 2, there might be a difference in effects between Joint Ventures and Foreign Owned Enterprises from non-ethnically Chinese origins and those from Hong Kong, Macau or Taiwan. Therefore, I also estimate equation (2) for Joint Ventures and Foreign Owned Enterprises from either origin separately.

The set of further controls  $Controls_{ct}$  includes variables that may have an impact on both the sectoral shifts across industries and on foreign ownership shares. Following McMillan et al. (2014), I control for a city's initial energy intensity in time  $t$  to capture convergence effects. Arguably, the higher the initial energy intensity, the more room there is for a decrease. Additionally, I include the export share (measured as the export value per unit of output) since export and foreign ownership are often regarded as complements. Besides, there exists a growing literature indicating that China's exports have shifted towards relatively cleaner sectors over time (e.g. Dean and Lovely 2010). Moreover, I add a proxy for productivity, measured as the output per employee. Thereby, I consider the fact that increased productivity usually goes along with economic growth which in turn contributes to the shifting towards relatively cleaner sectors. The squared term of this variable accounts for potential non-linear relationships (Grossman and Krueger 1993).

Furthermore, as suggested by Aghion et al. (2015), I control for the correlation between competition and industrial policies on the city level. A positive correlation would suggest that

industrial policies are targeted towards more competitive sectors and thereby, contribute to an even further increase in competitiveness (potentially spurring productivity and reducing energy intensity). Competition is measured by a sector specific Lerner Index [0,1], where 1 indicates perfect competition and 0 a monopolistic situation. Moreover, I use two measures of industrial policies: First, I estimate the sector specific output share of firms that receive tax holidays, meaning they paid a lower tax rate than the official corporate tax rate. In China, the corporate tax rate for foreign-invested firms was 15% until 2008, gradually increased to 20% in 2009 and eventually reached 25% in 2012. On the contrary, domestic firms permanently face a statutory tax rate of 33% (Du et al. 2014) Thus, if more firms in a more competitive sector receive tax holidays (thus, the output shares of those firms in the respective sector is higher), the correlation should be positive.

Another type of industrial policy proposed by Aghion et al. (2015) is the share of interest rate payments to current liabilities. Arguably, the lower the interest rate within one sector, the more preferential is the policy treatment. Hence, I additionally include the correlation between the interest rate payments over current liabilities and the sector specific Lerner Index as a control variable. In comparison to the first correlation variable, this time a *negative* correlation indicates that policies are targeted towards more competitive sectors. A more detailed description on the construction of all variables can be found in appendix ii.

### 3.2.2. Changes in Foreign Ownership Structure

Nevertheless, equation (2) only captures the relationship between the initial output share of foreign invested firms and changes in the structural composition within the following period. Therefore, it does not provide any information on the impact of *changes* in the ownership structure on the shift across industries. If a city experiences a lot of foreign investment inflows, the output share of foreign owned firms will arguably grow. If rather the inflow of new foreign investors than the initial stock results in a compositional shift across sectors, equation (2) would fail to capture such dynamic effects. Therefore, I extend it to the following:

$$\begin{aligned} \Delta Comp_{ct} = & \alpha_0 + \beta_1 \Delta JointVenture_{ct} + \beta_2 \Delta ForeignOwned_{ct} + \beta_3 JointVenture_{ct} \\ & + \beta_4 ForeignOwned_{ct} + \beta_5 SOE_{ct} + \gamma Controls_{ct} + \gamma_c + \delta_t + \varepsilon_{c,t} \end{aligned} \quad (3)$$

$\Delta$  indicates the change in output shares from  $t$  to  $t+1$  generated by Joint Ventures or Foreign Owned enterprises, respectively. Apart from that, equation (3) remains equal to equation (2). Both the terms  $JointVenture_{ct}$  and  $\beta_4 ForeignOwned_{ct}$  stay in the analysis to account for the fact that a shift in output shares largely depends on the initial value (convergence effects). Again, I will provide a more detailed insight on the impact of ownership structure by examining Joint Ventures and fully foreign owned enterprises coming from non-ethnically Chinese origins and those from HMT individually.

### 3.2.3. Alternative Measures

As pointed out by Brandt et al. (2014), there are different ways of classifying “foreign ownership” when working with the ASIF dataset. Besides using the output share assigned to the various firm types, one can also work with the information on the registered capital. Each firm reports the amount of foreign capital, capital from HMT, state capital, individual capital, collective capital and legal person capital separately. Thus, to ensure the results are not driven by the way I define foreign ownership, I reestimate both equation (2) and equation (3) using the capital share instead of the output share coming from HMT as well as from non-ethnically Chinese investors in the respective city to define foreign ownership. Again, I will not only consider the capital structure per se, but also its changes over time.

## 4. Data and Descriptive Statistics

### *4.1. Decomposition and Dependent Variable: The Composition Index*

In order to perform the decomposition analysis, data on energy intensity (energy consumption per unit of output) and citywide output for each two-digit sector are needed.

To obtain such data, I combine two datasets: Data on energy consumption (per 10,000 tons of standard coal equivalent) are taken from the China Statistical Yearbook (CSY), which issues yearly data on energy consumption on the two-digit level for the industrial sector. The data are available for all years of the analysis, namely 1998 until 2013. Additionally, the CSY published the volumes of Sulphur Dioxide Emissions ( $SO_2$ , in 10,000 tons) by two-digit manufacturing sector for the years 2003 until 2010. Thus, I am able to rerun the decomposition analysis for a shorter time span on pollution data directly, which I will further discuss in Section 6.

Data on industrial output (value at current prices) are obtained from the ASIF dataset, collected by China's National Bureau of Statistics (NBS). This survey is conducted annually among all manufacturing firms as well as those specialized in mining operations or electricity, gas and water supply and whose annual sales are exceeding 5 million RMB, which is around 770,000 US-Dollars (Brandt et al. 2014).

Data from the latter source are aggregated from the firm- to the city-level (4-digit geocode) to obtain output values for each city by sector.<sup>4</sup> For the results to be reliable, the aggregated output values on the country level must match with those published by the CSY, which is the case until 2008 (Brandt et al. 2014). In order to extend the time span further up to 2013, I work with two versions of the ASIF dataset, one issued by Fudan University and one issued by the Shanghai University of International Business and Economics (SUIBE), using each year the source for which the aggregation works best when compared to the CSY. However, for the year 2010, neither of the datasets matches the CSY on the aggregated level. Thus, the year 2010 is not considered throughout the analysis. Moreover, I omit the year 2012 when presenting the decomposition results, since the compositional changes in that year display disproportionate large results, which are rather due to data issues than to actual changes.

Furthermore, for the decomposition analysis to work, two conditions have to be met. First, all cities need to be included in the analysis, since I work with energy data on country level but aggregate sectoral output values up to country level in order to estimate sectoral energy intensity. If a substantial part of cities would now be dropped from the analysis, such measure would arguably not yield reliable data on sectoral energy intensity.

Second, it is important to track the exact same area of land (e.g. one prefecture-level city) over time and observe the changes in energy consumption within that limited area to ensure that, for example, an increase in energy consumption is not due to the geographical expansion of that particular city. Throughout the years of the analysis, many county-level cities were upgraded to prefecture-level cities, meaning they changed their 4-digit geocode but remained the same in terms of land area. As the identification of single cities within the dataset is based on geocodes, it is thus necessary to recode such county cities to their corresponding prefecture-level geocode for the years prior to the official upgrade. I did the recoding by individually identifying zip codes which are available on the firm-level and thereby matched

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<sup>4</sup> China is divided into five autonomous regions, 23 provinces and four major cities that are themselves provinces: Beijing, Chongqing, Shanghai and Tianjin (2-digit geocode). Each province is then divided into several prefecture-level-cities as well as county-level cities, which can both be identified through 4-digit geocodes.

101 cities. Furthermore, in some years prefecture-cities were newly established out of parts of other preexisting prefecture cities. In such cases, I recoded the whole area back to the initial prefecture-city geocode to ensure consistency throughout the whole period.

Eventually, the dataset contains 327 4-digit geocode cities (both prefecture-level and county-level) that consistently exist throughout the whole time span of the analysis.

Furthermore, the sample is subdivided into 32 2-digit industries, among which 28 belong to the manufacturing sector, three to the “Production and Supply Industry of Power, Fuel Gas and Water” and one to the mining industry.

Again, changes in the nomenclature of Chinese industry codes (cic-codes) in 2002 and 2012 made it necessary to recode all sectors to their 2002 values ensuring consistency of sectors. An overview about which sectors exactly are included in the analysis can be found in appendix i.

#### *4.2. Explanatory Variables and Controls*

The main explanatory variables regarding the output share of foreign invested firms is constructed by dividing the citywide output of all firms that are either coded as Joint Ventures or Foreign Owned Enterprises through the overall city output. For example, if for a given city in a given year, the variable *JointVenture* equals 0.5, it means that 50% of the city’s output was generated by firms that are listed as either equity joint ventures or cooperative ventures. In line with that, the variable  $\Delta JointVenture$  indicates the changes of the output share generated by Joint Ventures from one period to another. Thus, if *JointVenture* takes the value 0.5 in period  $t$  and 0.7 in period  $t+1$  (for example 2001 and 2005), the value for  $\Delta JointVenture$  is 0.05, since the share grew by 0.2, divided through four years. At this point, it is important to remember that throughout the empirical part of the paper, changes from  $t$  to  $t+1$  refer to annual averages within the respective periods (e.g. from 2001 to 2005). The output share for SOEs is constructed in the same manner. Accordingly, capital shares are constructed by dividing the foreign capital of city at time  $t$  by the overall capital of the respective city.

The ASIF dataset further provides detailed firm information on the number of employees, the export value, the firm’s capital structure, the revenue, the interest rate payment, the current liabilities and the income tax paid. Thus, I can construct all control variables using the information provided by the ASIF dataset. A detailed overview on the exact estimation of each variable is given in appendix ii.

