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# The economic impact of China's "New Normal" environmental policy

by

Shengtong Wang

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# Abstract

Over the past decades, China's economy has been growing rapidly. The continuous years of double digit GDP growth has made China one of the world's biggest economies. However, with economic development at such high speed, the limitation of previous developments started to emerge, such as high $CO_2$ emissions, pollution problems, a heavy industry dependent economy, a coal based energy system, etc. Chinese leaders in the past years have started to refer to the "New Normal". With this they mean that China is moving to a new model with a better quality of economic growth, by combining structural improvements and policy instruments towards energy use, environment and economic development. If followed up, the "New Normal" is a grand shift in policy that has not only Chinese but also global implications that should be investigated further. Therefore, this research traces the origins of the "New Normal" trend, looks at what the main characteristics and targets of the "New Normal" approach are, calculates the potential impact with a focus on China, and aims to indicate likely implications in practice. We employ one of the best models available to date to look at this kind of question: the E3MG model, whereby E3 stands for 'energy-environment-economy'.

The E3MG simulation suggests that the "New Normal" policy will indeed achieve ambitious GHG emission and environmental goals: GHG emissions would decline by 18.6 percent and energy consumption by 10.1 percent. The energy and environmental results have implications for the economy, however. GDP in 2030 will be 2.8 percent lower than without the "New Normal". Decoupling of growth from emissions through more R&D would therefore be an important flanking measure the Chinese government could push for next to the "New Normal". Consumption is expected to be 6.8 percent lower (due to higher prices by 6.8 percent). Exports will decline slightly (0.4 percent) while imports remain at the same level. Interestingly, investments are expected to decline only by 0.3 percent and employment by only 0.1 percent. If investments and employment only drop marginally, it implies that both shift away from heavy industries (that are taxed under the "New Normal") but do not leave China. Rather they shift towards other sectors – like services sectors or other manufacturing sectors. The same goes for employment. This implies that the "New Normal" policy has a structural adjustment consequence away from polluting towards cleaner sectors as engines for economic growth. Also it implies that it does not lead to a big drop in aggregate demand. That means that the "New Normal" is indeed potentially a true sustainable growth strategy.

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## List of Abbreviations

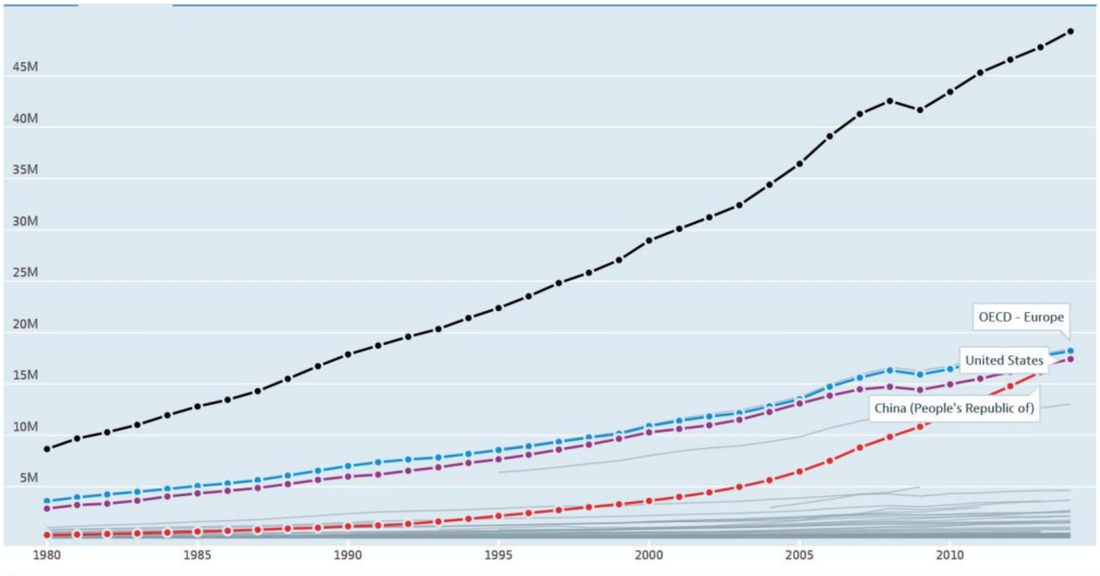
| | |
|---|---|
| AMECO | Annual macro-economic database of the European Commission's |
| Bn | Billion |
| CCA | Climate Change Agreements |
| CGE | Computable general equilibrium |
| $CO_2$ | Carbon dioxide |
| DOS | Disk Operating System |
| E3 | Energy-Environment-Economy |
| E3MG | Global Energy-Environment-Economy Model |
| Em | CO2 emissions |
| En | Energy Consumed |
| ESA95 | European system of national and regional accounts |
| EU | European Union |
| GDP | Gross Domestic Product |
| GHG | Greenhouse gas |
| GVA | Gross Value Added |
| IDIOM | International Dynamic Input-Output Modelling |
| IMF | International Monetary Fund |
| INDC | Intended Nationally Determined Contribution |
| M | Million |
| MT | 1000 kilograms (metric tons) |
| Mtc | Million tonnes of carbon |
| NACE | Statistical classification of economic activities in the EU |
| OECD | Organisation for Economic Co-operation and Development |
| Ox | Object-oriented statistical system |
| Pa | Per annum |
| Pb | Per barrel of oil equivalent |
| PRC | People’s Republic of China |
| R&D | Research and Development |
| STAN | Structural analysis |
| Toe | Tonnes of oil equivalent |
| US | United States |

