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State and Private Company Ownership Effect on CO_2 Emissions: A Chinese Provincial Level Analysis

William Dendy
wi6022de-s@student.lu.se

Abstract: China has experienced unprecedented economic success since the liberalisation process began in 1978. However, this expansion has also brought with it large scale environmental damage. Using data obtained from the Chinese National Buraeu of Statistics, this study investigates CO_2 emissions from the years 2000 − 2012 on a provincial level in comparison with company state and private ownership structure, to understand which ownership form is a less CO_2 intensive producer of goods and services. The study's results from 29 Chinese provinces show that private firms are less CO_2 polluting than state owned firms for equivalent economic activity, thus making an expansion of the private sector and reduction of the state owned sector a potential contributor towards China's carbon mitigations. Additionally, the results show that as China moves away from primary industry as the majority source of income, towards high-tech and service sectors, the CO_2 intensity is reduced. This has implications for Chinese policy formation, where the focus moves towards improving environmental sustainability whilst continuing to maintan strong annual economic growth.

Keywords: Provincial CO_2; Company Ownership; Emission Decomposition; China

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Lund University
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Chapter 1

Introduction

China has been undergoing a transition from a centrally planned economy towards a market based economy since 1978, during which time China has experienced miraculous economic growth of approximately 9 percent annually (Nee and Opper, 2012). However, this economic success has had negative environmental impacts, with China responsible for the largest share of Carbon Dioxide (CO_2) emissions of any country. China's CO_2 emissions totalled the US and the EU combined in 2012 (Lui, 2015) and are projected to increase until at least 2040, despite the 11^{th} five year plan placing greater emphasis on environmentally sustainable economic development (He et al., 2012).

China's shift towards a market based economy and its subsequent economic success are by no means coincidental. Inefficient state-owned firms and lack of rewards for employees meant that there was little incentive for effective performance (Li, 1998) or innovation to improve productivity (Schleifer, 1998). State-led reforms enacted in the early 1980's attempted to address the lack of incentives for efficient State-Owned Enterprise (SOE) performance, with lifetime tenure of government officials abolished and education requirements were brought in (Xiaoping, 1983). The embracing of the free-market by development of private property rights and the introduction of company law officially recognizing private companies induced the bottom-up capitalism China is so widely recognized for today (Nee and Opper, 2012). Whilst SOEs are less efficient economically, and are not so quick to adopt new technologies than Privately Owned Enterprises, (POEs), (Boardman and Vinning, 1998; Schleifer, 1998) it remains to be seen if this translates into a lower energy efficiency than these businesses' privately owned counterparts.

The puzzle for Chinese policy-makers today is how to reduce environmental damage whilst maintaining the free-market principles that led to Chinese economic prosperity. Environmental economic theory would suggest that increasing prosperity and improving environmental conditions are intertwined, with the environmental Kuznets curve (EKC) (Grossman and

Kreuger, 1991; IBRD, 1992) and environmental leapfrogging theory (Perkins, 2003) suggesting that increasing per capita income can reduce negative externalities.

However, there is doubt as to whether these theories are applicable in the Chinese context, with there being little empirical evidence for the EKC on a Chinese national level (Auffhammer and Carson, 2008; Wagner, 2007). On the contrary, provincial studies have identified the EKC as an applicable concept on the regional level (Song, Zheng and Tong, 2008). Chinese income inequality across regions is vast, with provinces like Zhejiang having three-times the Chinese national average income per capita (Chinese Statistical Yearbook, 2015), it is no surprise that an income based theory like EKC does not hold up to scrutiny on a national level. The provincial income inequality would also suggest regional differences in environmental leapfrogging, in combination with China's regional difference in human capital and resource endowment it is difficult to understand continent sized China as a whole. Despite the large differences in provinces, there have been limited studies analysing regional CO_2 data in the Chinese context (Bin et al. 2017; Wang, Zeng and Wu, 2016).

With empirical evidence showing private companies outperform State-Owned companies (Boardman and Vinning, 1998; Schleifer, 1998), it remains to be seen if it is fact that environmental economic theories may be more applicable to wealthy provinces where state ownership forms a lesser proportion of income than private owned companies. Literature on this subject is sparce, this study will attempt to add to aforementioned ownership studies researching productivity and company performance differences by identifying what effect ownership has on negative externalities, and which form is best for internalising and reducing these externalities. The implications of this study and its contribution towards the existing literature lays in the addition to a surprisingly small body of literature on Chinese provincial-level CO_2 analysis. Furthermore, using the resultant data and analysing variables' effects upon CO_2 emissions at a regional level has gained even less scholarly attention. This study can add to the literature on the benefits and drawbacks of state involvement, by presenting an empirical study of environmental effects of state and private ownership.

1.1 Objective of the study

The principal objective of this study is to examine the CO_2 emissions of both state-owned and private companies on a provincial level from 2000 to 2012. The research question is: When controlling for contributing factors such as industry and region, whether the public or private sectors are more efficient and thus which ownership structure tends to emit less CO_2? The scope of this problem warrants different questions in each section and thus differing forms of analysis. These questions include: (i) What are the CO_2 emissions for each region in China based on energy consumption, calculated using Intergovernmental Panel on Climate Change (IPCC) 2006 guidelines? (ii) In order to separate out confounding effects, what are the factors that contribute towards CO_2 emissions? (iii) What is the relationship between provincial CO_2 emissions and ownership structure? By understanding these three questions, it will then be possible to understand the implications of policy-makers' economic decisions upon environmental quality.

1.2 Method and sample

This study will obtain provincial energy consumption data from Chinese Statistical Yearbooks from 2000 to 2012. Furthermore, the emissions based on apparent fossil fuel combustion will be calculated using IPCC (2006) guidelines, the globally accepted method for CO_2 emissions calculation based on energy consumption data. This data will then be regressed against regional data, including control variables to separate out confounding effects which may be present, allowing this study to perceive the effects of ownership upon CO_2 emissions for the period 2000 to 2012.

Data for the regression will be obtained from the Chinese National Bureau of Statistics, using their Chinese Provincial Statistical Yearbooks for the 29 provinces of mainland China. This data will be agregated into a panel dataset for statistical analysis using Generalised Least Squares (GLS) regression and STATA software.

1.3 Outline of the thesis

Chapter 2 provides an overview and discussion of the main theories and hypothesis related to the investigation into the relationship between ownership structure and CO_2 emissions of Chinese firms. Chapter 3 provides country background and overview of the political structure, historical changes and Logarithmic Mead Divisa Index (LMDI) CO_2 emission decomposition for the years 1990 - 2009. Chapter 4 looks at the main studies previously undertaken in the field to give context to this study. Chapter 5 describes in detail the data collected and used in this study, and the potential distortions present within the official Chinese economic data. Chapter 6 describes the methodology employed and details of model testing. Chapter 7 analyses the results obtained and Chapter 8 discusses the implications of the study's findings. Chapter 9 provides an overview of the entire study and presents conclusions and recomendations on further study to undertake in future.

Chapter 2

Theory and Hypothesis

2.1 Theoretical context

China's rise as an economic superpower has brought with it significant environmental degridation, China's energy related CO_2 emissions have risen 150% since 2000, from 3,300 $MtCO_2$ to 8,500 $MtCO_2$ in 2014 (Grubb et al. 2015). China's economic 'opening up' gained significant traction in 1992, when Deng Xioping's southern tour of China enlightened him to the prosperity induced by private entrepreneurial activity (Nee and Opper, 2012). What followed was an expansion of his reformation policies which began in the 1980s, reducing the role of the state in economic activity.

China's resource endowment of raw industrial materials and abundance of unskilled, cheap labour led China's Communist Party (CCP) to focus on heavy-industry orientated development strategy (HIODS) to compete on the world stage (Lin, Fang and Li, 1996). The HIODS was implemented in the 1950s and is highly energy intensive, requiring vastly more energy input per dollar of economic activity than the agricultural or service sectors (Kander, Malanima and Warde, 2013). Chinese heavy industry was, and still is, predominantly state-owned, with the communist party seeing them as key to Chinese infrastructure building. Europe could not compete with heavy industry enjoying subsidies from the Chinese state, and thus production of these CO_2 and energy intensive goods was undertaken in China. This only increased total CO_2 emissions from China's economy, and saw China become somewhat of a 'pollution haven' (Birdsall and Wheeler, 1993). Increased economic activity in specific regions led to provincial disparities in wealth from coastal provinces with trade links to wealthy American and European companies in comparison to inland provinces (Chen and Fleisher, 1995).

There are additional differences in China's regions, for geographical reasons. This can be explained by China's size, where some regions have large supplies of raw materials and fuels and others are ideal for the use of renewable energies. An example would be Inner Mongolia, whose supply of coal make this fossil fuel cheap, in contrast to Beijing whose highly dense urban population and lack of fossil fuels may mean that solar power is more suitable.

An interesting development which has occurred in China over the following 50 years is an expansion of China's economic and industrial activity in ever advancing and more complex industrial sectors (Nee and Opper, 2012). There has been a marked shift away from the HIODS on a national level, and China's private entrepreneurs are utilizing China's increasingly educated population to specialise in consumer products and advanced technology manufacture, both of which are significantly less energy and CO_2 intensive than the heavy industry with which China first began its economic reformation.

Chinese fiscal federalism has been cited as the political base for economic reform, and provided incentives for local governments to support and embrace private entreprenuerial activity as a source of tax revenue (Montinola, Qian, and Weingast, 1995). These private firms operated under different rules to SOEs, whereby private companies were unsupported and relied entirely on innovation and cost efficient operation for survival. This is in contrast to SOEs, who enjoyed soft budget constraints (Kornai, 1980). This means that means that SOEs are backed by the Chinese state as their purpose is, in part, to fulfil political goals. This means that the state often supplies these companies with an abundance of direct access to state bank credit and other resources. Therefore it is nearly impossible for these SOEs to go bankrupt because the government would bail them out from their financial difficulties (Kornai, Maskin and Roland, 2003; Xu, Zhu and Lin, 2005). Due to this abundance of funding, these companies therefore did not have the same incentives to innovate or employ energy and cost efficient production methods (Hayek, 1945; Walder, 1995a). SOEs are older than private firms in China, and taking into account the fact that environmental leapfrogging theory suggests newer machinery and processes are more energy efficient and due to soft budget constraints, the incentives to implement new technologies for energy efficiency and reduced costs is not present in the SOE context.

The development of human capital and improved education of Chinese employees, combined with the CCP sanctioning of private entrepreneural activity, led to the expansion of the high-tech knowledge based economy within China and reduction in share of total GDP from SOE activity (Chen, 2002). Knowledge based industry is less energy intensive than traditional heavy industry such as steel manufacture, therefore, CO_2 intensity per capita is reduced as a larger share of economic activity is derived from 'cleaner' industries and sectors (Kander, Malanima and Warde, 2013). This would support the EKC hypothesis in the Chinese context, where as income per capita is increased, CO_2 per dollar of economic activity is reduced. These factors are all interlaced and form the basis for this study's hypothesis. To form a more complete picture of each of these factors briefly mentioned, a more in-depth explanation is provided below.