However, as a firm dataset, the ASIF does not contain any information on macro related city variables such as GDP or population size. China Data Online, a dataset compiled by the University of Michigan, provides such data for all prefecture-level cities in China. To further check the robustness of my results, I will include macro variables in the regression, and rerun the analysis on prefecture level cities only, as explained more detailed in Section 6.

### 4.3. Descriptive Statistics

Table 1 shows the sample size, the mean, the standard deviation as well as the minimum and the maximum values of the dependent variable as well as the key explanatory variables.

The first row indicates that the mean change in the composition across sectors was 0.01%, stretching from -9% to +18.8%. However, on average, the foreign output share is relatively small (column 2, *mean*), with 8.25% for Joint Ventures and 5.11% for fully foreign owned enterprises from either destination. Note that the values for *JointVenture from HMT* and *JointVenture from Non-Chinese* necessarily have to add up to *JointVenture*. The same applies for foreign owned enterprises.

**Table 1:** Descriptive Statistics

| Variables  | N    | mean       | SD        | min        | max       |
|--|------|------------|-----------|------------|-----------|
| % Change in Energy Intensity due to the composition effect | 1307 | -0.0019002 | 0.0123171 | -0.0902045 | 0.1880879 |
| JointVenture   | 1307 | 0.0825274  | 0.0905936 | 0          | 0.746847  |
| Foreign Owned Enterprise                                   | 1307 | 0.0511259  | 0.0995061 | 0          | 0.6997998 |
| JointVenture from HMT                                      | 1307 | 0.0356285  | 0.0530876 | 0          | 0.3732503 |
| JointVenture from Non-Chinese                              | 1307 | 0.0468988  | 0.0626825 | 0          | 0.7458851 |
| Foreign Owned by HMT                                       | 1307 | 0.0245594  | 0.0594505 | 0          | 0.5842804 |
| Foreign Owned by Non-Chinese                               | 1307 | 0.0265689  | 0.059996  | 0          | 0.6973426 |
| $\Delta$ JointVenture                                      | 1305 | -0.0009729 | 0.0161100 | -0.1353589 | 0.1724408 |
| $\Delta$ Foreign Owned Enterprise                          | 1305 | 0.0028155  | 0.0127926 | -0.0928996 | 0.1169304 |
| $\Delta$ JointVenture from HMT                             | 1305 | -0.0011239 | 0.0104804 | -0.0914507 | 0.1337656 |
| $\Delta$ JointVenture from Non-Chinese                     | 1305 | 0.0001448  | 0.0140633 | -0.1353589 | 0.1747146 |
| $\Delta$ Foreign Owned by HMT                              | 1305 | 0.0010961  | 0.0076332 | -0.054264  | 0.0805002 |
| $\Delta$ Foreign Owned by Non-Chinese                      | 1305 | 0.001705   | 0.0103163 | -0.0975893 | 0.1169304 |

Note: JointVenture refers to the output share generated by Joint Ventures in city  $c$  at time  $t$ ,  $\Delta$  JointVenture to the change in such output share from  $t$  to  $t+1$ . All other foreign ownership measures are constructed accordingly.

Moreover, the *changes* in output shares appear to be even smaller. On average, only the share of Joint Ventures from HMT decreased over time, namely by 0.1 percentage points (note that

the negative value for  $\Delta JointVenture$  is driven by that decline since it combines Joint Ventures from both HMT and non-ethnically Chinese origins). The difference in sample size between absolute values and changes is due to the cities *Linzhi* and *Ali* that are both located in Tibet. The overall city output for those two cities is zero in 2013, thus, changes in output shares between 2009 and 2013 are coded as missing. Furthermore, there is no city output reported for *Linzhi* in 2009, hence, the sample contains 1307 observations (327 cities x four years = 1308 –  $Linzhi_{2009}$  = 1307).

## 5. Results

### 5.1. The Decomposition Results

**Figure 1:** % Change in Energy Consumption due to Technique and Composition  
(weighted average, with respect to 1998)

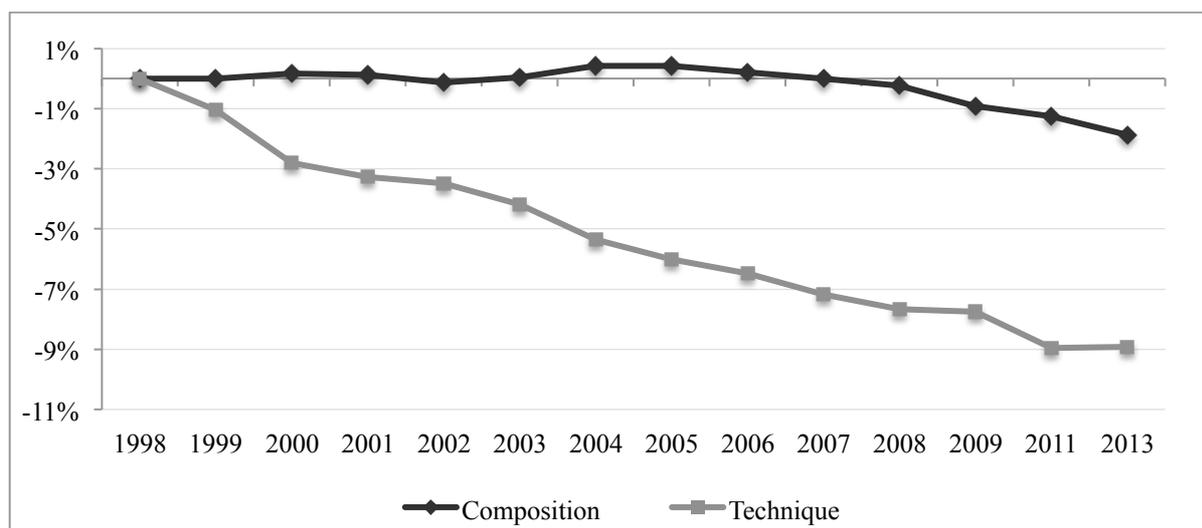


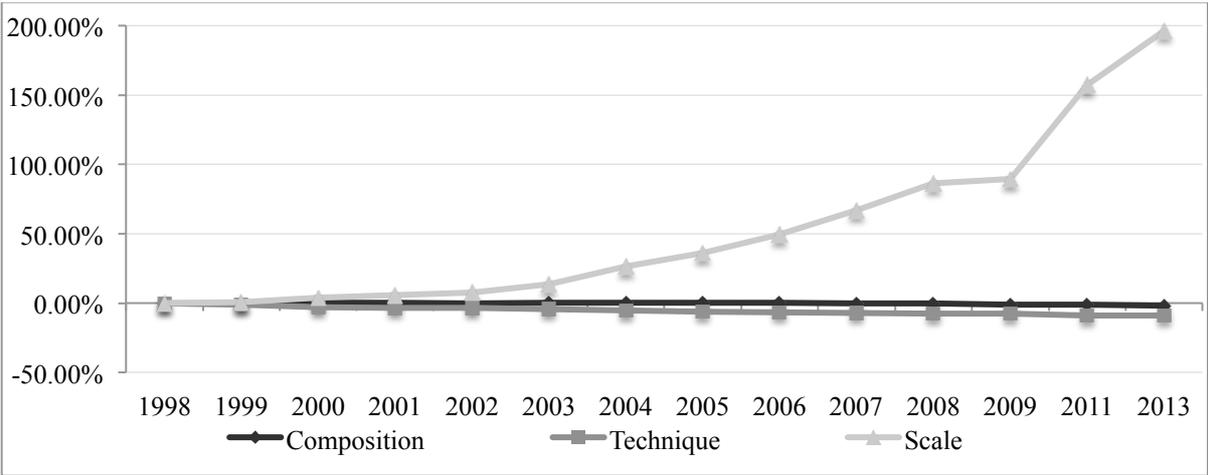
Figure 1 illustrates the results of the decomposition analysis for average percentage changes in energy consumption due to the *composition* and the *technique* effect among Chinese cities, weighted by their output shares.<sup>5</sup> It can clearly be seen that both effects seem to have a positive impact, thus, they contribute to an overall reduction in energy consumption over the sample period. Thereby, the *technique* effect outweighs the *composition* effect: While an increase in energy efficiency contributes to 8.9% of overall energy consumption reduction, shifts among sectors account for 1.87%. However, when looking at the *scale* effect (Figure 2) both effects seem rather small. Due to the expansion in total output, energy consumption

<sup>5</sup> It is to note that, for the decomposition analysis, percentage changes in energy consumption and percentage changes in energy intensity display the same values by means of construction. For reasons of simplicity, I therefore refer to *changes in energy consumption* throughout Section 5.1.

increased by 196.36% from 1998 to 2013, reflecting China’s rapid economic growth during the past decade.

In contrast, when directly estimating the decomposition analysis for the country as a whole, the *technique* effect only accounts for 3% of the decline in energy consumption and the *scale* effect for an increase of 77% (reported in Table 2, row 2). Interestingly, the *composition* effect seems to have almost no impact on the change in energy consumption in this specification. It is only responsible for *plus* 0.4%, meaning if there is any effect, it contributed to an increase in energy consumption. Thus, the weighted averages appear to overestimate all three effects. Those differences can be most likely explained by the fact that cities with relatively large output values cleaned up disproportionately. However, since the paper focuses on the heterogeneity across cities, I emphasize on the weighted averages case throughout the further course of this chapter.