# 1. Introduction

## *1.1 General context*

During the past decades, China' economy has been growing at a high speed (often higher than 10 percent). This booming economic growth was based on the economic strategy that focused on big investments, high exports and high energy consumption. With this strategy, China has completed its transformation from a country with lagged economy to a country with an enormous size economy today. While Chinese citizens enjoy the benefits of economic growth, the negative side of this success is that also vulnerabilities became clear: high levels of pollution, an underdeveloped industrial structure, and high greenhouse gas emissions. These have started to attract more and more public attention.

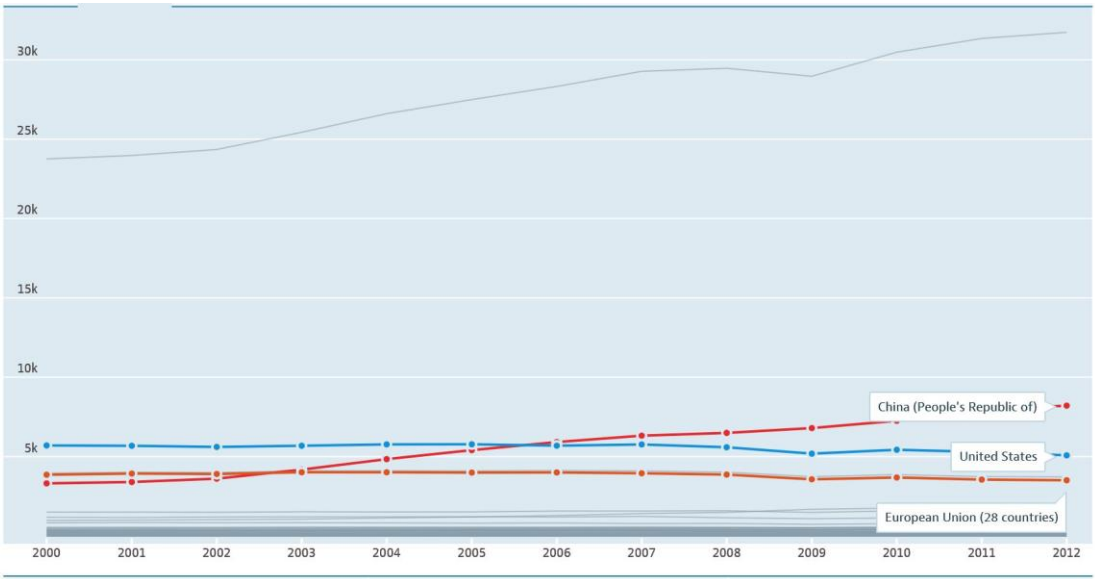
Figure 1 China's GDP (Million US dollars) from 1980 to 2014




Source: (OECD, 2015)

As President Xi stated in late 2013, China's current growth model is "unbalanced, uncoordinated and unsustainable". China's energy resources and industrial production is highly dependent on coal-fired power. The rapidly increasing number of cars not only caused traffic congestion but also produced significant amounts of GHG emissions. It has been pointed out in several government conferences that China's environmental bearing capacity is close to its upper limit. The investment driven growth has caused overcapacity and led to worsening levels of competitiveness. Meanwhile, China is losing its cheap labour advantage due to the increasing wages and the changing of population structure. Moreover, the Chinese population is ageing. Additionally, China's energy resources are more and more relied on import and the resources storage level per capital is extremely low, which means that the cost for energy consumption in future will increase.