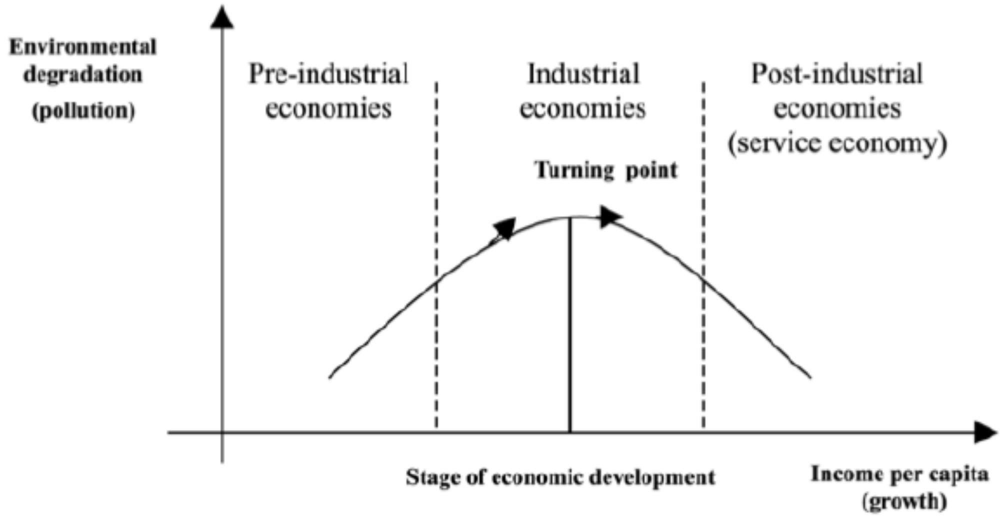
2.2 The environmental Kuznets curve

The Kuznets Curve is traditionally used in developmental economics to demonstrate the relationship between economic inequality against income per capita as an economy develops (Kuznets, 1955). The concept of the phenomenom whereby CO_2 emissions first increase with increasing income, and then reduce after an inflection point was suggested by Grossman and Kreuger (1991). This hypothesis first arose when their study analysed the economic impacts of the North American Free Trade Agreement (NAFTA), and later became seen as a panacea for potentially limiting economic damage as global income increases. This concept was subsequently dubbed by Panayotou (1993) as the 'environmental Kuznets curve'. Figure 2.1 is the EKC and shows an inverted U-shaped relationship between economic growth and environmental quality, whereby as an economy initially expands, there is an increase in pollutants, eventually reaching a peak. According to EKC theory, as GDP per capita continues to increase, environmental damage decreases, suggesting pollution as a 'transitory phenomenon.' This theory was propagated by the World Bank Development Report (IBRD, 1992).

The reason for the U-shaped curve has a number of explanations, including the fact that under free trade, countries will focus primarily on their specialisation, Taylor and Copeland (2004) also proposed that reduction in CO_2 emissions might be a result of developed countries transferring activity to less developed countries. This would suggest a shift of the polluting activity towards developing countries and away from middle income countries, and may explain the peak and subsequent reduction as more economic activity is outsourced (Jiborn and Kander, 2014). Additional studies also demonstrated how environmental regulation in wealthy countries would also encourage production to shift to cheaper countries with less stringent regulation (Lucas, Wheeler and Hettige, 1992). Copeland and Taylor (2004) provided empirical evidence to support this production shift under increased regulations.

Whilst some countries have outsourced their CO_2 emissions, there are examples of countries where CO_2 emissions were reduced without outsourcing (Jiborn et al, 2015; Kander, Malanima and Warde, 2013), and a complex endowment of factors are the driving factor in this principle. Potentially including a country's resource endowment, level of development, industrial structure, and differing policy towards the environment and trade structure. The combination of the aforementioned factors suggests that the EKC concept and related studies are inconclusive as a solution to ecological damage under the global 'race to the top' in economic growth.

Figure 2.1: Environmental Kuznets curve



Source: Panayotou (1993).

Using data obtained in China, a study conducted by Gallagher (2003) presents evidence that China is adopting European standards in the car industry when it comes to pollution regulation and standards, albeit with an 8-10-year lag. Selden and Song (1994) have presented empirical evidence based on four air pollutants supporting the EKC concept and estimated the following turning point GDP per capita values for four pollutants; SO_2, \$10,391; NO_x, \$13,383; SPM, \$12,275; and CO_2, \$7,114. However, these figures are questionable, particularly the low figure for CO_2 emission turning point.

When compared with the income of the world's population, these income figures are not too dissimilar to the mean, suggesting that environmental damage should have decreased from the time of the study (IBRD, 1992). Studies indicate that world income is not normally distributed but skewed to the right (Kochhar, 2015) with many more people below the mean income than above it. Therefore, the estimated turning points should be based on the median income and not the mean, making the turning point figures lower than what could be true in reality.

Within the Chinese context, the level of economic development and technological levels in China's provinces are distinctly different (Tian et al., 2016). As EKC is a theory based on income per capita, There have been a number of studies providing critique of EKC, and consequently propose potential flaws in the theory. The main criticism proposed on EKC is that the econometric empirical evidence is flawed (Stern, 2004; Wagner, 2007) and the random-effects model employed by Grossman and Krueger (1991) cannot be estimated consistently due to correlation with the dependent variable (Hsiao, 1986).

In the Chinese context, critique of the EKC is supported by Auffhammer and Carson, (2008) who present data based on China provincial level data to forecast the path of China's CO_2 emissions. Their empirical evidence shows that despite a significant increase in income, China's emissions have been accelerating. With each new year, China's anticipated emissions path has embarked upon an increasing trajectory. Potentially this is due to the increasing labour participation and urbanisation rate, whereby persons who were non-consumers in rural areas are being brought into employment and increasing their consumption. This would mean that whilst efficiency may be increasing, the population and income per capita factors are more than negating the decrease in energy consumption by efficiency. Therefore, total CO_2 will be shown to be increasing.

If China's population were less unequal in terms of income and labour participation, as is the case in the Western world, perhaps a more clear EKC will be visible. By performing a provincial level study, those wealthy regions with 'Western' level incomes may show an EKC pattern in the more defined sense. EKC concept is important in this study to demonstrate that during different stages of development, environmental damage can reduce, thus income is an important control variable in the study.

2.3 Technological leapfrogging's role in CO_2 reduction

Gerschenkron (1962) explained how the advantage of backwardness leads to the possibility to achieve faster development and catch up economic forerunners in the form of more developed economies. This theory was expanded upon in the early 1990s, when the concept of a technological leapfrog was introduced (Antonelli, 1991; Lamberton, 1994; Mody and Dahlman, 1992). Based on the suggestion of and preliminary work on technological leapfrogging in a study by Anderson (1996), Perkins (2003) presented an analysis and subsequent critique of the idea of the environmental technological leapfrog, where less developed countries could skip resource and energy intensive technologies, thus bypassing the 'dirty' stages of development.

Modern developing countries are the would be beneficiaries of technological leapfrogging, due to the fact that they can use energy efficient burning technology and and less CO_2 intensive fuels for transport and production than were prevalent in the European industrial revolution experience of the 19^{th} century. A commonly cited example is in the case of African nations developing a communications infrastructure, who can skip the installation of landlines, and therefore avoid installing hundreds of miles of phone cables. This enables them to skip the resource intensive step and jump straight to the installation of a network of GSM base stations for using mobile phones (Sauter and Watson, 2008).

New technology can also enable a country to develop cleaner policy and reduced energy dependence as more efficient energy production technology is developed and deployed (MacKay, 2009). This represents a complete jumping of a stage of growth, in contrast to the technological leapfrogging suggested as a potential to reduce environmental damage, whereby the energy mix is altered more towards renewable energy.

On the consumption side, newer technologies are often more energy efficient (Kander, Malanima and Warde, 2013). By installing factories and technological infrastructure and utilizing newer technology on the household level, energy consumption can be significantly reduced from the use of technology developed and produced in the past (Kander and Henriques, 2010; Steinmuller, 2001).

A criticism of the concept of technological leapfrogging as a panacea for environmental damage reduction is that a non-developed country will leapfrog straight into technologies and consumption patterns consistent with that of more developed countries (Kander, Malanima and Warde, 2013). These patterns are much more energy and material intensive and will only increase the ecological burden overall, despite reducing damage in certain areas. For example, cars may become more efficient, using less fuel and therefore cheaper to run. The income saved could then be used to consume more meat, which is more environmentally damaging than vegitation based diets (McMichael, et al,. 2007). Additionally, Murphy (2001) explained how low carbon substitute technologies might face social acceptance problems. As an example, the adoption of low carbon, gas cooking technology may not be as popular as traditional cooking stoves, meaning there will be a slower adoption.

2.4 Property rights, company ownership and technology adoption

Property rights are divided the bundle of property rights into four claims: the right to use a good (usus), the right to make decisions relating to formal and material adjustments of the good (abusus), the right to the profit/losses resulting from the good (usus fructus), and finally, the right to sell the good to others (Demsetz, 1967). Rational individuals respond to risk and return when making decisions, however, without holding the full distribution of private property rights this basic relationship wouldn't hold. How this property rights distribution translates to innovation is interesting. Innovation often involves risk and an increase of effort by employees and managers. Thus, if a firm manager lacks financial incentives to make optimal decisions and expend effort, technology adoption will suffer and thus affect the long-term profitability and sustainability of the firm's economic activities (Aghion, Van Reenen and Zingales, 2013). Empirical studies further suggest that there are performance differences between public and private firms in competitive environments (Boardman and Vining, 1989; Nee and Opper, 2012) in-part due to the soft budget constraints mentioned earlier

In addition, SOE managers are only authorized to the first of the four property rights (usus), consequently they are not responsible for financial losses that occur within the SOE and most importantly – they lack incentives to seek profitable and efficient production procedures to achieve profit-maximization and business expansion, and are not entitled to retain profits. Moreover, with high government intervention comes the obligation for SOEs to achieve political goals, such as forcing SOEs to employ excess labour to increase political support for the party by reducing unemployment, resulting in unnecessary costs compared to the cost of an optimal number of workers (Xu, Zhu and Lin, 2005). The reasons stated above also explain why SOE managers are not generally aiming to increase innovation activities to achieve higher returns, improve technology to increase the firm's productivity or accommodate its products or services to meet consumer demand more effectively. Additionally, large sized firms tend to suppress creativity and are slow in responding to opportunities (Cohen and Klepper, 1996).

Meanwhile, private firm managers that are often entrepreneurs possess the full collection of claims that come with the property rights. Therefore, entrepreneurs are motivated to actively seek profitable investment opportunities, and aim for efficient production capacity through product or process improvements and energy efficient technology adoption. Because the potential profits can be used as they wish they therefore want to and can maximize the value of their property (Schleifer, 1998). Further, when an entrepreneur has the right to sell, it motivates the entrepreneur to continue reinvesting to potentially increase the value of the future sale. Hence, POEs operate under the hardest budget constraints of all ownership forms in China, as they are aware the government will not back them up or bail them out in the event of bankruptcy. The Chinese state also does not provide private firms with start-up capital or tax redemptions. Although technology adoption is proxy to increased investment costs, efficient production methods provide higher rewards for private business owners due to the exclusivity of property rights and the right to retain the rewards that come with an efficient and thus successful business.

As previously mentioned, China's form of fiscal federalism incentivised local governments to support economic activity in their jurisdiction to gain tax revenue. This also means that local governments do not have the same incentives to enforce strict environmental standards on those companies who are sources of revenue, thus tolerate heavy pollution (Jiang, Lin and Lin, 2013). This shows in the adoption of new technology and equipment to improve efficiency and reduce emissions. Data obtained by this study in the

World Bank 2012 Manufacturing Survey shows that 64% of private enterprises introduced new technology and equipment in the prior three years, compared with only 35% of state-owned firms (World Bank, 2012). Based on technological leapfrogging theory this would suggest that state-owned firms have older technology and therefore have a higher energy intensity (EI) technological endowment.