**Figure 2:** % Change in Energy Consumption due to Technique, Composition and Scale (weighted average, with respect to 1998)



The general result implying that the *technique* effect is the major contributor to a decrease in city wide energy intensity (only *technique* and *composition* effect) is in line with the previous literature, covering both the non-Chinese case (see e.g. Levinson 2009 for the U.S. or Voigt et al. 2014 for a worldwide example) and China itself (e.g. He 2010; Liu et al. 2015). However, my results seem to be much smaller in magnitude. Exemplarily, He (2010) examines changes in SO<sub>2</sub> emissions across Chinese provinces for 13 industrial sectors between the years 1991 and 2001 and finds the *technique* effect to have decreased emissions by on average 9.4% annually and the *scale* effect to have increase them by approximately the same amount

(9.8%). The *composition* effect only plays a minor role with an annual contribution of 1.8% to an overall decrease.

Such gaps in magnitude may be due to differences in the underlying base years. For example, He (2010), whose analysis starts in 1991, observes that most of the changes in energy consumption occurred prior to 1998, the starting point of my analysis. Combined with my findings, one can reason that the majority of the “clean-up” among the Chinese industry seem to have taken place in the 1990’s.

In line with that, when looking at Figure 1, the graph for the *technique* effect depicts a relatively steeper slope during the years 1998 until 2000. There even seems to be a “bump” around the years 2001 to 2004, slowing down the improvement in sector specific energy intensity. One explanation for this deceleration in the *technique* effect is China’s entrance to the WTO in 2001. The accession initially led to a slowdown of the decline in sector specific energy intensity, which was encountered by policies targeting the reduction of energy intensity by 20% within the 11<sup>th</sup> Five-Year-Plan (2006-2010) (Liu et. al 2015).

Around the same time (approx. 2002), an increase of the *composition* effect – corresponding to a shift towards more polluting industries – can be observed (Figure 1). As Liu et al. (2015) argue, the WTO-membership did not only slow down the *technique* effect, but also spurred especially the production of relatively energy-intensive sectors, such as the manufacture and casting of both ferrous and non-ferrous metals. Indeed, when looking at the data, both of those sectors increased their output share over the sample period (from 6.2% to 7.2% for ferrous metals and from 2.4% to 2.8% for non-ferrous metals, respectively).

In order to get a better understanding of the heterogeneity across Chinese cities, Table 2 presents summary statistics of the decomposition analysis for various subsamples. The single columns show the percentage changes in energy consumption from 1998 until 2013 for the *technique*, *composition* and *scale* effect. Row one refers to Figure 1 and 2, whereas rows two respectively three present the results for the whole country case and the simple average across all cities.

Rows four and five show the weighted average for the coastal area and the western part of China separately. Wu et al. (2016) argue that more polluting firms might relocate from the industrialized coast to the western regions of China, since environmental regulation policies tend to be more lenient in the west. Hence, if one part of China would be cleaning up while

the other part would become dirtier, both results might neutralize each other. The displayed results do not confirm this conjecture, since all three effects point in the same direction for both regions.<sup>6</sup> However, the coastal area reduced its energy intensity stronger than the west, thus, both the technique and the composition effect display more negative values for the coast. Those findings hint towards a convergence effect, meaning that regions with low initial energy intensity cleaned up less than those with higher initial values. In line with that, the correlation between energy intensity in 1998 and the composition effect from 1998 to 2013 for the whole sample is -0.297.

**Table 2:** Decomposition Results – Various subsamples

|   | Composition Effect<br>(1998-2013) | Technique Effect<br>(1998-2013) | Scale Effect<br>(1998-2013) |
|---|-----------------------------------|---------------------------------|-----------------------------|
| Whole Sample  | -1.87%                            | -8.92%                          | 196.36%                     |
| Whole Sample (country level)                                      | 0.41%                             | -4.10%                          | 77.18%                      |
| Whole Sample (simple mean)  | -3.41%                            | -13.52%                         | 257.04%                     |
| Coast Region  | -1.15%                            | -7.47%                          | 174.22%                     |
| West Region   | -2.35%                            | -10.98%                         | 259.89%                     |
| Center Region   | -1.93%                            | -9.37%                          | 171.96%                     |
| Boundary Region   | -1.82%                            | -8.49%                          | 219.75%                     |
| SOEs (Upper 50 percentile)  | -4.46%                            | -15.40%                         | 280.02%                     |
| SOEs (Lower 50 percentile)  | -1.10%                            | -6.88%                          | 170.11%                     |
| Joint Ventures (Upper 50 percentile)                              | -0.95%                            | -7.05%                          | 135.21%                     |
| Joint Ventures (Lower 50 percentile)                              | -4.91%                            | -14.64%                         | 380.87%                     |
| Joint Ventures from HMT (Upper 50 percentile)                     | -0.60%                            | -6.72%                          | 130.14%                     |
| Joint Ventures from HMT (Lower 50 percentile)                     | -4.82%                            | -13.78%                         | 345.25%                     |
| Joint Ventures from non-China (Upper 50 percentile)               | -1.20%                            | -6.94%                          | 132.05%                     |
| Joint Ventures from non-China<br>(Lower 50 percentile)            | -3.36%                            | -12.90%                         | 324.17%                     |
| Foreign Owned Enterprises (Upper 50 percentile)                   | -1.05%                            | -6.20%                          | 111.66%                     |
| Foreign Owned Enterprises (Lower 50 percentile)                   | -2.46%                            | -11.81%                         | 224.77%                     |
| Foreign Owned Enterprises by HMT<br>(Upper 50 percentile)         | -0.79%                            | -5.84%                          | 101.78%                     |
| Foreign Owned Enterprises by HMT<br>(Lower 50 percentile)         | -2.16%                            | -10.64%                         | 199.32%                     |
| Foreign Owned Enterprises by non-Chinese<br>(Upper 50 percentile) | -0.84%                            | -5.92%                          | 106.49%                     |
| Foreign Owned Enterprises by non-Chinese<br>(Lower 50 percentile) | -1.86%                            | -10.31%                         | 203.54%                     |

**Note:** All values display weighted averages (by the output shares) across cities, if not stated differently. The percentage changes indicate changes in energy consumption from 1998-2013 that is due to the composition, the technique or the scale effect, respectively. “SOEs (Upper 50 percentile)” stands for the subsample of cities whose output share of SOEs is in the upper 50 percentile when compared to the whole sample. All subsamples beneath that are constructed accordingly.

<sup>6</sup> In contrast to Wu et al. (2016), He’s (2010) results suggest that the composition effect was largely positive for provinces located in the north and in the south of China, whereas it was largely negative for provinces in the center. As shown in Table 2, rows six and seven, the decomposition results are also robust against such geographic specification. Although not reported, the same applies for estimating the three effects for every geographic region on the country level directly. A description of which provinces refer to west, coast, center and boundary can be found in appendix ii.

Moreover, rows 8 to 21 present the results when the overall sample is divided into cities in the upper and lower 50 percentile of output shares generated by Joint Ventures, Foreign owned enterprises and SOEs, respectively (in year 1998). Those values provide a first insight towards the impact of foreign firm ownership on the sectoral shifts within cities. As it can be seen, the lower 50 percentiles of foreign ownership subsamples experienced larger shifts than their counterparts of the upper 50 percentile. Those results can have several explanations. First, it might display a convergence effect, meaning cities with a larger output share of foreign firm ownership started with lower energy intensity values and higher absolute output in 1998, leaving them less space to clean up and grow further. Second, it might hint towards the “pollution haven” hypotheses: If foreign investors offshore the relatively dirty stages of their production towards China, more energy intensive sectors will expand in cities with higher foreign output shares, thus, the *composition* effect displays less negative values for such cases. For the output share of SOEs, the reverse seems to be the case: Cities in the upper 50 percentile cleaned more up on average and also grew more (higher *scale* effect). Again, it can either display a convergence effect or the fact that SOEs contribute to the expansion of relatively cleaner sectors. However, there appears to be largely accordance in the literature (e.g. Jiang et al. 2014; Wang and Jin 2002) that SOEs generally contribute to more pollution emissions, thus, the latter value is most likely to display a convergence effect. Indeed, the correlation between the part of the *composition* effect that is not explained by the initial energy intensity and the share of SOEs is highly positive (0.62), indicating that a higher output share from SOEs contributes on average to the expansion of relatively dirtier sectors.

However, one important drawback to mention is that the decomposition analysis does not account for *intra*-industry changes of sectoral activity (Levinson 2009). Thus, if there has been substantial movement within single 2-digit industries from heavier to less energy intensive subindustries, the analysis overestimates the *technique* and underestimates the *composition* effect. Unfortunately, data on energy consumption for the Chinese manufacturing sector is only available on the 2-digit industry level, and thus, a more detailed breakdown is currently not feasible. Moreover, one should keep in mind that such decomposition of energy consumption is solely descriptive. Hence, to see if the results are also meaningful in a statistical sense requires an empirical analysis, which I present in the following section.

## 5.2. *The Econometric Results*

When analyzing the regression tables, it should be noted that all estimations were carried out after omitting outliers. Since I work with firm level data aggregated to the city level, it frequently happens that certain variables display extremely high or low values. To exclude the possibility that the overall estimation results are driven by those cases, I identify multivariate outliers with respect to the dependent variable as well as to the foreign ownership types by working with the build-in command in Stata using the method proposed by Hadi (1992). Thereby, I use a cut-off significance level of 0.001. However, I report the results without omitting outliers and using a more conservative cut-off level (0.01) in appendix iv.

### 5.2.1. Baseline OLS

Table 3 presents the estimation results from equation (2). All columns include both city and year fixed effects. I carried out a Hausman Test to ensure that the fixed-effect model is the appropriate choice over using a random-effects estimator.<sup>7</sup>

Columns (1) and (2) refer to Joint Ventures and foreign owned firms from both non-ethnically China and HMT combined. Column (1) shows the baseline specification without further controls, whereas column (2) adds the control variables described in section 4.2. Since the specification is a standard OLS model, all coefficients can be directly interpreted as marginal effects. For both variables *JointVenture* and *Foreign Owned Enterprises*, the coefficients show a positive sign for the specifications with and without controls. This means if the output share of either Joint Ventures or Foreign Owned Enterprises increases, holding everything else constant, the change in energy intensity due to sectoral shifts will on average also *increase*. However, the coefficient for *JointVenture* loses its statistical significance after adding the control variables (column (2)) and the significance for *Foreign Owned Enterprises* decreases to the 10% level. It is important to note that this does not necessarily imply a shift towards relatively dirtier sectors (meaning the composition effect turns positive), but rather that the change in energy intensity is 0.014 percentage points lower than for a comparable city, everything else equal.