*Figure 2 China's CO2 emission (Million tonnes) from 2000-2012*




Source: (OECD, 2015)

As we can see from the figure above, China's CO2 emissions exceeded EU's in 2003, and exceeded US's in 2005. China is now the biggest CO2 emitter in the world. Thus, China's CO2 emission reduction is of vital importance for the world and for the country itself.

Considering the above challenges, a new and better structured development model also known as China's "New Normal" has been introduced. The "New Normal" is a development model introduced by the Chinese government in order to achieve a better quality growth in the future, with emphasis on natural environment, structural upgrading, energy consumption and efficiency. The "New Normal" is a development strategy which is still under development now, which means new policy instruments and goals are still being added to this strategy. At this moment, for example, it contains policy instruments such as higher tariff rate on coal import to shift the energy consumption from the traditional coal-fired model to a more sustainable one, shifting the high investment in heavy industry to other sectors such as service industry. Meanwhile, in the coming 5 years, the "New Normal" aims to slow down China's GDP growth to leave more space for achieving the goals but keep the rate around 7 percent, which is still a dynamic growth. With the implementation of specific policies related to pollution, energy use and industry upgrading, etc. China's new development strategy is expected to keep the speed of economic growth at an active rate and – at the same time - limit the GHG emissions to manageable levels in order for China's GHG emissions to peak no later than in 2030.

When thinking ahead, the current and upcoming policies in terms of the "New Normal" should be in line with future targets. The official Chinese targets regarding future GHG emissions and clean energy deployment released by Chinese government are the following:

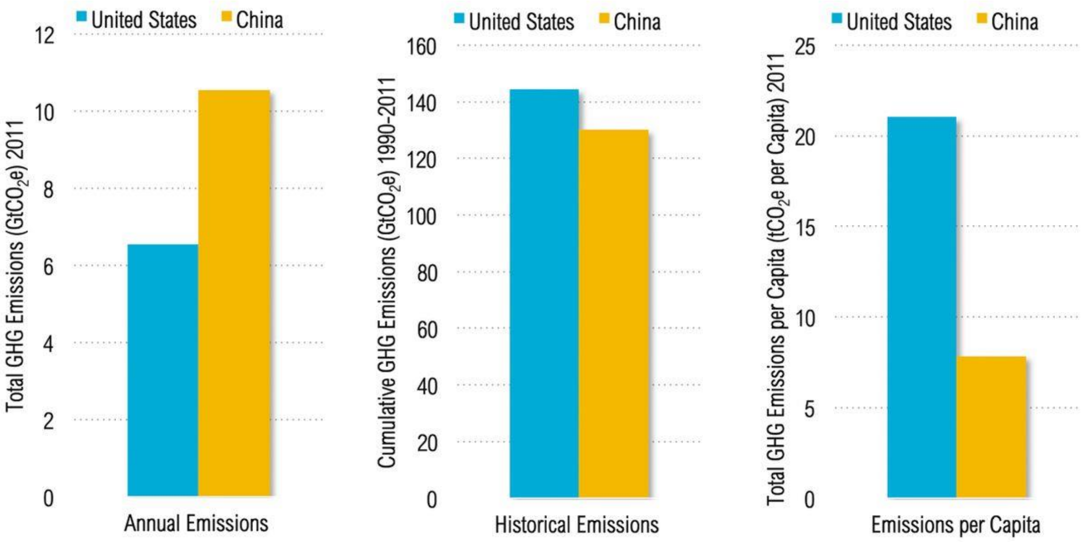
"Cut China's CO2 emissions per unit of GDP by 60-65 percent from 2005 levels by 2030. (The Climate Group, 2015)"

"Let carbon dioxide emissions peak around 2030, with the intention of peaking even earlier. (Office of the Press Secretary, 2014)"

"Raise the non-fossil fuel share of primary energy needs to around 20 percent by 2030" (Xinhua, 2014a) and to around 15 percent by 2020 (State Council, 2014), up from around 10 percent in 2013 (Office of the Press Secretary, 2014)"

Apart from those listed above, targets such as upgrading traditional industries also have been mentioned. Nevertheless, the "New Normal" is a long run plan which means the results of it will be seen only many years later – which is always subject to uncertainty. This research is focused on measuring the possible future impact of current and potential policies already voiced today and analysing the deeper meaning behind the policies from a practical perspective in order to make policy recommendations.