2.5 China and Eastern European centrally planned economies

Whilst China is not unique in the context of a government heavily involved in the role of resource allocation, there has been a marked transition away from Chinese government as a 'grabbing hand' towards a 'helping hand' (Walder, 1995b). Interesting in this case is how the experience of Eastern European centrally planned economies, and a country such as Czech Republic, formerly part of Czechoslovakia, can be used to form a loose comparison to China. The Czech Republic was a centrally planned economy, who also had vast coal reserves as a primary energy source, estimated currently at some 880 million tonnes (Eurocoal, 2017). This is similar to China's vast coal endowment and subsequent reliance on coal for energy production.

The role of government in production in former Czechoslovakia was environmentally damaging, with production waste and lacklustre environmental regulation resulting in some of the worst environmental damage in history (Nielsen, 2017). Nielsen outlines the key areas of waste present in government controlled industry, these are also applicable in the Chinese context due to the same institutional structure lacking the incentives for efficient production. These are: energy embodied in final products that had to be scrapped due to their low quality (a scrap rate of up to 30 per cent of the total production) or later modified to meet certain quality standards (again up to 30 per cent of the total production); energy embodied in the components used for the production of these scrapped products; technologically obsolete production processes; and unoptimized production processes (Nielsen, 2017).

From a productivity point of view however, Nielsen shows that in spite of the research showing that non-market economies are detrimental to productive efficiency, Czechoslovakia managed to make satisfactory progress in their industrial development and capacity between the years 1973 – 1989. This was achieved through a combination of factors, including effective policy development and implementation, efficiency targets, technology improvements and industry scaling. Scaling was of particular importance in Czechoslovakia, with the country focusing on cost savings and efficiency, and possessing far larger steel plants than were installed in the West. It remains to be seen if this is the case in China, but due to the size of the country and decentralised nature of fiscal policy, the hypothesis is still supported that SOEs are comparatively less economically and CO_2 efficient.

Further empirical analysis would be useful in forming a more in-depth understanding of the transitions of similar command and control economies, for example additional former Soviet Republics. This would inform us of the reduction of the role of government and how that affected emissions, but the lack of long-run data is a major constraint in this area (Nielsen, 2017). Additionally, the retrenchment of government omnipotence was experienced vastly differently in these two cases. China's pragmatic approach to market liberalisation and economic transition was a slow and gradual process (Nee and Opper, 2012) where the Soviet transition was a different experience, with an almost overnight collapse of centrally planned government.

2.6 Testable hypothesis

It is based upon the aforementioned studies and associated theories that the following empirically testable hypothesis is specified:

All being ceteris paribus, state-owned firms will be less CO_2 efficient than privately owned firms.

Chapter 3

The Chinese Background

China's reformation process began in 1978 with the introduction of the Household Responsibility System, following the Great Leap Forward in 1958 – 1962 and the Cultural Revolution from 1966 – 1976. Before 1978, China was a poverty stricken centrally planned economy and millions of people starved to death. The years after 1978 and associated economic freedom saw 170 million people within China being lifted out of poverty (World Bank, 2004). This study will therefore only look at the four-stage SOE and private company reforms during the post-1978 period, where the foundations were laid for Chinese economic prosperity of the following 40 years.

3.1 Overview of the reformation process

3.1.1 Stage 1 (1978 – 1983)

Early on, the Chinese government identified structural imbalances brought by the lack of incentives for managers in state-owned firms and inefficient allocative capacity from central allocation. The first attempt was made in 1958 - 1960, the second in 1961 - 1965, and the third in 1966 - 1976 (Wu and Zhang, 1993). However, these are not relevant to this study due to their ineffective and short lived nature, thus stage 1 of the on-going reformation process begins in 1978. The creation of the Household Responsibility System in 1978 and thus replacement of collective farming with individual responsibility incentivised farmers on the local level to increase yields by efficient production, with farmers gaining the right to keep their produce. The estimated loss of total factor productivity before 1978 was estimated at 20 percent of total agricultural production due to lack of incentives (Lin, 1992). By 1983, 98 percent of agricultural collectives had adopted the new system, cementing the Household Responsibility System as the key reformation that began the shift towards a decentralised, more efficient economy (Lin, Fang and Li, 1996).

The Chinese government recognised the innefficient nature of state-owned Enterprises and the lack of incentives for employees for efficient production, and implemented changes to the financial incentives within the traditional economic system. Most notably, these included performance-related bonuses for SOE employees and giving SOEs the right to produce and sell goods outside of the usual mandatory state plan. Enterprises selling to foreign countries were allowed to retain part of their foreign earnings and invest them as they wished. These measures shifted power from central planners and government bureaucrats to producers, giving them the capacity to produce goods they believed were required by consumers (Nee and Opper, 2014).

3.1.2 Stage 2 (1984 - 1986)

Stage 2 formalised the financial obligations of SOEs and exposed the SOEs to market influences. From 1983 onwards, payments from central government to SOEs were halted and a profit tax was introduced. In the following year, government negotiated prices allowing SOEs to sell excess output to the market, and the duel-track pricing system was established. This meant that SOEs had incentives for efficient production and could adjust their output according to market demand and productive capacity. The larger the amout of profit an enterprise is allowed to retain, management incentives for positive change become greater (Groves et al. 1994).

3.1.3 Stage 3 (1987 – 1992)

During stage 3, the contract responsibility system outlined and clearly defined the responsibilities and authority of SOE managers, combined with the removal of lifetime tenure of SOE employees. By this time, Township Village Enterprises, a form of semi-private enterprise run by local governments, were well established as economic actors within the Chinese economy, enjoying supernormal profits from the lack of competition within the market (McMillan and Woodruff, 2002). However, the rapid rise of new entrants quickly reduced these profits, giving consumers the propensity to consume a higher quantity of goods and services than any point previously.

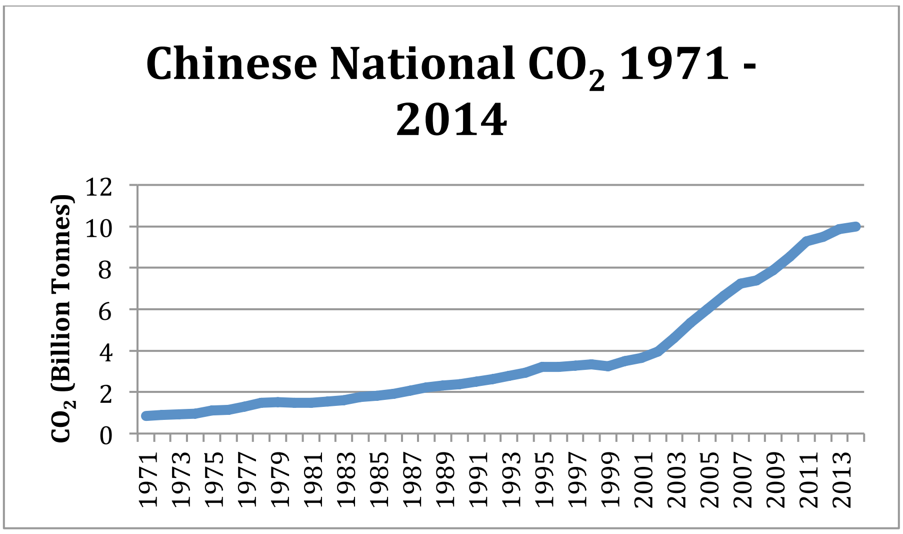
3.1.4 Stage 4 (1993 – Present)

During stage 4, SOEs were further subjected to market forces, with government intervention further reduced and SOEs gaining more autonomy. Successful SOEs were floated on the newly formed Chinese Stockmarket, albeit with strict regulations on share ownership. Poor performing SOEs were privatised, allowing productive private entrepreneurs to obtain their assets and attempt to run them more efficiently, however, economic institutions and regulations were still in favour of state-owned firms (Nee and Opper, 2014). The freeing up of regulations allowed entrepreneurs to endogenously develop the economic institutions to support their free market activities. The preceeding stages combined with stage 4 suceeded in improving technical efficiency with nearly half of the 42.2 percent productivity improvements brought about by the reforms during 1978 -1984 (Lin, Fang and Li, 1996).

3.2 China's membership in the World Trade Organisation

In 2001, China joined the World Trade Organisation (WTO) at a critical time during the transition process. Rife with productive overcapacity and low industrial concentration, Chinese firms consolidated in preperation for WTO entry. This made Chinese firms more efficient and more competitive, forcing domestic fringe firms out of business (Chen, 2002). The surviving firms enjoyed an increased level of economic prosperity due to their new found efficiency and access to foreign markets, particularly the United States (US) becoming a major trading partner. However, this further step onto the world stage for China had the negative effect of increasing Chinese CO_2 emissions, as shown in Figure 3.1 where CO_2 emissions spike sharply upwards after WTO entry in 2001.

Figure 3.1: Chinese National CO_2 emissions 1971 - 2014



Source: Chinese Statistical Yearbooks 1971 – 2014. Author's Construction.

China’s ascension into the WTO and the added competition continued the retrenchment of SOE activity within the economy, with both value of industrial output and size and share of employment in urban areas. However, the CCP still retains dominace in industries they see as vital to national prosperity and national security (Chen, 2002). Due to state enforced monopolisation, SOEs in these key sectors face little competition from the more efficient, newly consolidated private industrialists, meaning they are still less likely to be energy and CO_2 efficient than private industry.

3.3 Chinese emission decomposition

In order to give context to China’s current CO_2 emissions and major sources of these emissions, this study has decomposed Chinese emissions using Logarithmic Mean Divisia Index (LDMI) and Kaya Identity methodology. These widely accepted decomposition methods enable us to gain insight into the factors contributing to CO_2 growth from a historical perspective, and a more defined breakdown of sectoral expansion and contraction using the LDMI method. The formula used to express Kaya identity is as follows:

$$F = P \, x \, \frac{G}{P} \, x \, \frac{E}{G} \, x \, \frac{F}{E} \qquad (1)$$

Where:
F is Chinese CO_2 emissions from human sources
P is Chinese population
G is Chinese GDP
E is Chinese energy consumption

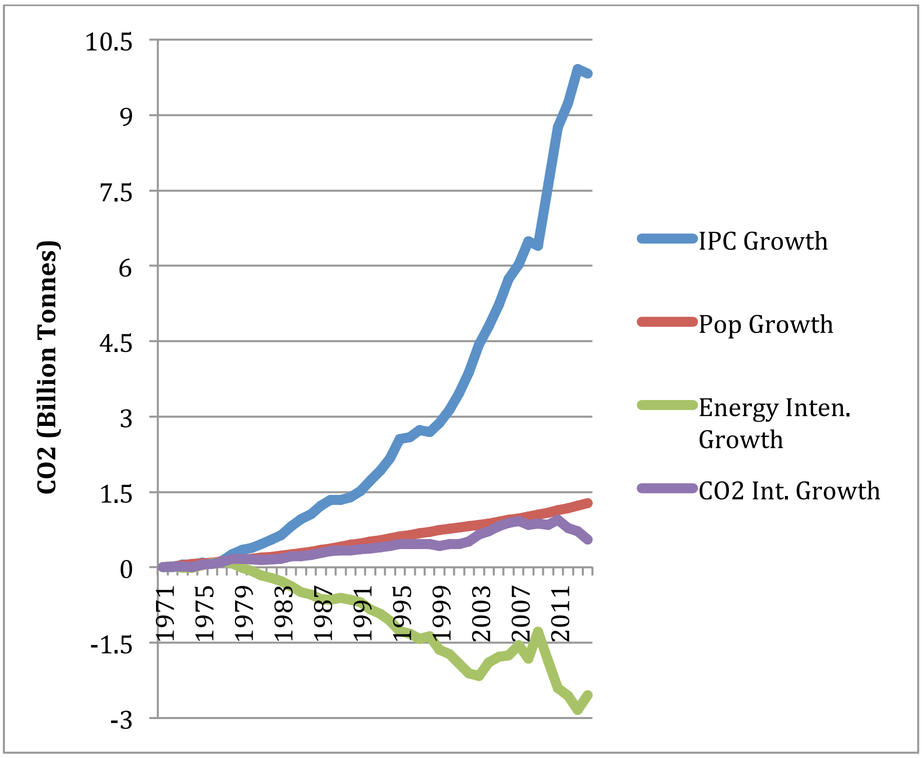
3.3.1 Kaya Identity Decomposition Results

Figure 3.2 shows that Income Per Capita (IPC) growth was by far the highest contributor to CO_2 emission growth in the Chinese context from 1971 – 2014, but particularly beginning to increase at a higher rate around the year 2000. I discuss this further in ‘driving factors’. IPC growth has had the largest effect on increasing CO_2 emissions, as more of the Chinese population has been drawn into the labour market and thus are becoming producers and consumers (Dollar, 2013).