When looking at the coefficients of the control variables, the output share of SOEs depicts – as expected – a positive sign, indicating that a higher share of SOEs is related to a shift towards relatively dirtier sectors, though falling short of statistical significance after adding

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<sup>7</sup> It yields a p.-value of 0.017 for the specification reported in column (4). Thus, it rejects the null-hypothesis that the difference in coefficients is not systematic.

further controls. On the other hand, the coefficient for  $\ln(\text{energy intensity})$  is negative, hence a relatively higher initial energy intensity contributes to a shift towards relatively cleaner sectors. Thereby, it is statistically significant at the 5% level. Those findings are in line with the decomposition results from Section 5.1. Indeed, there seems to exist a convergence effect and moreover, after adding the initial energy intensity as a control variable, the output share of SOEs displays (although statistically insignificant) a positive sign, pointing towards a shift to relatively more energy intensive sectors.

**Table 3:** Regression Results – Output Shares, Levels

| Dependent Variable:            | (1)  | (2)                     | (3)                   | (4)                     |
|--------------------------------|--|-------------------------|-----------------------|-------------------------|
|                                | % Change in Energy Intensity due to the composition effect |                         |                       |                         |
| JointVenture                   | 0.00957<br>(0.00860)                                       | 0.00932<br>(0.0106)     |                       |                         |
| Foreign Owned Enterprise       | 0.0219***<br>(0.00775)                                     | 0.0144*<br>(0.00847)    |                       |                         |
| JointVenture from HMT          |  |                         | 0.00325<br>(0.0131)   | 0.00509<br>(0.0136)     |
| JointVenture from Non-Chinese  |  |                         | 0.0236**<br>(0.0112)  | 0.0154<br>(0.0126)      |
| Foreign Owned by HMT           |  |                         | 0.0249<br>(0.0273)    | 0.0188<br>(0.0274)      |
| Foreign Owned by Non-Chinese   |  |                         | 0.0514***<br>(0.0151) | 0.0443***<br>(0.0150)   |
| SOE                            | 0.00895**<br>(0.00377)                                     | 0.00393<br>(0.00394)    | 0.00682*<br>(0.00407) | 0.00166<br>(0.00409)    |
| $\ln(\text{energy intensity})$ |  | -0.00688**<br>(0.00271) |                       | -0.00637**<br>(0.00291) |
| $\ln(\text{productivity})$     |  | -0.00939<br>(0.00661)   |                       | -0.0109<br>(0.00725)    |
| $[\ln(\text{productivity})]^2$ |  | 0.000593<br>(0.000538)  |                       | 0.000692<br>(0.000581)  |
| Export/Output                  |  | -0.00795<br>(0.00843)   |                       | -0.00488<br>(0.0122)    |
| corrTAX                        |  | 0.000716<br>(0.00174)   |                       | 0.00105<br>(0.00193)    |
| corrINTERST                    |  | 0.000105<br>(0.00169)   |                       | 0.000390<br>(0.00189)   |
| City and year fixed effects    | Yes  | Yes                     | Yes                   | Yes                     |
| Observations                   | 1,282  | 1,147                   | 1,159                 | 1,027                   |
| R <sup>2</sup>                 | 0.088  | 0.103                   | 0.103                 | 0.121                   |
| Number of cities               | 327  | 311                     | 309                   | 293                     |

**Note:** Heteroscedasticity robust standard errors in parentheses, \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ . The variable *JointVenture* refers to the output share generated by Joint Ventures in city  $c$  at time  $t$ . All other ownership variables are constructed accordingly.

The remaining controls are all statistically insignificant, however, their signs, besides the one for *corrTAX*, point in the expected direction. Initially, one might have thought that cities who target their industrial policies (defined as the output share of firms receiving tax holidays)

towards more competitive sectors would clean up more, which would have been indicated by a negative value for the coefficient of *corrTAX*.

Columns (3) and (4) show the results for Joint Ventures and Foreign Owned Enterprises funded by foreign investors from Hong Kong, Macau or Taiwan and those funded by other foreign origins separately. Again, the left-hand side (3) displays the baseline regression, whereas the right-hand side (4) adds further control variables. All control variables behave similar in terms of sign and significance when compared to column (2).

Again, the four variables indicating foreign ownership have a positive coefficient. Thus, it seems that the descriptive statistics presented in Table 2 were on the one hand due to convergence effects but also reflected the fact that, everything else equal, cities with a higher output share from foreign invested firms clean up relatively less in terms of compositional changes.

Noteworthy, the coefficient for *Foreign Owned by Non-Chinese* remains statistically significant at the 5% level even after adding controls. Recall that *Foreign Owned by Non-Chinese* refers to the output share of fully foreign owned enterprises, foreign invested cooperations or other foreign invested enterprises, whereas “foreign” refers to non-ethnically Chinese origins. Hence, an increase in the output share of such firms by 1 percentage point contributes, *ceteris paribus*, to a change in the composition effect by on average 0.044 percentage points. Considering that the mean value of the composition effect is -0.1%, a 1 percentage point increase in the output share of foreign owned firms from non-ethnically Chinese origins would result in a change the *composition* effect from -0.1% to -0.056%. Given that the sectoral shifts appear in general to be very little, that shift can be seen as a remarkable change, serving as a first indicator towards the “pollution haven” hypothesis.

#### 5.2.2. Changes in Foreign Ownership Structure

Table 4 shows the results of equation (3), namely when changes in the foreign ownership structure are added. Again, columns (1) and (2) refer to Joint Ventures and Foreign Owned Enterprises in general, whereas columns (3) and (4) distinguish between HMT funded and non-ethnically Chinese funded (e.g. the rest of the world).

First of all it can be seen that the included control variables neither change their sign nor their statistical significance when compared to Table 3 (Only the coefficient for *ln(energy intensity)* in column (4) is now statistical significant at the 10% level instead of at the 5%

level). Furthermore, the coefficient indicating the output share of Foreign Owned Enterprises from non-ethnically Chinese regions (*Foreign Owned by Non-Chinese*) loses its statistical significance.

**Table 4:** Regression Results – Output Shares, Changes

| Dependent Variable:                    | (1)  | (2)                     | (3)                    | (4)                    |
|--|--|-------------------------|------------------------|------------------------|
|  | % Change in Energy Intensity due to the composition effect |                         |                        |                        |
| $\Delta$ JointVenture                  | -0.0206<br>(0.0238)  | -0.0276<br>(0.0348)     |                        |                        |
| $\Delta$ Foreign Owned Enterprise      | -0.0934***<br>(0.0226)                                     | -0.0577**<br>(0.0263)   |                        |                        |
| $\Delta$ JointVenture from HMT         |  |                         | 0.0290<br>(0.0491)     | -0.0395<br>(0.0758)    |
| $\Delta$ JointVenture from Non-Chinese |  |                         | -0.0684*<br>(0.0355)   | -0.0271<br>(0.0458)    |
| $\Delta$ Foreign Owned by Non-Chinese  |  |                         | -0.0955***<br>(0.0339) | -0.0565<br>(0.0421)    |
| $\Delta$ Foreign Owned by HMT          |  |                         | -0.0426<br>(0.0490)    | -0.00189<br>(0.0582)   |
| JointVenture                           |  | 0.000191<br>(0.0134)    |                        |                        |
| Foreign Owned Enterprise               |  | 0.00484<br>(0.00922)    |                        |                        |
| JointVenture from Non-Chinese          |  |                         |                        | 0.0179<br>(0.0158)     |
| JointVenture from HMT                  |  |                         |                        | -0.0213<br>(0.0272)    |
| Foreign Owned by HMT                   |  |                         |                        | 0.00393<br>(0.0165)    |
| Foreign Owned by Non-Chinese           |  |                         |                        | 0.00878<br>(0.0128)    |
| SOE                                    |  | 0.00292<br>(0.00394)    |                        | 0.00262<br>(0.00419)   |
| ln (energy intensity)                  |  | -0.00690**<br>(0.00269) |                        | -0.00536*<br>(0.00273) |
| ln (productivity)                      |  | -0.00879<br>(0.00657)   |                        | -0.00686<br>(0.00699)  |
| [ln (productivity)] <sup>2</sup>       |  | 0.000569<br>(0.000533)  |                        | 0.000411<br>(0.000561) |
| Export/Output                          |  | -0.00439<br>(0.00813)   |                        | -0.00357<br>(0.00904)  |
| corrTAX                                |  | 0.00106<br>(0.00175)    |                        | 0.000819<br>(0.00185)  |
| corrINTEREST                           |  | 0.000686<br>(0.00166)   |                        | 0.000320<br>(0.00182)  |
| Time and year fixed effects            | Yes  | Yes                     | Yes                    | Yes                    |
| Observations                           | 1,271  | 1,140                   | 1,194                  | 1,069                  |
| R <sup>2</sup>                         | 0.080  | 0.106                   | 0.090                  | 0.115                  |
| Number of cities                       | 327  | 312                     | 327                    | 311                    |

**Note:** Heteroscedasticity robust standard errors in parentheses, \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .  
The variable *JointVenture* refers to the output share generated by Joint Ventures in city  $c$  at time  $t$ .  
All other ownership variables are constructed accordingly.

Interestingly, although the initial output shares of all types of foreign ownership have a positive coefficient, the *changes* in those output shares display a negative one. Thus, if a city experiences a relatively large increase in foreign ownership (meaning a high rising output share of those firms), it is more likely to shift towards relatively cleaner sectors (indicated by a *more negative* composition effect).