Figure 3 Emissions in China and the United States




Source: (World Resource Institution, 2014)

### *1.2 Research objectives*

This research aims to measure the potential impacts of the “New Normal” policy within the economy, environment and energy scope. The research takes the latest policy changes into consideration, including policies designed to promote the “E3” changes (energy, environment and economy), policies may have an impact on “E3” changes and policies in line with the “New Normal” policy as a whole. These policies challenge the existing development model by setting regulations, energy prices, giving incentives, levying tax, etc., and it means the future development model is incentivised to be more environmental friendly, technology oriented and less labour and environment-polluting energy intensive. Possible impacts can be found in the future in terms of economics and labour markets, energy consumption and emissions. This research studies the announced policies to then ‘translate’ them into quantitative input for the E3MG model. The E3MG model stands for energy-environment-economy model at the global level. In order to further derive the outputs, which include a range of economic and labour market indicators, plus indicators for energy consumption and emissions. By processing the inputs extracted from the “New Normal”, the indicators state above will be provided by the E3MG.

Thus, the main research question that needs to be answered in this study is the following: “What is the potential impact of the “New Normal” in terms of energy, environment and the economy?”

The main thinking behind this research question is that the change in the existing development model will lead to a significant shift in energy deployment, the driving force for economic growth and environmental protection. We proxy environmental impact by looking at CO2 emissions and the new compound ratio of energy consumption between different types of energy sources. We capture the macroeconomic impact of the “New Normal” by looking at the impact on GDP growth, and sectorally, we look at sectors that win and that lose – for all industry sectors that the E3GM model covers.

In order to sufficiently answer the main research question, there are several sub-research questions that need to be addressed:
What is the “New Normal” in practice?
How do the “New Normal” policies affect the existing Chinese development model?
What model can we use best to look at energy, environmental and economic impacts of the new Chinese policy?
How can we measure the potential impact of the “New Normal” with the model?

### *1.3 Relevance*

China as one of the world's biggest economies and also the world's biggest GHG producer, has a profound impact on the world's future situation, both economically and environmentally. Over the past decades China's economy has grown at a high speed. The fast growth of China's economy has had a positive influence on both the world economy and the living standard of the Chinese as well as the living standard of other people in the world. However, the past high-speed growth was based on an economic growth model that has come at a significant environmental cost. Nowadays, China is facing fierce challenges related to its traditional economic growth model while the pressure from the global community to act responsibly by limiting GHG emissions is mounting. In order to get over this developmental bottleneck, a new economic growth model has been introduced by the Chinese central government headed by Chairman Xi Jinping.

The "New Normal" aims at constructing a sustainable model for economic growth, which may also alleviate environmental pressures while stimulating economic growth by technology driven factors. The "New Normal" has become visible in a series of policy changes towards macro level indicators, environmental goals and regulations. Also some policies are undergoing and/or are expected to be implemented in the near future.

With the implementation of these policies, potential impacts will affect the future. This may be vitally important for both China and the world. In this research, potential changes will be measured with a global macro econometric model, namely the E3MG model. In the methodology section of Chapter 3 we will explain the E3MG model further. By applying this model, the impact of new policies can be measured in three dimensions:

- Environmental impacts that indicate expected GHG emission, energy prices, etc.
- Macroeconomic impacts that reveal potential macroeconomic indicators including GDP, profits, incomes, etc.
- Sectoral impacts that indicate potential "win and lose" situations of targeted industrial sectors.

With the results of this research, the potential impact of the "New Normal" will be revealed and possible policy recommendations can be made on the basis of those results. Considering the importance of the future situation that current policies would lead the country and world to if not changed, we are looking at a highly relevant and important (global) issue.