China is such a large country that it would be interesting to further understand the regional decompositions of emissions, with coastal regions experiencing far higher levels of economic success than inland regions (Nee and Opper, 2012). This provides coastal regions with the propensity and incentives to switch to a cleaner fuel mix and adopt new technology, whilst inland provinces may be languishing behind and burning dirty, inefficient coal. These cleaner alternatives include natural gas, a fossil fuel with a much lower CO_2 emission factor that coal, building nuclear plants or even renewable energies such as solar, wind or hydro. Due to the size of China, some renewable energies may be more applicable to certain regions than others. For example, Inner Mongila has large, flat plains and thus would be perfect for wind power, but hydro power may be more efficient and abundant in the river rich area of the south.

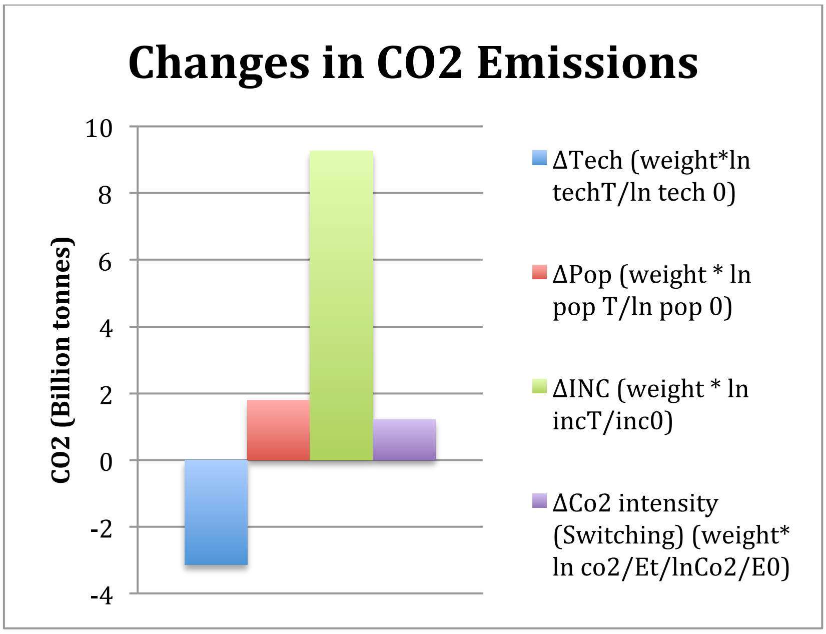
Figures 3.2 and 3.3 show the same story in energy usage and changes in CO_2 emissions, but they are useful to visualise the timing of changes in measures for a more in-depth analysis.

Figure 3.2: Cumulative Kaya time series decomposition 1971 - 2014



Source: Chinese Statistical Yearbooks (China NBS). Author's construction.

Figure 3.3: Changes in Chinese CO_2 emissions (kt) 1990 - 2005



Source: Chinese Statistical Yearbooks (China NBS). Author's construction.

3.3.2 LMDI decomposition results

Interpretation of Table 3.1 is relatively simple, with numbers less than 1 showing a reduction in CO_2 and a number more than 1 showing an increase. With *n* being the result and where 1 represents 100 percent of energy intensity, the percentage change is exactly specified by *n–1*. However, whilst interpreting the numerical results is simple, trends within sectors can be concealed and are more difficult to unveil. For example, a significant part of the decrease in CO_2 is due to the Chinese diversification away from heavy industry and the HIODS as the primary source of revenue, as previously mentioned in 2.1. This is a structural change concealed within the Industry sector, where due to an enormous increase of activity, it may appear that industry is contributing more CO_2 for the same economic activity. The LMDI decomposition in Table 3.1 shows a vast decrease in energy intensity in the 1990 – 2009 period analysed, largely brought about by technological efficiencies in the productive sector of 45%. Whilst in Industry, intensity reduced by 71%, overall Structure has increased by 13%, this is due to a vast increase in economic activity within China, although as mentioned, the structure within each industry is not visible and therefore CO_2 attributable to light and heavy industry is unable to be caputred. The LMDI decomposition 'Total Impact' result shows that Energy Intensity in China decreased by 67 percent from 1990 to 2009.

Table 3.1: LMDI Decomposition China 1990 – 2009

Agriculture	
Intensity	0.98
Structure	0.96
Industry	
Intensity	0.59
Structure	1.18
Services	
Intensity	0.97
Structure	1.01
Transportation	
Intensity	0.98
Structure	0.99
Total Productive Sector	
Intensity	0.55
Structure	1.13
Sub Total	0.63
Consumption	
Residential	0.53
Total	
Intensity	0.29
Structure	1.13
Total Impact	0.33
Residual Check Sum	1

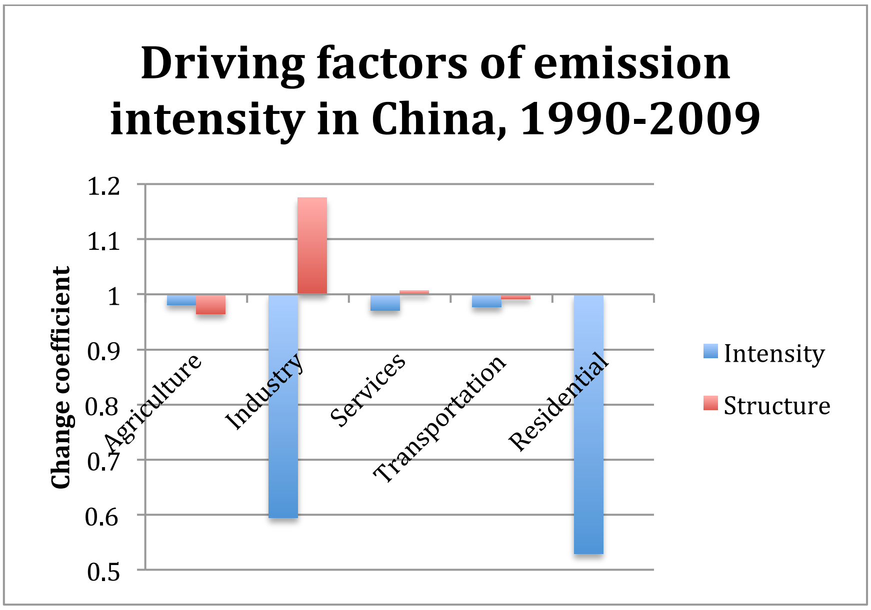
Source: LMDI Decomposition from Chinese Statistical Yearbook data. Author's Construction.

3.3.3 Sector with significant changes

It is clear by the LMDI decomposition that Industry is the sector with the largest changes, with structure increasing by 18% and intensity decreasing by 41%. It would be interesting to further break down these statistics, with intensity perhaps decreasing towards an increasing share of manufacturing activity shifting towards pharmaceuticals and electronics, much less energy intensive than heavy industry (Kander, Malanima and Warde, 2013). This theory is supported by Olivier et al. (2015) who explain that the slowdown of the growth in China's CO_2 emissions reflects structural changes in China's economy towards a less energy-intensive service sector and high value-added manufacturing industry that is more focused on domestic consumption.

It is possible to interpret the driving factors for sectoral changes from the graph below, with residential and industry clearly having the largest improvements in technology (intensity). This is due to the development of electronics, which assist in production efficiency in industry by improving quality, improving design capability, machine energy efficiency due to microcontrollers. Residential efficiencies could include refrigerators becoming more efficient and televisions improving from Cathode Ray Tube (CRT) to more energy efficient Liquid Crystal Display (LCD) however, the number of electronic devices in homes has increased significantly, thus if structure were measurable in the residential context that may see an increase (Kander, Malanima and Warde, 2013).

Figure 3.4: LMDI sectoral breakdown of emission changes 1990 - 2009



Source: LMDI Decomposition from Chinese Statistical Yearbook data. Author's Construction.

One discernable difference between the literature presented, such as Borowiecki and Henriques (2017), and this study's decompositions, is that the structural and technological transitions occurred from a much longer period of time than seen in these results. This demonstrates that technological leapfrogging can take place as a panacea for improvements in environmental quality. This is in line with the technological leapfrogging theories as put forward by Allen (2012) who demonstrated that those countries with coal supplies rely heavily on them in the early stages of development, then switching away when the economy is sufficiently developed. China appears to have adopted technology quicker than was seen in 19th century Europe, due to the technological abundance in the present day and ongoing development during that century.

Whilst the results show that China has progressed significantly with technological efficiency, the switch away from coal as a fuel on a national level appears not to have happened in the CO_2 data this study has obtained. This can be due to a number of reasons, primarily China's lack of oil and natural gas and abundant supply of coal and therefore its relatively low cost. With electricity being produced by any primary fuel, coal still represents the best value for money for China. When understanding the economic and institutional history of China, the timings of the biggest changes in trajectory are also expected, with the biggest changes occurring in 1978 when reformation began and 2001, Chinese WTO entry.

3.3.4 Results contrast with existing research

Using the LMDI decomposition, the results seem to coincide with the research of Kander (2005) and Kander and Henriques (2010). Service sector intensity is 0.98 and structure is 1.01, therefore structural shifts towards the service sector do not play as large role in CO_2 intensity reduction as technological shifts. However, the results in the Chinese context are somewhat harder to accurately interpret than the developed countries presented in the aforementioned papers. This is once again due to the disparity in relative wealth between coastal and inland regions (Nee and Opper, 2012) and therefore the increase in operation of a coal based industrial activity inland can offset the shift towards clean energy in Shanghai industry.

An additional difference between Western studies and Kaya/LMDI decompositions is that the economic benchmark for decomposition was set as 1971. Whilst Western countries were not equally prosperous in 1971, they had developed markets and industries by that time. The same cannot be said for China, however, since reformation began in 1978 from a period of complete poverty in which millions of Chinese people died during 'the great leap forward' (Nee and Opper, 2012). This means that the entire industrial transformation is captured and thus a larger jump from base to current day in decrease of energy intensity. The Industry technology ‘within-sector’ jump is much higher than seen in the research of Kander and Henriques (2010), with Agriculture making only modest gains in efficiency and structural efficiency.

Chapter 4

Literature Review

There is little empirical evidence of ownership structure in comparison to CO_2 emissions in the Chinese context, however, there are a number of studies exploring factors which play a role in determining CO_2 emissions. Taking into consideration the environmental economic theories and Chinese historical transition previously discussed, the following literature plays an additional role in explaining and motivating this study.