Nevertheless, only the change in the output share of Foreign Owned Enterprises from all origins combined (*Foreign Owned Enterprises*, column (2)) remains statistically significant at the 5% level after adding further controls. More precisely, an increase in the *change* of the output share of Foreign Owned Enterprises by one percentage point contributes, *ceteris paribus*, to a decrease in the *composition* effect of on average 0.05 percentage points. At the mean values, it shifts the *composition* effect from -0.1% to -0.15%.

It is noteworthy that the coefficient for  $\Delta Joint Venture$  from HMT is positive for the case without controls (column (3)). In line with that, the coefficient for *Joint Venture from HMT* now displays a negative sign (column (4)), hinting towards the fact that this variable might have different effects on the compositional changes than the other types of foreign firm ownership. However, it should be regarded with caution, since all of the coefficients of for Joints Ventures from HMT ( $\Delta$  and initial shares) fall short of statistical significance and seem to largely depend on which cities exactly I include in the sample.

Summing up, my findings seem at first in line with the “pollution haven” hypothesis, suggesting that the initial output share of foreign firms in a given city tends to expand relatively dirty sectors, whereas this effect is strongest for fully foreign owned firms from non-ethnically Chinese origins. This result is to some extent in line with the findings by Cole et al. (2011), who relate an increase in the output share from non-ethnically Chinese origins to higher pollution intensities, whereas they do not find robust results for the case of HMT. However, when looking at the effect of *changes* in the ownership shares, it appears to be the opposite, suggesting that the inflow of foreign owned enterprises is rather beneficial for the environment, whereas this effect is again more pronounced for foreign firms from non-ethnically Chinese origins.

### 5.2.3. Alternative Measures

Table 5 shows the regression results if foreign ownership is measured as the share of foreign capital in the respective city instead of as the output share of firms reported as “foreign”. Due

to reasons of space, I only display the estimations with all controls already included and combine both the absolute levels and changes in one table. Now, columns (1) and (2) refer to the results with only the capital shares as explanatory variables, whereas columns (3) and (4) also add the *changes* in such shares.

However, two things are important to consider: First, the capital structure is only reported until 2008, therefore, one year is lost and the sample size drops by approximately one fourth.<sup>8</sup> Moreover, foreign capital is both present in Joint Ventures as well as in foreign owned firms. Thus, when comparing the share of “foreign capital” across cities, it is not possible to definitely say which part of this share refers to Joint Ventures and which one to fully foreign owned firms. For the stated reasons, one should be cautious when directly comparing results across different specifications.

When looking at columns (1) and (2), one can see that, as in Table 3, the variables indicating foreign ownership all have positive coefficients. However, for the case of capital shares, none of them is statistical significant. Most of the control variables behave similar in terms of sign and significance when compared to Table 3. Only the coefficient for the squared term of  $\ln(\text{productivity})$  is now statistically significant at the 10% level, hinting towards a potential non-linear relationship. Moreover the coefficient for *corrTAX* is negative, what is to some extent more intuitive than the positive sign in Table 3 (as described in Section 5.2.1). Thus, it seems that the overall result indicating an increased share if foreign firm ownership is on average related to a shift towards relatively dirtier sectors is not driven by the way I define foreign ownership.<sup>9</sup>

Nevertheless, when moving to columns (3) and (4), which add the *changes* in capital shares, all  $\Delta$ -variables keep their positive sign. This is at odds with the results obtained in Table 4, where, after adding the control variables, each of the corresponding variables displayed a negative sign. The coefficient for  $\Delta\text{Capital from HMT}$  is even statistically significant, thus, supporting the potential positive impact of this variable outlined in Section 5.2.2. In line with that, when dropping the year 2009 and combining Joint Ventures as well as foreign owned

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<sup>8</sup> For the case of the  $\Delta$  variables, I would theoretically lose two time periods, since I can neither estimate changes from 2005 to 2009 nor those from 2009 to 2013. Thus, to be at least able to work with three time periods for either measure, I compute the average annual changes from 2005 to 2008 only for the last period.

<sup>9</sup> For a to some extent easier comparison, I also estimated the specification from Table 3 with Joint Ventures and fully foreign owned enterprises together and dropped the year 2009. In such specification, most of the variables behave the same way in terms of sign and significance when compared to the case of capital shares, the only difference being the coefficient for foreign invested enterprises from non-ethnically Chinese destinations, which is statistically significant at the 10% level.

enterprises for the “output-share” case,  $\Delta Foreign\ from\ HMT$  turns positive, whereas the coefficients for the remaining two foreign ownership variables stay negative.

**Table 5:** Regression Results – Capital Shares

| Dependent Variable:               | (1)  | (2)                    | (3)                    | (4)                    |
|-----------------------------------|--|------------------------|------------------------|------------------------|
|                                   | % Change in Energy Intensity due to the composition effect |                        |                        |                        |
| Foreign Capital                   | 0.00216<br>(0.00776)                                       |                        | 0.0119<br>(0.00906)    |                        |
| Capital from HMT                  |  | 0.000387<br>(0.00859)  |                        | 0.0171<br>(0.0110)     |
| Capital from Non-Chinese          |  | 0.00536<br>(0.0117)    |                        | 0.00265<br>(0.0123)    |
| $\Delta$ Foreign Capital          |  |                        | 0.0346<br>(0.0223)     |                        |
| $\Delta$ Capital from HMT         |  |                        |                        | 0.0837***<br>(0.0277)  |
| $\Delta$ Capital from Non-Chinese |  |                        |                        | 0.0311<br>(0.0301)     |
| ln (energy intensity)             | -0.00461*<br>(0.00253)                                     | -0.00488*<br>(0.00276) | -0.00488*<br>(0.00264) | -0.00498*<br>(0.00280) |
| State Capital                     | 0.00526<br>(0.00395)                                       | 0.00528<br>(0.00399)   | 0.00419<br>(0.00376)   | 0.00329<br>(0.00358)   |
| ln (productivity)                 | -0.0177**<br>(0.00776)                                     | -0.0184**<br>(0.00823) | -0.0146*<br>(0.00761)  | -0.0176**<br>(0.00767) |
| [ln (productivity)] <sup>2</sup>  | 0.00112*<br>(0.000646)                                     | 0.00115*<br>(0.000692) | 0.000882<br>(0.000638) | 0.00110*<br>(0.000646) |
| Export/Output                     | -0.0116<br>(0.0111)  | -0.0123<br>(0.0123)    | -0.00948<br>(0.0118)   | -0.00771<br>(0.0121)   |
| corrTAX                           | -0.000187<br>(0.00203)                                     | -0.000271<br>(0.00212) | 0.000132<br>(0.00199)  | 0.000515<br>(0.00199)  |
| corrINTEREST                      | 0.00196<br>(0.00210)                                       | 0.00184<br>(0.00218)   | 0.00238<br>(0.00206)   | 0.00187<br>(0.00207)   |
| City and year fixed effects       | Yes  | Yes                    | Yes                    | Yes                    |
| Observations                      | 867  | 851                    | 861                    | 847                    |
| R <sup>2</sup>                    | 0.141  | 0.144                  | 0.137                  | 0.148                  |
| Number of cities                  | 310  | 308                    | 310                    | 310                    |

**Note:** Heteroscedasticity robust standard errors in parentheses, \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ . The variable *ForeignCapital* refers to the share of foreign capital over total capital in city  $c$  at time  $t$ . All other capital variables are constructed accordingly. *State capital* indicates the share of state capital over total capital, which serves as a measure for state owned ownership.

Thus, summarizing the results, it appears that the overall result suggesting that an increased initial share of foreign owned firms is detrimental for the environment holds. However, the impact of *changes* in output shares seems to be unstable across different specifications. Thereby, a relatively high increase of the capital share (resp. output share) coming from HMT tends to shift the composition of sectors towards relatively dirtier sectors, whereas the sign for the other types of “foreign ownership” largely depends on the way “foreign ownership” is specified.

Finally, it is worth to mention that the presented results do not necessarily imply causality. Hence, they should be seen rather as a possible linkage, than as an ultimate answer to the relationship between foreign ownership and compositional changes. It is likely that there are confounding variables that influence both the dependent and the explanatory variables, such as certain policies attracting foreign investors and specially targeting energy intensive sectors (omitted variable bias).

## 6. Robustness Checks

Regarding the decomposition analysis, one might question the assumption that energy intensity works as a good measure for pollution intensity. Besides that this proxy has been frequently used in the literature before (e.g. Chung 2014), Cole et al. (2005) provide a direct estimation of the monotonic increasing relationship between energy intensity and major industrial pollutants for the manufacturing sector in the UK.<sup>10</sup> Moreover, Zhang et al. (2009) show the close relationship between energy intensity and CO<sub>2</sub> emissions for the Chinese overall economy. To further ensure that this relationship also holds for the industrial sector in China, I rerun the decomposition analysis on SO<sub>2</sub> emissions directly for the years 2003 until 2009 (the only years SO<sub>2</sub> data are available on industry level) and find very similar results. Between 2003 and 2009, SO<sub>2</sub> emissions (weighted average across cities) were reduced by 6.28% due to the technique effect, by 0.09% due to sectoral shifts and increased by 29.83% due to the scale effect. Even though the changes in energy consumption were larger in magnitude, the relative weight of each of the three effects is comparable across the two different measures. The corresponding graph for SO<sub>2</sub> emissions is reported in appendix iii.