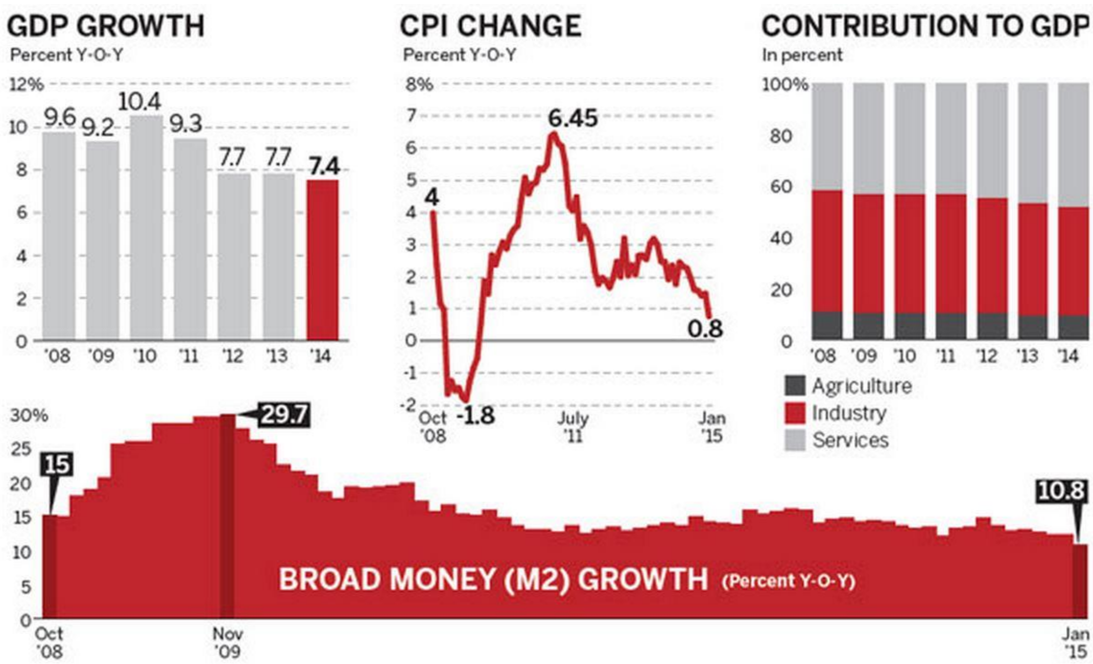
## *1.4 Thesis structure*

Chapter 2 will describe the situation today, focusing on illustrating the challenges and problems in the existing Chinese economic development model. Furthermore, we will introduce the notion of a policy shock that we will call China's "New Norma", focusing on the goals and plans of this new develop model. Chapter 3 will employ the E3MG model to generate output indicators of the "New Normal". This procedure includes data preparation and model adjustment. In chapter 4, the result will be presented and analysed. Comparison of results will be made between the "New Normal" situation and the situation without the "New Normal". In the last chapter, summary will be made towards the main findings of this research and implication of the listed findings will be illustrated. Furthermore, it will provide possible policy suggestions and suggestions for future research.

## 2. China’s “New Normal”

This chapter will provide the background information of China’s “New Normal” and theoretical foundation for the E3MG analysis carried out in this study. Section 2.1 provides information on the historical development of China after 1949 with respect to its policy emphasis and characters. This section is aimed to provide a review of China’s historical policies and periodic characters during the command economy era. We do it because China is the only country that developed along a socialist path and has a dynamic economy at present. Looking back at history, it helps to understand the reasons for the formation of China’s modern development model. Section 2.2 describes the legacies of the socialist era so many origins of China’s success, challenges and problems after 1987 (market reform) can be found in these historical legacies. Section 2.3 points out the challenges and problems in China’s latest situation. Section 2.4 explains the “New Normal” strategy including its goal and plan.

*Figure 4 The trend of China’s “New Normal”*




Source: (Wind Information, 2015)

### *2.1 China’s development from a historical perspective*

China’s development has experienced several different times. It can be categorised into mainly three stages, “Big Push”, “Command Economy” and “Economic Reform”.

This section will introduce the development model applied during each stage with an emphasis on development policy. In this section, the last stage “Economic Reform” will be studied in a more detailed way compared to others, since it is the model that China follows at this moment. The other two stages called “Big Push” and “Command Economy” are discussed because the development strategy during these years had a profound impact on China’s development structure of today. Many features of China’s modern development model have been formed during those stages and affected it in one way or another.