4.1 Regional level CO_2 emission calculation

There are many studies calculating regional level CO_2 emissions, in China and worldwide. Many of these studies employ the IPCC (2006) guidelines and emission factors (EFs) as a default, however some studies expand upon this and calculate new EFs. One study that utilize different EFs is Shan et al., (2016) who then calculate provincial level CO_2 emissions using energy consumption data and apparent emission factors. This was because their review of 2368 research articles on China's carbon emissions indicated that less than 1 percent of these studies were performed using EFs derived in experiments of field measurements. Liu et al. (2015) measured the CO_2 emitted from 602 samples of coal from 100 of China's coal mines, and discovered a discrepancy between the previous studies' default emission factors. According to the study, raw coal emitted far less CO_2 than was previously thought, thus regional emissions calculated using the 'new' EFs are generally lower than the IPCC and China National Development and Reform Commission (2011) guidelines, as demonstrated in Table 4.1. Studies have been limited on Chinese CO_2 at a regional level, however Bin et al. (2017) performed a regional calculation of CO_2 emissions, taking a bottom-up consumption approach, differing from the apparent energy consumption approach employed by Shan et al. (2016).

Table 4.1: Comparison of emission factors

Energy type	IPCC default value	NDRC default value	Liu's study
Raw Coal	0.946	0.518	0.499
Imported raw coal	0.946	0.518	0.508
Crude oil	0.733	0.839	0.838
Natural gas	0.561	0.591	0.59

Source: Shan et al. (2016).

Shan et al. (2016) conclude that total national Chinese emissions calculated using their measured EFs are 12.69 percent lower than the IPCC EF default value calculated CO_2 emissions. The gap comes from two parts: 6.94% from the emission factors and 5.75% from activity data, which was calculated using input – output data on a cross provincial basis.

It is therefore important to consider the trade of goods and energy between provinces in calculating CO_2 emissions, however, due to Chinese data or lack thereof, this is more difficult than would be possible with OECD countries. The literature in this area is limited, and uses short time-series data for empirical testing. A provincial study by Meng et al. (2016) used 2007 – 2010 data to perform a spacial-structural decomposition to determine interregional spillover effects. The study showed that the changes in production technology and investment preferences may exert positive or negative effects on other region's CO_2 emissions growth through domestic supply chains. The study's aim was to assist in understanding the driving forces behind China's regional CO_2 emissions growth. Whilst interesting and potentially useful, the study is based on sectoral decomposition rather than individual determinants of CO_2.

A study by Khalid (2016) uses provincial level data to examine the effects of capital growth on CO_2 emissions for public and private companies. The study concluded that capital in the hands of public enterprises leads to sub-optimal production in terms of energy efficiency in comparison to what would be possible in private hands. The study also identifies a number of determinants of CO_2 as control variables to separate out confounding effects, however, empirical evidence shows that not all of the determinants are applicable in the Chinese context. These determinants are discussed in more depth below.

4.2 Determinants of CO_2 emissions

There is an abundance of literature examining and explaining the determinants of CO_2 emissions. This study will explore the determinants to a greater degree than is normally used in Kaya emission decompositions. Kaya identity formula is given below, with determinants in this context being too broad to serve the purpose of this thesis.

$$CO_2 = \Delta Inc + \Delta Pop + \Delta Tech + \Delta CO_2 Intensity \tag{2}$$

Where *Inc* is income per capita, *Pop* is population, *Tech* is technology and *CO_2Intensity* is CO_2 emissions divided by GDP. Whilst these factors are drivers in change of CO_2 emissions, this study will discuss the greatest individual contributors to CO_2 and main determinants applicable in the Chinese context.

4.2.1 Fossil fuel combustion

By far the largest determinant in Chinese and global CO_2 emissions is the combustion of fossil fuels, especially coal. Fossil fuels make up 83 percent of China's CO_2 emissions (Olivier et al. 2015) and 75.9 percent of China's energy mix consists of coal. This is due to China's natural resource endowment and the relative abundance of coal as a cheap energy source. The CO_2 emission factor of each fuel is vitally important in understanding the emissions and carbon reduction incentives for fuel switching. Coal is much more CO_2 intensive per MJ of energy produced than other fossil fuels, such as petroleum or natural gas as shown in Table 4.2 by Levander (1991).

Table 4.2: CO_2 Emission factors for fossil fuels gCO_2/MJ

Fuel	CO_2 (g/MJ)
Raw coal	92
Crude oil	74
Natural gas	56

Source: Levander (1991).

In terms of sectoral demand for energy and its impact upon CO_2 emissions, the industry does make a large difference in demand for energy. In comparison to the service sector or knowledge based industries, heavy industry is highly energy intensive, with coal and coke being used directly for heating processes and other heavy machinery which have an increased demand for electricity (Kander, Malanima and Warde, 2013). However, sectoral demand as a determinant of CO_2 emissions is included in fossil fuels, due to the fact that fossil fuels still remains the primary source of energy for electrical production in China.

Despite a concerted policy move towards natural gas consumption (Wang et al. 2013), China has yet to immitate the European experience of the 20^{th} century and undergo the transition away from coal as the economy grows. This transition may prove difficult considering China's abundant coal resources and limited domestic supply of crude oil and natural gas, thus they need to switch to solar and wind energy if they have the goal of reducing emissions. However, China has made attempts to reduce the negative externalities arising from coal use. China has recently invested in the introduction of supercritical coal power plants and the scrapping of older, less efficient plants (Barnes, 2015). This has led to an improvement in the efficiency of thermal power generation from coal of 37.4 percent in 2000 to 43 percent in 2012. This means that whilst the negative impact of the burning of fossil fuels is being gradually reduced, it is still the largest determinant of CO_2 emissions worldwide, and specifically in the case of China.

4.2.2 Cement production

China is the world's largest producer of cement, an energy intensive process to support the expansion of China's urban areas. In 2013, China produced 30 times more cement than the United States of America (China NBS, 2014). Cement production currently accounts for 7 percent of China's total CO_2 emissions, meaning there is large potential for reduction in this sector. Using Log-Mean Divisia Index (LMDI) decomposition, a study by Xu et al. (2012) concluded that adoption of newest and most advanced technology could significantly reduce China's CO_2 emissions. Within the cement production sector, applying new technology has an energy saving potential of 26 percent and a CO_2 mitigation potential of 33 percent in comparison to 2009.

4.2.3 Urbanisation

The urbanisation rate of China is currently 39.5 percent (China NBS, 2015) and due to its population of 1.3 billion people, a positive or negative influence of urbanisation upon CO_2 emissions would have a large effect on total global greenhouse gas emissions. Logic would suggest that urbanisation increases CO_2 emissions and energy consumption, with greater access to energy consuming technologies than rural citizens. However, the empirical evidence is inconclusive, and appears to suggest that CO_2 emission in the urban context is more a function of increased income than of urbanisation itself. The most applicable literature to this study began to be published in the early 1990s, with Jones (1991) performing a regression of 59 developing countries to understand the impact of urbanisation on energy consumption. He concluded that for the year 1980, a 10 percent increase in urbanisation increased energy consumption per capita by approximately 4.6 percent. This study was expanded upon by Parikh and Shukla (1995) who used a panel dataset 1965 – 1987 to test urbanisations effect on greenhouse gas emissions and per cepita energy consumption. The study concluded that a 10 percent increase in urbanisation only had the effect of a 0.3 percent increase in per capita CO_2 emissions. Other studies based on Chinese provincial data including Sun (2012) and Wang and Jin (2012) show that urbanisation has the effect of increasing CO_2 emissions while Fan et al. (2006) found an inverse relationship between CO_2 and urbanisation, whereby CO_2 is reduced with urbanisation.

As previously mentioned, the studies on urbanisation are inconclusive but tend to lean towards a reduction in CO_2 with an increase of urbanisation. Potential reasons for this are explained by Dodman (2009) who explains that urban areas have more intensive construction and people have lower living space, thus energy consumption is reduced and CO_2 is lower. Additionally, there is more public transport in cities and lower private car use than rural areas. Taking these factors into account, it could be possible that urbanisation's effect upon CO_2 differs at different stages of development, thus it may hold a non-linear relationship, with CO_2 from urbanisation first increasing then decreasing as income increases. To test this and create an accurate model accounting for urbanisation's effect in Chinese provinces would be useful in seperating out determinants of CO_2. However, this is complex and not within the scope of this study, therefore a more basic employment urbanisation rate at the provincial level will be included in the regression to attempt to account for any effects urbanisation may potentially have on CO_2 emissions.

4.3 Company ownership

Company ownership has an impact upon CO_2 emissions for a number of reasons, including political preference for supporting state-owned enterprises (SOEs) by lack of regulation enforcement and less incentives for SOEs to adopt newer and therefore more energy efficient technologies, as covered in depth in section 2.4. Additionally, literature suggests that the objectives of a company and proximity to negative externalities may also have an effect upon firms emission and CO_2 intensity.

4.3.1 Implementation of environmental regulations

Using a firm-level dataset, Jiang, Lin and Lin (2013) present evidence from the Chinese manufacturing sector that SOEs have a higher emission intensity in three pollutants than foreign-owned firms and domestic public-listed firms. These pollutants are sulphur dioxide (SO_2), wastewater and soot. This is in contrast to the pollution haven theory developed by Birdsall and Wheeler, (1993) and discussed in a more applicable context by Neumayer (2001), who hypothesised that foreign-owned firms will relocate production and therefore emissions to countries where environmental standards are lower. Whilst these three pollutants are higher in SOEs, it is not certain that CO_2 is higher. However, we make the logical step that if SOEs are less environmentally efficient with a number of pollutants and use older machinery, it is likely that they produce more CO_2 than private industry when controlling for a number of factors. Part of the explanation for the foreign-firms' less than expected pollution was proposed by Jiang, Lin and Lin (2013) as sensitivity to reputational damage on the firms behalf. The study suggested that if a firm was seen as a negative factor on the environment upon entering one country, it may damage their ability to set up production facilities and enter the market in another country. Also applicable in this context is the potential differing implementation of environmental regulations and firm financial penalties. Local governments have an incentive to use more resources in investigating and financially penalising foreign owned firms than their SOE counterparts, when profits from foreign firms are repatriated to their country of origin. Therefore, environmental restrictions are less stringent upon state-owned companies than private or foreign-owned companies.

Chapter 5

Data

The data for this study is obtained predominantly from two sources, Chinese National Statistical Yearbooks and Chinese Provincial Statistical Yearbooks. The primary English language source for these data is China Data Online which uses using China Statistical Yearbooks (China Statistical Yearbooks, 2000 - 2015) produced by the China Data Center at the University of Michigan, in collaboration with the All China Market Research Company. Using official data from the government of China, National Chinese Bureau of Statistics and these are seen as the most important sources of Chinese data (Nee and Opper, 2012). They provide a unique data collection of various Census data with a completed coverage of all provinces, cities, counties and townships of Mainland China, which include approximately 3,000 electronic Census data books.

5.1 Data for calculation of CO_2 emissions

To obtain data for calculating CO_2 emissions to use as the dependent variable, this study will utilize Chinese Provincial Statistical Yearbooks. On an annual basis, the statistical yearbooks will be parsed for data on provincial energy generation by raw coal, crude oil and natural gas. CO_2 emissions are calculated as a linear funtion of these different fuels. In using the IPCC (2006) guidelines for national greenhouse gas inventories, this gives us an estimate of provincial energy consumption and energy related CO_2 production consistent with World Bank's Development Indicators.

A weakness of this study is the exclusion of provincial linkages in energy production and consumption. Energy is traded cross-provincially and thus consumption occurs in a province where the CO_2 production would not be captured within this study's calculations (Meng et al., 2016). Due to the proximity of some provinces to others, it is therefore more likely that one provinces economic activity will directly affect anothers, including trade links of goods and energy (Conley and Ligon, 2002).