Additionally, Liu et al. (2015) stress the importance of single sectors for the decomposition. For example, they argue that the increase in the *composition* effect after 2002 was mainly due to manufacture and casting of both ferrous and non-ferrous metals. Therefore, I decompose the energy consumption with those sectors as well as “Manufacture and Supply of Gas” and “Chemical raw materials and Manufacture of other basic chemical raw materials” excluded. Those four sectors combined were the most energy intensive ones in 1998. The overall decomposition results (for both the weighted average and the country as a whole) appear to be robust against such specification, however, as expected, both the *technique* and the *scale*

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<sup>10</sup> They estimate the impact of energy use on sulphur dioxides (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), particulate matter (PM10) as well as total acid rain precursors and find a positive significant relationship for each of them.

effect decrease in magnitude, whereas the *composition* effect is more pronounced. A more detailed description of such results can be found in appendix iii.

For the empirical analysis, as mentioned in the beginning of section 5.2, I continuously use a cut-off level of 0.001 when omitting outliers. However, the overall results appear to be robust to more conservative cut-off levels (0.01) as well as to including all observations in the regression. The according output tables (Tables 6 and 7) are presented in appendix iv.

Moreover, when looking at the literature (e.g. Antweiler et al. 2001; He 2006), it seems to be the case that macro related city variables like GDP/capita, the squared term of GDP/capita and the economic intensity (GDP/land area) might have an impact on both foreign investment and changes in the industrial sectors and thus, should be included as control variables. Table 8 in appendix iv reports the results when such variables are additionally added. The reason I did not consider them in the main analysis is that the macro related data are only available for prefecture-level cities, reducing the sample size to 267 cities. In any case, the overall results do not significantly change when including such variables.

I further rerun equations (2) and (3) after applying several modifications to the data in order to ensure the consistency of results. However, due to reasons of space, and since they do not impact the key results, I do not report such output tables. First, I measured the “amount” of foreign owned firms in a city not by its output share but by its employment share. Second, as mention in Section 4.1, the values the year 2012 seem somewhat extreme. Even though such concerns are not as severe for the empirical analysis, as I run the regression with annual averages, I omitted the year 2012 from the analysis. The finding that the share of *Foreign Owned by Non-Chinese* is positive and statistical significant and all other foreign ownership variables display a positive sign is robust against such specifications. Furthermore, I performed the empirical analysis on prefecture-level cities only and I included each type of “foreign ownership” separately in the regression. Moreover, it is to mention that in the literature (e.g. de Sousa et al. 2015), the capital-to-labor ratio is sometimes described as a measure to capture the composition effect and thus, it should be included as a control. However, the ASIF dataset only reports value on fixed assets (as a proxy for the capital stock) until 2008. Nevertheless, the key results appear to be robust against dropping the year 2009 and including both  $(K/L)$  and  $(K/L)^2$  as control variables.

When dividing the sample in Coast and West, the main finding that the initial share of Joint Ventures and Foreign Owned Enterprises depicts a positive sign and the changes in such shares a negative one, remains. When further subdividing the sample into those coming from HMT and those coming from other origins, it seems at first striking since the coefficient for  $\Delta$  *Foreign Owned by Non-Chinese* displays a negative sign for the coast but a positive for the west. This might serve as a hint towards the “pollution haven” hypothesis, indicating that foreign firms outsource their relatively dirty stages of production rather to the Western part of China, where environmental regulations are not as enforced as in the coastal provinces (Wu et al. 2016). However, regarding the huge drop in sample size due to the splitting up of the sample, those results should be seen with extreme caution and rather works as a potential avenue for future research.

## 7. Conclusion

The objective of this paper was to decompose the energy consumption among Chinese cities and to empirically assess the role of foreign firm ownership on changes in the structural composition across sectors. Findings suggest that, although energy intensity in China on average declined, this “clean-up” was rather driven rather by the *technique* than by the *composition* effect, which is in line with the previous literature.

Regarding the empirical part of the paper, results point towards the “pollution haven” hypothesis meaning that an increase in the output share of foreign firms (resp. share of foreign capital) shifts the industry towards relatively dirtier sectors, thus, contributing to an increase in the *composition* effect. However, among the different types of foreign firms, only the impact of the output share of fully foreign owned enterprises from non-ethnically Chinese origins remains statistical significant across different specifications. When looking at the *changes* in the output share of foreign owned firms, it seems that, also falling short of statistical significance, a higher increase contributes to a shift towards relatively less energy intensive industries. Nevertheless, the latter results are not robust against different ways of defining “foreign ownership”, and especially the changes in the share of firms (or capital) coming from HMT might in the end rather have detrimental than beneficial effects for the environment.

Generally, it is to note that the presented results do not aim at establishing a causal relationship and thus, they should not be viewed as the conclusive answer to the impact of

foreign firm ownership on compositional changes. Nevertheless, they do provide important first insight since the energy decomposition analysis on city level enables me to directly link changes in the compositional structure across sectors to the foreign ownership shares without using any kind of proxies and still preserve a certain degree of variation when running the regression analysis.

Therefore, future research can build on this paper by reassuring that the found relations are indeed due to causality and, as noted in Section 6, emphasize on potential differences between geographical regions across China. Moreover, it seems that the *composition* effect among Chinese cities increased after the WTO accessions, but is again decreasing since approximately 2007. Thus, it might be the case that potential effects of foreign firm ownership will be more pronounced when redoing this analysis in a couple of years, with more data after the start of the decline available.

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## Appendix

### i. Sector Overview

| cic-classification | Description of Sectors  |
|--------------------|---|
| 10                 | Mining of Non-metal Ores  |
| 13                 | Processing industry of agricultural and subsidiary food                             |
| 14                 | Manufacture of Food Products  |
| 15                 | Manufacture of Drinking Products  |
| 16                 | Manufacture of Tobacco Products   |
| 17                 | Manufacture of Textile  |
| 18                 | Manufacture of Wearing Apparel, Footwear and Headwear                               |
| 19                 | Manufacture of Leather, Fur Apparel, Feather and Products                           |
| 20                 | Manufacture of Wood and Articles of Wood, Bamboo, Bine, Palm Fiber, Straw and Grass |
| 21                 | Furniture manufacturing   |
| 22                 | Manufacture of Pulp, Paper, Paperboard and Articles of Paper and Paperboard         |
| 23                 | Printing and Reproduction of Recorded Media   |
| 24                 | Manufacture of Cultural, educational and Sporting Products                          |
| 25                 | Processing of crude oil, coking and Nuclear fuel                                    |
| 26                 | Chemical raw materials and Manufacture of other basic chemical raw materials        |
| 27                 | Manufacture of Pharmaceuticals  |
| 28                 | Manufacture of Chemical Fibers  |
| 29                 | Manufacture of Rubber Products  |
| 30                 | Manufacture of Plastic Products   |
| 31                 | Manufacture of Non-metal Products   |
| 32                 | Manufacture and Casting of Ferrous Metals   |
| 33                 | Manufacture and Casting of Non-ferrous Metals                                       |
| 34                 | Manufacture of Metal Products   |
| 35                 | Universal Equipment Manufacturing   |
| 36                 | Manufacture of Special Equipment  |
| 37                 | Manufacture of Transportation Equipment   |
| 39                 | Manufacture of Electric Machines and Equipment                                      |
| 40                 | Manufacture of Telecommunication Equipment, Computers and Other Electric Equipment  |
| 41                 | Manufacture of Instruments and Appliances, Culture-related and Office Machinery     |
| 44                 | Production and Supply of Electricity and Heat                                       |
| 45                 | Manufacture and Supply of Gas   |
| 46                 | Manufacture and Supply of Water   |

**Note:** Sectors 13-43 belong to the manufacturing sector, 44,45 and 46 form the industry "Production and Supply Industry of Power, Fuel Gas and Water". Sector 10 belongs to the Mining Industry. Although contained in the ASIF Dataset, more sectors from the mining industry could not be added due to missing data on energy consumption. All cic-codes refer to the 2002 nomenclature.