### *2.1.1 The Socialist Era, China’s policy from 1949 - 1978*

“After 1949 when the People’s Republic of China (PRC) was established, a socialist heavy-industry-priority development strategy has been introduced to China. (Naughton, 2006)” China’s economy and development model we completely reoriented and its traditional framework of household-based economy structure was replaced by a massive socialist industrial model controlled directly by government. (Naughton, 2006) Instead of making the best use of China’s large population in labour-intensive sectors, the new leaders decided to pour large amounts of resources into factories which were resource and energy consuming. (Naughton, 2006) All these inputs were dedicated to production of metals, machinery and chemicals. (Naughton, 2006)

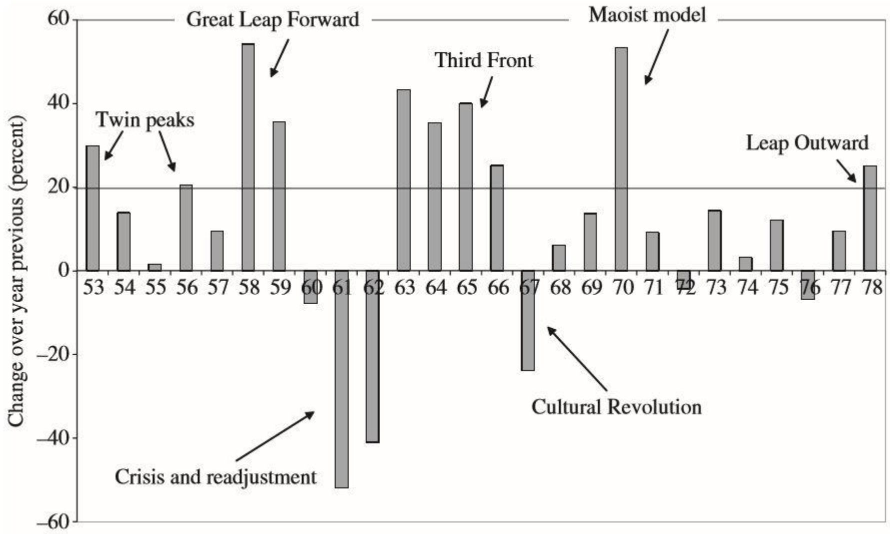
China pursued the socialism goal for over 30 years and the development model was named “Big Push Industrialisation. “By giving priority to achieving high industrial goal, the “Big Push” model invested mainly in heavy industry. (Naughton, 2006)” This character can be seen from the allocation of resources.

During the “Big Push” time, consumption was limited due to the industry-oriented strategy. Contrary to consumption, government controlled investments boomed significantly, pushed beyond 25 percent of national income. According to Naughton (2006), the world investment rate started to increase since 1950. However today investment rate for poor countries is around 20 percent on average. By 1954, still as a poor country, China’s investment rate accounted for 26 percent of its GDP. And these investments were mainly made into the construction industry. As a result, it is understandable that China’s industrial output grew at an average annual rate of 11.5 percent from 1952 to 1978 (Naughton, 2006). Furthermore, “the share of GDP for industry increased from 18 percent to 44 percent, while agriculture’s share declined from 51 percent to 28 percent. (Naughton, 2006)” With these efforts, China’s economy started to set off. During this period of time, financial flows were also controlled by the government from the top, a state owned banking system, which meant that financial flow was allocated to support the strategy, including prices, profits, money, and banking. China's economy, energy and environment condition later on was also shaped by this strategy.

### 2.1.2 Policy instability

Since 1949 China has gone through some major policy changes. Due to the various revolutions and political turnaround events, China as a country where power is highly centralised, saw power clusters apply their favourite policies (for a certain period) once they won power. That is why many economic and other policies were driven by politics and political change.

*Figure 5 China's historical growth of investment*




In the next few sections, a narrative of policies during 1949-1978 will be made with the emphasis on economic changes. The research will downplay the politics factor in order to highlight the economy, energy and environment aspects in line with the main research question.

### 2.1.3 Economic Recovery 1949 - 1952

As it has been discussed before, China's new leader committed to build socialism in China. This meant that Soviet Union's economic model was copied and applied in new China. In fact, for China at that moment, the problem was neither how rapidly should Soviet model be built nor to what extent it should it be applied. After many years of war, China was facing fierce economic problems and challenges. Industry and agriculture were substantially damaged by war. Due to the Korean War in 1950, China's relationship with the Soviet Union became closer.

The ideology of the new leaders was achieved in a highly effective way. It was followed by several policies in different sectors. Firstly, in 1950 land was redistributed to farmers by a land reform. At that moment, the land was still owned by private owners. The previous poor peasants were given more land to work on and therefore had more motivation to cultivate. Because of the land reform, 3 billions of poor peasants who had no farm land or little farm land gained almost 0.5 billion hectares of farm land and means of production. (Han, 1966)

By 1953, farmland ownership was transferred from the private agricultural sector to the government. As compensation and as a support incentive, rental costs in the form of 30 million tons of grain were eliminated. With this policy, the new government won public support, especially from the people at the grassroots level. This policy built a solid basis for agriculture and effectively improved China's financial situation. Furthermore, improvement in the agricultural and financial sectors provided a guarantee of resources and consumer market for industrial products.