5.2 Data for regression

In order to control for determinants of CO_2 emissions other than ownership structure and avoid confounding effects, this study will obtain data for independent and control variables from Chinese Provincial Statistical Yearbooks. National Yearbooks only provide a limited coverage of regional data, and thus the provincial level yearbooks provide highly detailed regional data and contain annual observations from 1949 onwards. The yearbooks are often arranged around one specific chapter or topic. Yearbooks of year *t* are showing data for year t^{-1}. Data available in time series presentation is extremely limited, and thus this study will create and perform regression upon a bespoke made panel dataset with the required variables.

5.3 Description of data

Table 5.1: Description of statistics

Variable	Obs.	Mean	Std. Dev	Min	Max
Province	29	N/A	N/A	N/A	N/A
Year	12	N/A	N/A	2000	2012
CO_2Mt	373	210.58	166.17	6.57	911.88
TotalEmployed	366	2393.39	1567.68	238.57	6554.3
UrbanAreas	342	643.79	469.74	66.33	3084.3
RuralAreas	329	1721.79	1219.47	160.8	4914.7
Primary	359	1046.21	741.73	57.3	3569.04
Secondary	359	596.50	534.00	31.14	2526.48
Tertiary	359	748.33	471.89	61.42	2275.6
Private	377	387.96	227.69	40.51	1262.06
StateOwned	360	219.93	108.20	30.87	542.07
UrbanCollective	360	28.08	23.95	0.68	137.33
Other	360	139.06	137.97	1.56	789.76
GDP	377	9142.22	9670.25	263.68	57067.92
PrimarySecGDP	377	1153.00	1591.27	40.12	15880.58
SecondarySecGDP	377	4483.81	5084.33	103.97	27700.97
IndustryGDP	377	4036.15	4583.08	70.46	25810.07
ConstructGDP	377	641.56	816.66	24.73	7735.78
TertiarySecGDP	377	3705.31	4110.16	98.38	26519.69
GDPpercapita	377	22055.83	17468.29	2759	93173
Kg$CO_2$100RMB	373	40.00	62.73	5.18	660.51
Population	377	4383.70	2645.20	517	10594

Private refers to the persons who work in (and receive payment therefrom) enterprises and institutions of state ownership, collective ownership, joint ownership, share holding and foreign ownership. It only includes staff who are fully employed, and not those who have left employment but remain under employment contract. Staff and Workers in *StateOwned* economic units refer to the persons who work in the state-owned economic units or their attached units and are listed in their payrolls. Staff and Workers of *UrbanCollective* owned units in urban areas refer to the persons who work in collective owned units in urban areas and receive their payment from this enterprise. 'One unit' of these variables refers to employment in 10,000 persons. As a proxy to measure the level of activity of firms, the number of employees is used in the model since there is a high correlation (0.8) between output share and employment share (Khalid, 2016). This also helps to control against regional differences in firm scale.

China Data Online outlines the following details of how the data on the provincial level is constructed, and what industries the variables present in the data contain. Industry structure GDP has been classified according to the historical sequence of development. Primary industry refers to extraction of natural resources; secondary industry involves processing of primary products; and tertiary industry provides services of various kinds for production and consumption. The above classification is universal although it varies to some extent from country to country. Industry in China comprises:

(1) Primary industry agriculture (including farming, forestry, animal husbandry and fishery).
(2) Secondary industry (including mining and quarrying, manufacturing, production and supply of electricity, water and gas) and construction.
(3) Tertiary industry all other industries not included in primary or secondary industry.

There are a large number of service industries in China, and on a provincial level, statistics are usually divided into a number of additional variables within the service sector including transport and telecommunications. However, this is not the case with all provinces, as data differs depending on the province. For the purpose of this study, the service sector is grouped together into tertiary for inclusion in the study's dataset, since not all Chinese Statistical Yearbooks have sufficient detail on the provincial level.

Whilst the data in Table 5.1 is displayed to 2 decimal places for illustration purposes, data in the dataset employed is up to 5 decimal places. This is to ensure greater accuracy when performing the regression.

5.4 Reliability of Chinese economic data

The reliability of official Chinese data is questionable, with media sources such as Bloomberg (2017) reporting Liaoning admitted the falsification of data for multiple years. Their governor reported that revenues were inflated by as much as 20 per cent, with other statistics being falisified. Khan (2016) wrote an article in the British newspaper, The Telegraph, reporting that influential figures claim that Chinese statistics have long been manipulated, additionally reporting that Wikileaks published diplomatic telegrams written by the Chinese premier who himself admits that GDP numbers are a fabrication.

Scholaraly articles on the subject are equally as sceptical of Chinese statistical figures, with a number of articles providing evidence of their falsification including Meng, 1999; Meng and Wang, 2000. When considering the distortion to GDP figures, it is clear that this will have an effect on the figures for CO_2 intensity. Additionally, the figures may be distored to a different degree for state and private companies, with inflation of state revenue more likely than private revenue. This would have the effect of making state companies look more CO_2 efficient than they actually are, against the hypothesis of this study. Despite these possible flaws, it will still be possible to see a pattern of ownership and CO_2 emissions, albeit the differences between ownership forms will be reduced or exacerbated by the inflated GDP figures depending on the result. For example, if SOEs are less CO_2 efficient than POEs, the difference in coefficient is likely even larger due to SOE CO_2 intensity appearing lower with more revenue credited to SOEs.

The emission factors presented in Liu (2015) have faced significant academic critique are less reliable than the official IPCC emission factors due to the reasons previously discussed, therefore this study will employ only the IPCC emission factors in calculation of CO_2 on a regional basis.

Chapter 6

Methodology

This study will employ the following empirical methods to create and analyse the dataset of Chinese provincial CO_2 data.

6.1 Calculation of apparent fossil fuel combustion

The study will first calculate apparent fossil fuel consumption on the individual provincial level. This means that we take the estimated amount of fossil fuels burnt to derive our CO_2 emissions. The following model is used, taking data from the Chinese Provincial Statistical Yearbooks published by the Chinese National Bureau of Statistics for the years 2000 – 2012.

Apparent fossil fuel consumption = Provincial/Domestic production + Imports – exports + Moving in from other provinces - Sending out to other provinces – Stock change

An aspect not present in the statistics and therefore not present in this study is the amount of loss or wastage of fossil uels before they are combusted. This may mean the apparent CO_2 of all 29 provinces aggregated differs from the Chinese national total of CO_2 emission statistics.

6.2 Calculation of CO_2 emissions from fossil fuel combustion

Using the Intergovernmental Pannel on Climate Change (2006) methodology outlined below, emissions data are calculated using activity data from Chinese Provincial Yearbooks based on the combustion of three fossil fuels, using the apparent provincial combustion data obtained in 6.1.

$$E_{CO2,\ fuel} = \sum_{fuel} (FC_{fuel}\ x\ \ EF_{fuel}) \qquad (3)$$

$E_{CO2,\ fuel}$ is the total sum of CO_2 emissions from all fuels, FC_{fuel} denotes the total amount of each fossil fuel combusted in terajoules and EF_{fuel} represents the IPCC carbon emission factor of each fuel ($kgCO_2/TJ$). Table 6.2 shows the three fuels used for calculating CO_2 emissions in this study. These are raw coal, crude oil and natural gas, with the IPCC emission factors and the percentage of China's energy obtained from each fuel.

Table 6.1: Emission Factors and Energy Mix

Energy Type	IPCC EF Value	China Energy Mix
Raw Coal	0.946	75.9%
Crude Oil	0.733	19.7%
Natural Gas	0.561	4.3%

Source: IPCC (2006). China NBS. Author's Construction.

It is apparent from Table 6.2 that most of the CO_2 emissions in China were released by the combustion of raw coal. This is mostly used in thermal power generation, and therefore used in most industries, with energy intensive heavy industry contributing proportionately larger than service industries.

6.3 Regression

In order to separate out confounding effects and quantify the CO_2 emission differences due to ownership, this study will use the random-effects Generalised Least Squares regression method and STATA analysis software. The panel variable for this study is *province*, and the time variable is *year*.
To test the hypothesis, this study will use the following preliminary model:

$$Y\ CO_2Mt_{it} = \beta_0 + \beta_1\ Ownership_{it} + \beta_2\ Industry_{it} + \beta_3\ Population_{it} + \beta_4\ GDPpercapita_{it} + \beta_5\ Urbanisation_{it} + \hat{u}i$$

Where:
CO_2Mt is the total CO_2 emissions in million tonnes.
Ownership represents the persons employed in each ownership category in 10,000.
Industry represents the GDP of industry, ie. primary, secondary and tertiary in 100 million Chinese RMB.
Population is the number of inhabitants in 10,000.
GDPpercapita is the GDP of each inhabitant in Chinese RMB.
Urbanisation is the number of people in urban and rural areas in 100,000.
i represents the province and t represents the period of time being analysed.

Data is difficult to obtain for specific aspects required for the study, including data on urbanisation and percentage of GDP aquired from rural and urban business. Therefore, urbanisation will be in terms of population currently registered in particular urban or rural regions. Additionally, this may help to avoid multicolinearity problems with GDP variables, such as value of industrial production from each sector. This is because there will be no direct correlation between the variables, which may be the case if urbanisation was measured in GDP, the total of urban and rural GDP would equal the total of the three industrial sector's GDP.

6.4 Regression testing

In line with Gujurati and Porter (2009), the regression was performed using White's robust standard errors, a common feature of statistical software to correct for potential heteroskedasticity. These corrected standard errors are included in parenthesis below the coefficient in the result Table 7.1.

Using additional variables from the dataset the study has created, variables present in the model were swapped out for similar variables to understand if the effect upon the coefficient was large. An example of this is the removal of *Industry* total GDP, substituted for total number of people working in primary, secondary and tertiary industry for the 29 regions over the period of time. There was no significant change in coefficients for the dependent variable, signifying that the model is as well specified as possible in this study's time constraints.

Furthermore, regressions were performed using the original model and then adding additional variables to see if coefficients altered significantly. The dependent variable's coefficients did not alter significantly where variables were uncorrelated to the original variables. However, the coefficient of determination (R^2) did not increase and coefficients altered significantly where the newly introduced variables were correlated to the original variables. An example of this is where GDP of each industry, overall GDP, urban and rural population, population working in each industry and provincial population were added simultaneously. This suggests that, in this case, multicolinearity was an issue and therefore these variables were removed.