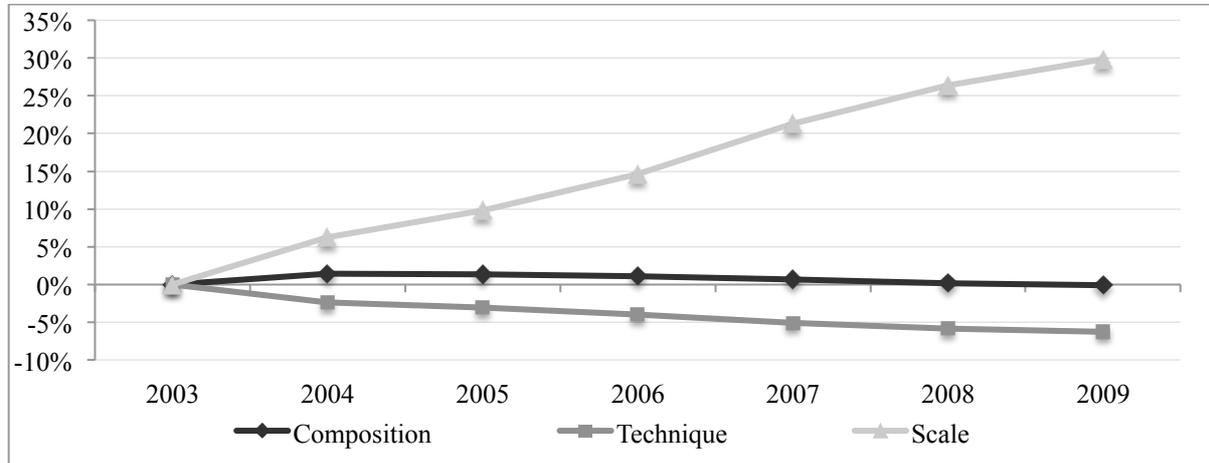
## ii. Detailed Variables Description

| Name                           | Source                              | Description   |
|--------------------------------|-------------------------------------|---|
| <b>Ownership Variables</b>     |                                     |   |
| Joint Venture                  | ASIF Dataset                        | Output of foreign equity joint ventures or foreign cooperative joint ventures divided by the overall output of city <i>c</i> at time <i>t</i>   |
| Foreign Owned Enterprises      | ASIF Dataset                        | Output of fully foreign owned enterprises, foreign invested cooperations or other foreign invested enterprises divided by the overall output of city <i>c</i> at time <i>t</i>  |
| Joint Venture from HMT         | ASIF Dataset                        | Output of foreign equity joint ventures or foreign cooperative joint ventures funded by HMT divided by the overall output of city <i>c</i> at time <i>t</i>   |
| Joint Venture from Non-Chinese | ASIF Dataset                        | Output of foreign equity joint ventures or foreign cooperative joint ventures funded by non-ethnically Chinese origins divided by the overall output of city <i>c</i> at time <i>t</i>  |
| Foreign Owned by HMT           | ASIF Dataset                        | Output of fully foreign owned enterprises, foreign invested cooperations or other foreign invested enterprises funded by HMT divided by the overall output of city <i>c</i> at time <i>t</i>  |
| Foreign Owned by Non-Chinese   | ASIF Dataset                        | Output of fully foreign owned enterprises, foreign invested cooperations or other foreign invested enterprises funded by non-ethnically Chinese origins divided by the overall output of city <i>c</i> at time <i>t</i>   |
| SOE                            | ASIF Dataset                        | Output of state owned enterprises, state cooperative enterprises, state and collective enterprises or state-owned limited liabilities divided by the overall output of city <i>c</i> at time <i>t</i>   |
| Foreign Capital                | ASIF Dataset                        | Foreign Capital from non-ethnically Chinese and HMT Capital divided by the overall capital (Foreign, HMT, State, Collective, Legal Person and Individual) of city <i>c</i> at time <i>t</i>   |
| Capital from HMT               | ASIF Dataset                        | HMT Capital divided by the overall capital (Foreign, HMT, State, Collective, Legal Person and Individual) of city <i>c</i> at time <i>t</i>   |
| Capital From Non-Chinese       | ASIF Dataset                        | Foreign Capital from non-ethnically Chinese divided by the overall capital (Foreign, HMT, State, Collective, Legal Person and Individual) of city <i>c</i> at time <i>t</i>   |
| State Capital                  | ASIF Dataset                        | State Capital from non-ethnically Chinese divided by the overall capital (Foreign, HMT, State, Collective, Legal Person and Individual) of city <i>c</i> at time <i>t</i>   |
| <b>Geographical Variables</b>  |                                     |   |
| Coast                          | ASIF Dataset                        | Dummy = 1 if the city is located in: Fujian, Guangdong, Guangxi, Hainan, Hebei, Juangsu, Liaoning, Shandong, Shanghai, Tianjing or Zhejiang   |
| West                           | ASIF Dataset                        | Dummy = 1 if the city is located in: Chongqing, Gansu, Guizhou, Qinghai, Ningxia, Shaanxi, Sichuan, Tibet, Xinjiang or Yunnan   |
| Center                         | ASIF Dataset                        | Dummy = 1 if the city is located in: Anhui, Beijing, Hubei, Jiangsu, Jilin, Hebei, Heilongjinag, Hunan, Liaoning, Shangdong, Sichuan, Tianjin or Tibet  |
| Boundary                       | ASIF Dataset                        | Dummy = 1 if the city is located in: Chongqing, Fujian, Gansu, Guangdong, Guangxi, Guizhou, Hainan, Heilongjiang, Inner Mongolia, Jiangxi, Ningxia, Qinghai, Shaanxi, Shangdong, Shanghai, Shanxi, Xinjiang, Yunnan or Zhejiang   |
| <b>Control Variables</b>       |                                     |   |
| LN (Energy Intensity)          | ASIF Dataset/CSY                    | Natural Logarithm of Energy Intensity of city <i>c</i> at time <i>t</i> , computed as the Energy Consumption in 10,000 tons of SCE divided by the output (in current prices)  |
| LN (productivity)              | ASIF Dataset                        | Natural Logarithm of the output (in current prices) divided by the number of employees in city <i>c</i> at time <i>t</i>  |
| Export/Output                  | ASIF Dataset                        | Overall Export value divided by the overall output value in city <i>c</i> at time <i>t</i>  |
| corrTAX                        | ASIF Dataset / Aghion et al. (2015) | Correlation between a sector-specific Lerner Index and the output share of firms that received a tax holiday  |
| corrINTEREST                   | ASIF Dataset / Aghion et al. (2015) | Correlation between a sector-specific Lerner Index and the interest expenses over current liabilities   |
| Lerner                         | ASIF Dataset / Aghion et al. (2015) | Serves as a measure of competition, constructed accordingly to Aghion et al. (2015):<br>$1 - \frac{(\text{Profits} - \text{Capital Costs})}{\text{Revenues}}$<br>Capital Cost is defined as: $0.085 * \text{Gross Fixed Assets}$<br>Firms that received a tax holidays are defined as:  |
| Tax Holiday                    | ASIF Dataset / Aghion et al. (2015) | Foreign firms for who the value $(\text{Revenue} * 0.15) - \text{Income tax}$ was greater 0 (Indicating they paid less taxes than the official corporate tax rate of 15%), for 2009: 18%. State owned firms for who the value $(\text{Revenue} * 0.33) - \text{Income tax}$ was greater 0 (Indicating they paid less taxes than the official corporate tax rate of 33%) |
| Interest Rate Payment          | ASIF Dataset / Aghion et al. (2015) | Interest expense of city <i>c</i> at time <i>t</i> divided by the current liabilities of city <i>c</i> at time <i>t</i>   |
| K/L                            | ASIF Dataset                        | Capital-to-employment ratio, computed as the Total Fixed Assets (original) price divided by the number of employees in city <i>c</i> at time <i>t</i>   |
| <b>Macro Variables</b>         |                                     |   |
| LN (GDP/capita)                | China Data Online                   | Natural Logarithm of the GDP in city <i>c</i> at time <i>t</i> divided by its population  |
| LN (Economic Intensity)        | China Data Online                   | Natural Logarithm of the GDP in city <i>c</i> at time <i>t</i> divided by its land area   |

### iii. Decomposition results: Alternative Specifications

#### a. Decomposition Analysis for SO<sub>2</sub> emissions

**Figure 3:** % Change in SO<sub>2</sub> emissions due to Technique, Composition and Scale  
(weighted average, with respect to 2003)



As for the case of energy consumption, it can be seen that both the *composition* as well as the *technique* effect seem rather small when compared to the *scale* effect. Moreover, there is a slight increase of the *composition* effect in the years directly after 2003. Although not clear in the graph, there also appears to be the “bump” around the same years for the *technique* effect. As discussed in section 5.1, such developments are most likely due to China’s entrance to the WTO in 2001. In any case, all of those characteristics are as well visible for the analysis of energy consumption, highlighting the similarity in results and hence, confirming the close relationship between energy consumption and SO<sub>2</sub> emissions.

#### b. Decomposition Analysis when certain sectors are dropped

As described in Section 6, I carried out the decomposition analysis without including the sectors 26, 31, 32 and 45 for both the *weighted averages* and the *whole country* case. For the weighted averages, the *composition* effect contributes to a decrease in energy consumption of -2.2%, the *technique* effect of -8.92% and the *scale* effect to an increase of 165%. (As a comparison, for all sectors included, the *composition* effect contributes to a -1.87% decrease, the *technique* effect to -7.8% and the *scale* effect to an increase of 196.36%). For the whole country case without the four mentioned sectors included, the *composition* effect was responsible for a decrease of -0.05%, the *technique* effect for -3.9% and the *scale* effect for +68.3%. (For the case with all sectors included, the *composition* effect contributed to an increase of 0.4%, the *technique* effect to a decrease of -4.1% and the *scale* effect to 77.18%).

iv. Further Regression Tables

Table 6 (7) corresponds to Table 4 (5) in Section 5.2.1 (5.2.2). Columns (1) and (2) refer to the case when a cut-off level for outlier of 0.01 is chosen, whereas columns (3) and (4) report the results without dropping any outliers. Columns (1) and (3) show the results for the case of HMT and non-ethnically Chinese “foreigners” combined, whereas columns (2) and (4) distinguish between the two origins. As it can be seen in Table 6, the statistical significance for *Foreign Owned by Non-Chinese* remains robust over all specifications. Generally, all reported variables behave similar in terms of sign and significance when compared to Table 4 (5).

a. *Different Outliers omitted - Levels*

**Table 6:** Regression Results – Different Outliers/Levels

| Dependent Variable:              | (1)  | (2)                    | (3)                      | (4)                      |
|----------------------------------|--|------------------------|--------------------------|--------------------------|
|                                  | % Change in Energy Intensity due to the composition effect |                        |                          |                          |
| JointVenture                     | 0.0145<br>(0.0103)   |                        | 0.00512<br>(0.00845)     |                          |
| Foreign Owned Enterprise         | 0.0107<br>(0.00911)  |                        | 0.0113<br>(0.00759)      |                          |
| JointVenture from HMT            |  | 0.00414<br>(0.0166)    |                          | -0.0125<br>(0.0123)      |
| Foreign Owned from HMT           |  | 0.0394<br>(0.0434)     |                          | 0.00216<br>(0.0108)      |
| JointVenture by Non-Chinese      |  | 0.0227<br>(0.0150)     |                          | 0.0128<br>(0.00888)      |
| Foreign Owned by Non-Chinese     |  | 0.0580**<br>(0.0260)   |                          | 0.0198**<br>(0.00908)    |
| SOE                              | 0.00231<br>(0.00399)                                       | 0.00279<br>(0.00429)   | 0.000793<br>(0.00433)    | 0.000577<br>(0.00416)    |
| ln (energy intensity)            | -0.00612**<br>(0.00275)                                    | -0.00518*<br>(0.00307) | -0.00741***<br>(0.00267) | -0.00677***<br>(0.00261) |
| ln (productivity)                | -0.0109<br>(0.00686)                                       | -0.00246<br>(0.00161)  | -0.00942<br>(0.00658)    | -0.00228*<br>(0.00123)   |
| [ln (productivity)] <sup>2</sup> | 0.000705<br>(0.000554)                                     |                        | 0.000577<br>(0.000539)   |                          |
| Export/Output                    | -0.00583<br>(0.0104)                                       | -0.00936<br>(0.0132)   | -0.00141<br>(0.00800)    | 0.00105<br>(0.00815)     |
| corrTAX                          | 0.000957<br>(0.00181)                                      | 0.00106<br>(0.00209)   | 0.000265<br>(0.00172)    | 1.09e-05<br>(0.00177)    |
| corrINTEREST                     | -4.45e-05<br>(0.00178)                                     | -0.000282<br>(0.00201) | -0.000330<br>(0.00171)   | -0.000635<br>(0.00171)   |
| City and year fixed effects      | Yes  | Yes                    | Yes                      | Yes                      |
| Observations                     | 1,098  | 918                    | 1,165                    | 1,165                    |
| R <sup>2</sup>                   | 0.103  | 0.119                  | 0.091                    | 0.095                    |
| Number of cities                 | 303  | 280                    | 312                      | 312                      |