During the same time, the new government rebuilt many factories. The policy towards industry was very open. Capitalists were encouraged to expand their production at their own factories if they wanted to stay in China. Many of them who worked for the previous Nationalist government chose to keep working for the Communist government with the same capacity. Intellectuals and scientists took initiatives to contribute their intelligence and skills for industry construction and production. (Perkins, 1975)

Because of these efforts, China's industry revived rapidly. The North-eastern part of China was the origin of heavy industry of the new China, and also played a critical role in the "Big Push". This region became a model and experimental example, and socialist industrialisation was spread across the whole country from the North to the South.

### *2.1.4 The First Five-Year Plan 1953 – 1957*

The period from 1953 to 1957 saw the first Five-Year Plan, launched by the Chinese government. During this period, adjustments to previous policies had been made in terms of the emerging problems. Just like what had happened in the Soviet Union in the past, supply could no longer satisfy the demand for products. The reason for this was – like in the Soviet Union – that equal pay, no private reward incentives, and egalitarianism eliminated the drive to stand out and excel and to work efficiently. The consequence was a strong decline in output over time.

These challenges put great pressure on the policy makers and finally the leaders made a decision to introduce a complete change of the policy. In the Eighth Congress, an economic moderation programme was adopted. The policies started to move away from the Soviet Union model and to paid more attention to the market-oriented mechanism. Different types of ownership were openly discussed and approved.

This new policy change was actually a promising one, it brought significant economic growth and industrial production expanded by 17 percent annually during the period of 1952 to 1957. (Naughton, 2006) Thanks to one of the new policies called “Hundred Flowers”, which encouraged culture, knowledge and technology development, a basis for sustained future growth had been built. Large investments were made into education and training. As a result, more citizens had an opportunity to go to schools and to study at the universities. Many peasants moved from their villages to cities to work and live there, which meant that the pace of urbanisation picked up significantly.

China at that moment, almost succeeded in finding its own way of socialism. However, the situation started to change soon from success directly to disaster. This happened as a result of a U-turn in economic policy, called the “Great Leap Forward”.

### *2.1.5 The Great Leap Forward 1958 - 1960*

In the middle of 1957 an “Anti-Rightist Campaign” was launched by the leading rulers of China. This was recognised as a political event aimed to condemn all those people with a different idea towards the direction of development of the country. A lot of resources went to industry rather than agriculture, and the following production trends, both in agriculture and industry, were unfavourable. People were encouraged to set very high goals in breaking the production limits regardless of the resource constraints. A lot of amazing figures on industrial outputs and agricultural outputs were released in newspapers as a result of competition and showing off between different local governments.

Most of the news releases by different local governments sketched a very rosy pictures of output increases of steel and grain harvests. This news was barely true nor accurate. However, ironically, the central government was not fully aware of the situation, and decided – as a consequence of all this optimistic news – to reduce the investments in production, while demanding an increase the quantity of produce collected from the local governments. (Han, 1966)

The unbalanced allocation of resources and labour led to a tragic result. Agricultural output reduced sharply, especially grain output. Industrial production chased the unrealistic goal which stated “Surpass Britain in 3 years and catch up with the United States in steel production.” Workers pursued this goal blindly, many farmers abandoned their land and went to steel production. As a result, steel output increased but most products were junk products which could not be further used due to their low quality. “In 1959, a famine happened. It lasted till the end of 1961, about 25-30 million people died due to the great Chinese famine. (Naughton, 2006)” “The famine lasted for 3 years and was recognised as the largest famine of the twentieth century, anywhere in the world. (Naughton, 2006)”

*Figure 6 The famine in China after the “Great Leap Forward” movement*


Suffering during the famine, the tragedy left a painful memory in the minds of the Chinese people. In the rapid growth after 1978, the Chinese society did not pay much attention to the environment, growth quality of economy. Most people cared more about accumulating their own fortunes regardless of any other side-effects to the society. Significant investments in real estate ramped up housing prices. Factories (especially privately owned factories) generated revenues, but at the same time they were releasing a lot of pollution into the atmosphere and water. This focus on fortune, growth and neglect of the environment may might find their origin (in part) in the disastrous famine of 1958-1960 period.