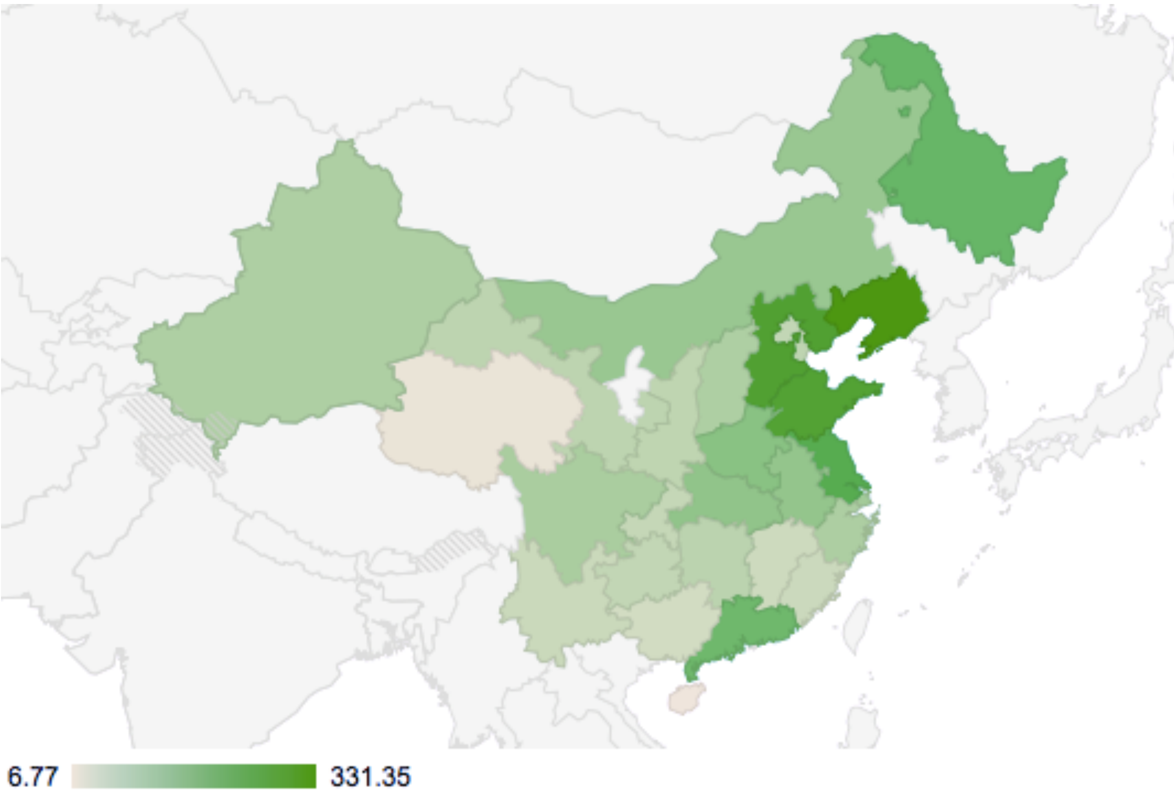
Chapter 7

Results

7.1 Regional level CO_2 emissions

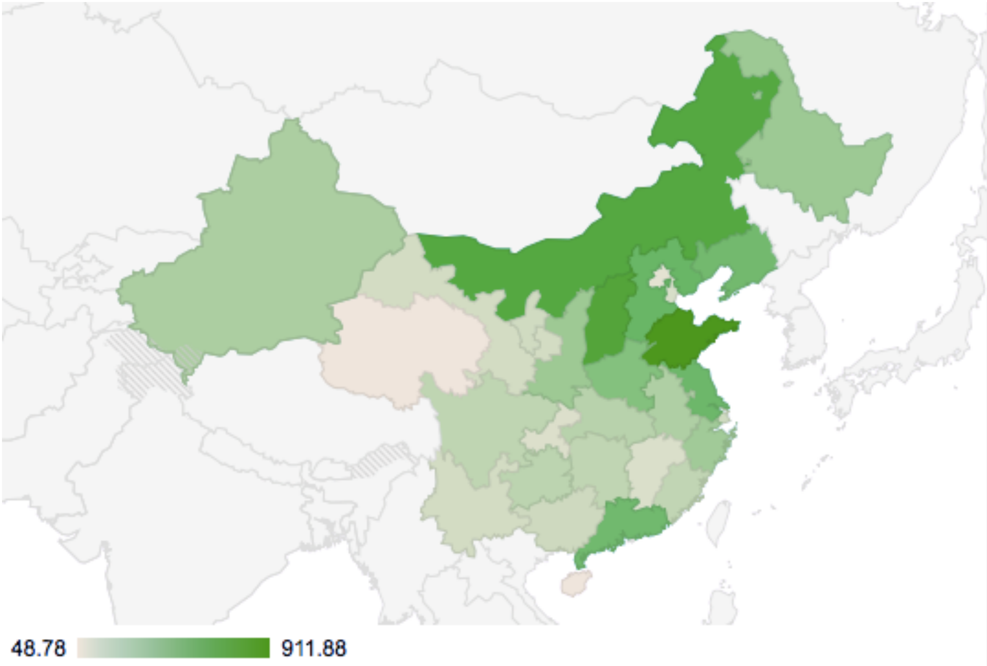
The heatmaps in Figures 7.1 and 7.2 show that CO_2 emissions have increased during the period 2000 – 2012 on the provincial level. However, it is clear to see that coastal regions around the Yangze River Delta are significantly cleaner than inland regions when taking into account GDP per capita as seen in Figures 7.3 and 7.4. That is to say, CO_2 intensity is much lower in developed coastal regions than industrially intensive inland and northern provinces. Whilst this CO_2 intensity is partly infrastructure dependent, controlling for province helps to minimize the effect captured in the results.

Figure 7.1: China regional CO_2 emissions 2000 (million tonnes/year)



Source: China Data Online (2001). Author's Construction.

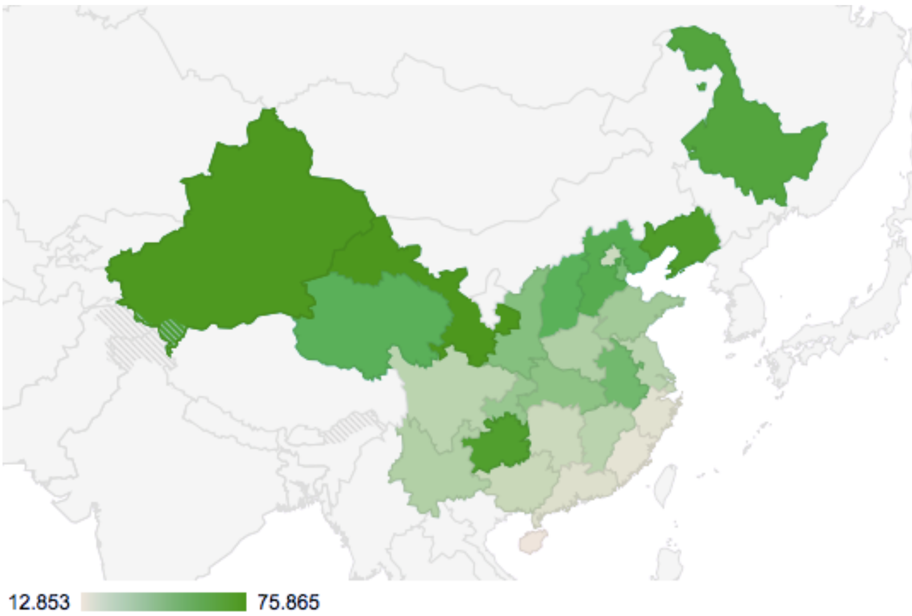
Figure 7.2: China regional CO_2 emissions 2012 (million tonnes/year)



Source: China Data Online (2013). Author's Construction.

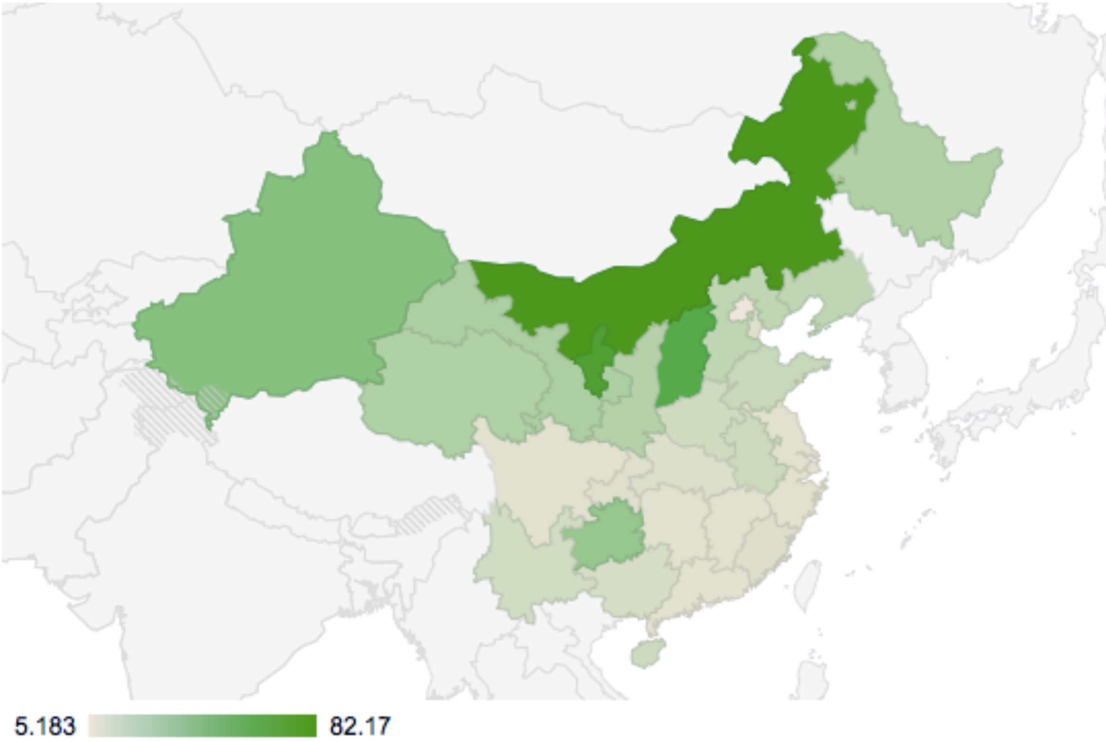
The CO_2 intensity heatmaps were produced by kilograms of CO_2 emissions per year of each province divided by the reported GDP of the province in 100 Chinese Renminbi (RMB) denominations. Thus, the darker the shade of green, the more kilograms of CO_2 are produced for each 100RMB of economic activity.

Figure 7.3: China regional CO_2 intensity 2000 ($kgCO_2$/100RMB)



Source: China Data Online (2001). Author's Construction.

Figure 7.4: China regional CO_2 intensity 2012 ($kgCO_2$/100RMB)



Source: China Data Online (2013). Author's Construction.

CO_2 intensity has decreased in a number of regions, due to the transitions shown in the LMDI decomposition Table in 3.1. Inner Mongolia was emitted from the year 2000 heatmap, due to the intensity being so high that it distorted the scale to the extent that all other regions were very light green indistinguishable from each other. It is clear to see in Figure 7.4 that Inner Mongolia is still the province with the highest CO_2 intensity, however it has greatly reduced from the year 2000 figure of 660.5$kgCO_2$/100RMB to 82.17$kgCO_2$/100RMB in 2012.

Upon a more detailed examination of Inner Mongolia's industrial structure and provincial level data in the Chinese National Bureau of Statistics, it is clear to see that the province's main sources of revenue are coal and metal mining. Heavy industry is concentrated in Inner Mongolia due to the abundance of coal, with the province holding one quarter of the world's total coal reserves (Jin, 2017). This resource abundance is a curse from an environmental perspective, however, Inner Mongolia's large plains mean that the province is now home to the largest wind farm in China (Jin, 2017). A full provincial map of China can be found in Appendix A, whereas the full numerical results of each provinces calculated CO_2 emissions from 2000 – 2012 is present in Appendix B.

7.2 Ownership and CO_2 emissions

The results of the regression show that, controlling for industrial sectoral differences, for every additional 10,000 people employed in state-owned enterprises an additional 0.4483 Mt of CO_2 is emitted. This is in comparison to the coefficients of 0.2013 MtCO_2 and -0.4213 MtCO_2 for *Private* and *UrbanCollective* respectively, however, *UrbanCollective* is not statistically significant. Therefore we do not reject the hypothesis that state-owned enterprises are more CO_2 polluting for equivalent activity than their privately owned rivals, with *StateOwned* significant to 10% and *Private* significant to the 5% level.