**Note:** Heteroscedasticity robust standard errors in parentheses, \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $< 0.1$ . The variable *JointVenture* refers to the output share generated by Joint Ventures in city  $c$  at time  $t$ . All other ownership variables are constructed accordingly.

b. Different Outliers omitted - Changes

**Table 7:** Regression Results – Different Outliers/Changes

| Dependent Variable:                     | (1)  | (2)                    | (3)                      | (4)                      |
|---|--|------------------------|--------------------------|--------------------------|
|   | % Change in Energy Intensity due to the composition effect |                        |                          |                          |
| $\Delta$ JointVenture                   | -0.0235<br>(0.0376)  |                        | -0.0252<br>(0.0226)      |                          |
| $\Delta$ Foreign Owned Enterprise       | -0.0391<br>(0.0256)  |                        | -0.0189<br>(0.0347)      |                          |
| $\Delta$ JointVenture from HMT          |  | -0.0410<br>(0.0805)    |                          | -0.0183<br>(0.0385)      |
| $\Delta$ Foreign Owned by HMT           |  | 0.0194<br>(0.0735)     |                          | 0.0190<br>(0.0420)       |
| $\Delta$ Joint Venture from Non-Chinese |  | -0.0290<br>(0.0519)    |                          | -0.0172<br>(0.0247)      |
| $\Delta$ Foreign Owned by Non-Chinese   |  | -0.0377<br>(0.0509)    |                          | -0.0308<br>(0.0618)      |
| JointVenture                            | 0.00108<br>(0.0136)  |                        | -0.000538<br>(0.0104)    |                          |
| Foreign Owned Enterprise                | 0.00499<br>(0.00872)                                       |                        | 0.00681<br>(0.00947)     |                          |
| JointVenture from Non-Chinese           |  | 0.0198<br>(0.0169)     |                          | 0.00790<br>(0.0106)      |
| JointVenture from HMT                   |  | -0.0237<br>(0.0283)    |                          | -0.0168<br>(0.0180)      |
| Foreign Owned by HMT                    |  | 0.00875<br>(0.0182)    |                          | 0.00582<br>(0.0147)      |
| Foreign Owned by Non-Chinese            |  | 0.0119<br>(0.0141)     |                          | 0.0103<br>(0.0139)       |
| SOE                                     | 0.00342<br>(0.00383)                                       | 0.00277<br>(0.00423)   | 0.000788<br>(0.00435)    | -0.000263<br>(0.00444)   |
| ln (energy intensity)                   | -0.00633**<br>(0.00252)                                    | -0.00539*<br>(0.00282) | -0.00740***<br>(0.00267) | -0.00692***<br>(0.00265) |
| ln (productivity)                       | -0.00770<br>(0.00649)                                      | -0.00675<br>(0.00705)  | -0.00943<br>(0.00660)    | -0.00833<br>(0.00665)    |
| [ln (productivity)] <sup>2</sup>        | 0.000486<br>(0.000528)                                     | 0.000414<br>(0.000563) | 0.000579<br>(0.000541)   | 0.000509<br>(0.000539)   |
| Export/Output                           | -0.00282<br>(0.00772)                                      | -0.00473<br>(0.00921)  | -0.000338<br>(0.00808)   | 0.00158<br>(0.00817)     |
| corrTAX                                 | 0.00139<br>(0.00174)                                       | 0.000943<br>(0.00193)  | 0.000314<br>(0.00173)    | 8.26e-05<br>(0.00175)    |
| corrINTEREST                            | 0.000159<br>(0.00165)                                      | 0.000204<br>(0.00182)  | -0.000304<br>(0.00172)   | -0.000459<br>(0.00173)   |
| City and year fixed effects             | Yes  | Yes                    | Yes                      | Yes                      |
| Observations                            | 1,130  | 1,046                  | 1,165                    | 1,165                    |
| R <sup>2</sup>                          | 0.102  | 0.116                  | 0.092                    | 0.098                    |
| Number of cities                        | 312  | 310                    | 312                      | 312                      |

**Note:** Heteroscedasticity robust standard errors in parentheses, \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ . The variable *JointVenture* refers to the output share generated by Joint Ventures in city  $c$  at time  $t$ . All other ownership variables are constructed accordingly.

For the case of capital shares (not reported),  $\Delta$ Capital from HMT remains positive and statistically significant for either specification, whereas  $\Delta$ Capital from Non-Chinese and  $\Delta$ Foreign Capital depict a positive sign, in line with Table 7.

*c. Macro Controls Included*

**Table 8:** Regression Results – Macro Controls Included

| Dependent Variable:              | (1)  | (2)                     | (3)                     | (4)                     |
|----------------------------------|--|-------------------------|-------------------------|-------------------------|
|                                  | % Change in Energy Intensity due to the composition effect |                         |                         |                         |
| JointVenture                     | 0.00223<br>(0.0106)  |                         | -0.00333<br>(0.0142)    |                         |
| Foreign Owned Enterprise         | 0.0214**<br>(0.00859)                                      |                         | 0.00924<br>(0.00972)    |                         |
| JointVenture from HMT            |  | -0.0115<br>(0.0147)     |                         | -0.0109<br>(0.0223)     |
| Foreign Owned by HMT             |  | 0.00562<br>(0.0128)     |                         | 0.0170<br>(0.0179)      |
| JointVenture from Non-Chinese    |  | 0.00981<br>(0.0130)     |                         | 0.00212<br>(0.0148)     |
| Foreign Owned by Non-Chinese     |  | 0.0322***<br>(0.0106)   |                         | 0.00919<br>(0.0148)     |
| Δ JointVenture                   |  |                         | -0.0274<br>(0.0276)     |                         |
| Δ Foreign Owned Enterprise       |  |                         | -0.0543*<br>(0.0319)    |                         |
| Δ JointVenture from HMT          |  |                         |                         | 0.00171<br>(0.0459)     |
| Δ Foreign Owned by HMT           |  |                         |                         | 0.0329<br>(0.0480)      |
| Δ JointVenture from Non-Chinese  |  |                         |                         | -0.0295<br>(0.0265)     |
| Δ Foreign Owned by Non-Chinese   |  |                         |                         | -0.107*<br>(0.0576)     |
| SOE                              | 0.00185<br>(0.00501)                                       | 0.00106<br>(0.00504)    | 0.00215<br>(0.00504)    | 0.00141<br>(0.00506)    |
| ln (energy intensity)            | -0.00793**<br>(0.00362)                                    | -0.00749**<br>(0.00356) | -0.00810**<br>(0.00362) | -0.00754**<br>(0.00360) |
| ln (productivity)                | -0.0104<br>(0.00866)                                       | -0.00986<br>(0.00854)   | -0.0103<br>(0.00866)    | -0.00979<br>(0.00851)   |
| [ln (productivity)] <sup>2</sup> | 0.000592<br>(0.000713)                                     | 0.000573<br>(0.000696)  | 0.000582<br>(0.000713)  | 0.000561<br>(0.000695)  |
| Export/Output                    | -0.00216<br>(0.00989)                                      | 0.000358<br>(0.0102)    | -1.97e-05<br>(0.00994)  | 0.000719<br>(0.0105)    |
| corrTAX                          | -0.000118<br>(0.00187)                                     | -0.000380<br>(0.00191)  | 6.61e-05<br>(0.00187)   | -0.000198<br>(0.00190)  |
| corrINTEREST                     | -0.00127<br>(0.00165)                                      | -0.00145<br>(0.00164)   | -0.00106<br>(0.00168)   | -0.00107<br>(0.00165)   |
| ln (GDP/capita)                  | 0.0109<br>(0.0100)   | 0.0144<br>(0.0104)      | 0.0105<br>(0.0101)      | 0.0139<br>(0.0105)      |
| ln [(GDP/capita)] <sup>2</sup>   | -0.000398<br>(0.000496)                                    | -0.000551<br>(0.000510) | -0.000384<br>(0.000498) | -0.000501<br>(0.000510) |
| ln (economic intensity)          | -0.00125<br>(0.000892)                                     | -0.00150<br>(0.00102)   | -0.000880<br>(0.000914) | -0.00174<br>(0.00113)   |
| City and year fixed effects      | Yes  | Yes                     | Yes                     | Yes                     |
| Observations                     | 931  | 931                     | 931                     | 931                     |
| R <sup>2</sup>                   | 0.113  | 0.119                   | 0.117                   | 0.126                   |
| Number of cities                 | 258  | 258                     | 258                     | 258                     |

**Note:** Heteroscedasticity robust standard errors in parentheses, \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ . The variable *JointVenture* refers to the output share generated by Joint Ventures in city  $c$  at time  $t$ . All other ownership variables are constructed accordingly.