Table 7.1 Regression Results

Variable	CO_2 (Mt)
StateOwned	0.4483*
	(0.2646)
Private	0.2013**
	(0.0754)
UrbanCollective	-0.4213
	(0.4223)
Urbanisation	-0.0599*
	(0.0357)
Kg$CO_2$100RMB	0.1937**
	(0.0809)
PerCapitaGDP	-0.0002
	(0.0004)
PrimaryGDP	0.0450***
	(0.003)
SecondaryGDP	0.0228***
	(0.0032)
TertiaryGDP	-0.0122***
	(0.0035)
Constant	110.8068**
	(45.1199)
Observations	324
R^2	0.7613

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The result for urban collective enterprises shows that as employment increases the CO_2 emissions decrease from the constant. The result was not statistically significant and the robust standard error was very high in comparison to the coefficient, therefore making this result's validity questionable. Also a result of note is the contribution towards CO_2 emissions each industrial sector makes in terms of emission intensity. As previously discussed, primary and secondary industry are more CO_2 intensive per unit of economic activity than the tertiary sector, inline with the findings of Kander and Henriques (2010). This is reflected in the results, with all three coefficients being statistically significant to the 1% level. An increase of 10,000 Yuan GDP in tertiary sector actually reduces CO_2 by 0.0122 Mt in comparison to the constant.

The result for *Urbanisation* shows a negative coefficient of -0.0599, and is statistically significant to the 10% level. This shows that for every 100,000 people present in a province who are living in urban areas rather than rural areas, CO_2 is reduced by 0.0599 megatonnes. This equates to 59,990 tonnes of CO_2 or approximately 600kg reduction of CO_2 per person per year. This may be due to the fact that this study only captures fossil fuel combustion in a specific area, therefore urban areas appear lower since the combustion was not in the urban area. As an example, an urban dweller buys a car and lives in an apartment with an efficient heating system, heating the whole building. The consumption of energy is lower due to the heating system being more efficient than may be found in urban houses, and the consumption of energy and therefore CO_2 captured in the car is registered to a highly rural region which manufactured the car, thus not appearing on the urban register.

Data reliability concerns were raised in section 5.4, but even when taking into account the potential for distortion towards making SOEs appear more efficient, state-owned companies are still less CO_2 efficient than private companies. This means that if economic data was accurately reported, the difference in coefficient between state and private ownership may be even larger.

The R^2 of the model is 0.7613, meaning that 76.1 percent of the variation in provincial CO_2 is explained by the variables in the model. Due to constraints in data collection, average annual temperature was omitted from the model because the data was not available in a majority of the provincial yearbooks.

Chapter 8

Discussion and Implications

At the beginning of this study it was hypothesised that CO_2 intensity would be higher for state-owned businesses than privately owned businesses. The results indicate that indeed, the CO_2 intensity of state-owned firms is higher than privately owned firms for equivalent economic activity, controlling for industrial sectoral differences. Urban collective companies show a negative coefficient, but not statistically significant.

For policy-makers within China, the result of the study is supportive in the ongoing transition towards a free market and reduced government ownership, but given China's starting position in the 1950s as a nation lagging behind world progress, this may mean the rest of the developed world may not experience the same results. Perhaps the CO_2 reductions of private industry transition is one of the advantages of backwardness theorised by Gerschenkron (1962), whereby SOEs in China have been so ingrained in the business and political culture of the communist country that there are reduced incentives for progress for these state owned entities. Now private companies in the Chinese context can leap forwards with technological adoption and efficiency improvements, far more agile and dynamic than their state-owned counterparts.

If China were attempting to vastly reduce their CO_2 emissions, this study shows that a further reduction in activity in the heavy industry sector would help CO_2 mitigation, or a further shift to cleaner industrial structure as demonstrated in the LMDI decomposition earlier in the study. Additionally, given the vast foreign exchange reserves currently under Chinese government's control amounting to \$2.5 trillion (Dollar, 2013), and an abundance of rare-earth metals required for solar panel production, China could reduce coal burning and roll out large solar farms and other renewable energy plants to more provinces. This is similar to the Inner Mongolia provincial development, whereby this study shows CO_2 intensity has reduced drastically on the provincial level, and the province is now home to the largest wind farm in China (Jin, 2017).

Chapter 9

Conclusion

China has become an economic powerhouse with an ever increasing trajectory of economic growth. It has also become the largest emitter of CO_2 emissions in the world, and as more and more of the 1.3 billion population enter the labour market and increase consumption, CO_2 emissions will only increase. As previously explained, policy-makers can counteract this increase by creating a framework to encourage more efficient production methods, requiring less energy. This could be an adoption of new technology or development of human capital and a continued shift into high-tech and knowledge based manufacturing., the state can actively reduce CO_2 emissions directly by moving to cleaner, albeit more expensive energy sources such as solar power and cleaner coal, as it has been doing.

Research has shown that the fiscal federalist system employed by the Chinese government has led to economic prosperity, and this study has shown that further reducing the role of government in production would also decrease CO_2 emissions. The problem for the Chinese government is that they are still a communist nation, and must maintain a discourse of socialism. Selling state production and relinquishing control of profit making state owned assets into the hands of private owners is a hotly debated topic in Europe, and may experience fierce resistance in China.

As is the case with China's transformation since 1978, a majority of the positive changes implemented in the Chinese context have arisen from need and a pragmatic approach from central government. As CO_2 emissions and other harmful greenhouse gas emissions become an ever increasing issue, perhaps the government will be forced into taking politically unpopular steps to address the issue. How Chinese policy-makers choose to balance the need for a perpetually expanding economy in order to remove people from poverty, with inherent ecological limitations remains to be seen, but going forwards they have the financial ability in the form of their \$2.5 trillion foreign reserves to fund clean technology and clean energy generation on a scale no other nation can possibly match.

9.1 Weaknesses of the study and potential for future research

As previously identified in Chapter 5, section 5.1, this study does not account for spatial spillover effects of energy production and consumption when determining Chinese provincial CO_2 emission figures. A way to alleviate this concern would be to perform a spatial based input-output structural decomposition analysis to determine trade flows. This would allow the data to be corrected and therefore give a more accurate picture of CO_2 production and energy consumption at the provincial level, making the analysis of the effect of ownership more accurate.

As discussed in section 5.4, the reliability of Chinese data is questionable and thus the results are distorted to an unknown degree. Employing a firm level dataset with emissions and ownership as variables for this study would greatly enhance the accuracy of the results if the dataset were large enough, with sufficient observations across China's provinces. This would allow us to undertake our study showing direct links between ownership and CO_2 emissions. The firm level data is collected by the Chinese Ministry of Environmental Protection (MEP) for a large number of business, both privately owned, collectively owned and state-owned. Due to language constraints and lacking the legal right to use the data, this study was unable to utilize the MEP dataset for analysis and publication.

Some additional variables would be desiarable for inclusion in the study, these include average temperature of the province in order to explain some of the energy consumption which may go into heating or cooling. Additionally, a more defined figure on urbanisation would be desirable, however, as shown in a number of studies previously mentioned, the increase in consumption from wealth and decrease in consumption from efficiency roughly balance in the Chinese context.

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Appendix A

Chinese provincial map

Source: http://www.chinadiscovery.com/china-maps/china-provincial-map.html

Appendix B

Table of estimated provincial CO_2 emissions 2000 – 2012 ($MtCO_2$)

Province	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Beijing	71.60	69.23	69.60	73.72	55.77	102.42	84.61	85.15	94.50	95.49	93.27	91.13	92.67
Tianjin	77.98	76.50	75.53	77.97	88.40	91.99	95.56	96.46	92.94	96.45	129.12	141.75	137.45
Hebei	293.52	298.05	303.67	331.16	381.37	396.50	407.05	457.04	451.44	468.64	492.89	533.12	566.41
Shanxi	101.45	104.50	219.56	328.13	347.17	295.56	322.87	245.71	460.74	566.43	603.58	680.40	764.50
Inner Mongolia	131.27	136.44	141.80	134.41	226.82	247.33	287.03	343.69	416.88	449.54	513.24	666.49	733.71
Liaoning	331.35	308.11	332.16	352.34	400.78	407.67	439.61	438.08	433.36	451.11	480.85	495.03	529.94
Jilin	110.55	116.32	112.95	123.98	133.88	146.22	168.79	168.49	182.54	187.93	202.83	234.49	238.69
Heilongjiang	201.22	188.21	180.86	187.68	215.79	234.39	244.64	237.91	236.88	267.49	324.11	345.94	364.28
Shanghai	117.25	122.49	122.28	136.88	152.15	146.11	146.21	141.40	147.32	143.81	158.30	166.12	172.73
Jiangsu	240.07	235.92	236.29	269.33	326.12	370.48	413.16	435.08	424.68	440.20	478.83	534.76	551.54
Zhejiang	102.56	156.06	161.87	180.19	236.68	249.32	291.61	320.20	308.83	319.36	332.79	351.94	351.48
Anhui	139.50	143.17	137.22	153.64	172.23	165.77	185.52	194.91	220.06	244.86	238.97	262.07	297.30
Fujian	58.53	56.53	62.47	74.26	89.31	93.81	108.75	124.51	119.04	144.12	171.82	198.96	226.85
Jiangxi	55.94	56.11	55.47	66.09	83.30	81.81	94.25	99.72	99.46	97.34	108.22	114.76	128.26
Shandong	288.34	332.20	356.36	431.83	540.51	637.77	741.35	778.31	790.57	829.01	837.90	871.22	911.88
Henan	154.85	167.41	164.76	237.59	247.83	332.88	350.21	394.06	298.11	425.14	496.19	558.98	463.51
Hubei	143.24	138.91	138.63	153.36	176.22	159.46	196.22	209.21	193.55	208.54	236.80	270.96	261.48
Hunan	82.11	87.15	95.84	104.49	117.87	160.76	182.37	200.21	179.25	185.37	192.07	223.91	231.67
Guangdong	193.74	195.72	204.47	227.64	263.33	258.99	302.01	329.24	318.21	372.80	432.76	486.67	534.60
Guangxi	49.18	45.46	37.89	45.53	66.85	62.93	74.19	86.13	67.91	89.74	116.76	149.88	177.15
Hainan	6.77	6.95	0.00	9.91	8.93	6.57	14.00	36.38	35.34	37.31	42.30	46.34	48.78
Chongqing	67.22	60.37	57.91	53.11	64.11	69.06	81.55	89.14	110.16	122.07	114.21	123.88	121.79
Sichuan	107.70	106.46	115.22	150.46	175.82	152.32	164.89	205.72	217.26	241.04	228.44	221.69	233.45
Guizhou	71.72	62.08	71.75	116.98	131.65	143.21	171.73	164.76	185.79	211.32	215.10	228.92	244.41
Yunnan	60.48	64.59	64.16	83.55	59.75	118.64	138.16	135.63	136.15	145.30	145.08	151.56	156.67
Shaanxi	77.26	76.65	89.62	97.40	125.85	217.55	194.36	233.25	266.26	248.95	277.55	304.61	361.20
Gansu	79.88	81.58	84.50	95.93	109.27	104.42	114.20	123.90	124.26	120.37	133.48	154.25	157.26
Qinghai	14.51	17.51	17.52	19.52	20.77	21.25	25.30	25.91	31.50	33.26	32.74	44.01	50.70
Ningxia	0.00	0.00	0.00	39.91	65.99	74.21	85.17	102.68	105.26	133.03	135.31	169.15	169.82
Xinjiang	101.10	104.72	100.26	110.56	133.63	136.60	160.10	165.55	182.53	212.59	228.53	267.14	309.45