### 2.1.6 Policy Adjustment 1961 - 1963

In the beginning of 1961, central government realised the situation and the importance of making policy adjustment. Later on, 20 million labour forces moved back to agricultural production from the industrial sector. Finance allocation also moved back to rural areas for grain production. These phenomenon was the consequence of policy adjustment led by central government.

Unfortunately, the Culture Revolution started in 1966 and China was caught in 10 years of great calamity.

### 2.1.7 The Cultural Revolution 1966 – 1976

In 1966, the Cultural Revolution began. It was a complex movement which, even nowadays, is not an open topic in China. In this section, we do not discuss it in detail but list the effect of the Cultural Revolution for the economy. Since many non-economic factors are involved, it goes beyond our research to look at various other dimensions of the Cultural Revolution.

From 1967 to 1976, total industrial and agricultural outputs increased by 7.1 percent per year on average. (MacRarquhar, 2006) Total production of Chinese society (i.e. National income growth) increased by 6.8 percent on average. (MacRarquhar, 2006) Compared to the year 1966, for the main products large increases were found: steel output increased by 33.5 percent, coal output increased by 91.7 percent, crude oil output increased by 499 percent, amount of electricity generated increased by 146 percent, agriculture fertilizer production increased by 117.7 percent, plastic output increased by 158.2 percent, textile increased by 20.9 percent, grain output increased by 33.8 percent and oil corps increased by 61.6 percent. (MacRarquhar, 2006)

From 1966 until 1978, the crude oil yield increased with an average rate of 18.6 percent. In 1978 the 1 billion-ton mark was passed. China, as a country with a lack of oil became the world 8th oil producing country, the total output increased 5 times compared the level of 1966. (China Statistical Press, 1994) Number of workers grew from 11295 thousand to 32565 thousand, which showed a 2.46 times increase. (China Statistical Press, 1994)

After 1972, Mao Zedong and Deng Xiaoping approved a finance plan called “Plan 43”, investing billions of dollars and 20 billion of RMB in modern factory construction. (MacRarquhar, 2006) 26 large sets of complex facilities and related techniques were imported from foreign countries, dozens of big companies were set up in such sectors as oil refining, mining, fertilizer producing and textile. It basically satisfied China’s demand in these industrial sectors and built up solid basis for the future development. (MacRarquhar, 2006)

During these 10 years, the economic, industrial and agricultural development did not stagnate because of the Cultural Revolution – surprisingly enough the opposite happened. And all the development determined China's future energy, economy and environment trend in a way. However, it is worth to mention that culture, education and also people's mentality were seriously destroyed by the Cultural Revolution, which had a negative influence on China's future technology, industry structure and even focus on environmental protection.

## *2.2 The effects of the Socialist Era*

*1. Impact on future policy making*

The socialist policies built centralised systems and strategies which poured most resources into industrial construction and production to achieve maximised level of industrial output. The top leaders had incomparable decision power and were able to invoke resources from their own willingness. This character of power formation increased the possibility of "Great Leap" type of develop strategy. When the industrialisation started to accelerate, the fundamental problem emerged. The agricultural sector could not produce enough food while the system was also not able to provide enough productive employment for the available workers, resulting in (hidden) unemployment.

As a result of these experiences, two main consequences can be seen:

- First, previous failures created doubts about the typical socialist model among people, including among China's leadership. Although there were no voices pushing for building another system instead of the socialist one, adjustment and corrections of the previous Soviet Union model seemed highly necessary.
- Second, the central government could find a better development model which would be more suitable for China's practical conditions and character by studying previous experimentations and economic recovery. For example, history showed the "Hundred Flowers" policy as a suitable model for cultural and educational development. The evidence that China's development during 1956 to 1957 had largely benefited from it was clear. On the other hand, the planned economy caused disasters in China in the late 1970s. China's leaders were aware of the potential ways to replace the planned economy model in the near future.

*2. Failures during socialist era*

A clear failure during the Socialist era was neglected investments with a sole focus on industry-oriented development. "From 1952 to 1978, gross capital formation increased at a speed of 10.4 percent each year on average. It was 13 times higher in 1978 compared to the level of 1952. “However, household consumption grew at only at a rate of 4.3 percent and was only three times the 1952 level by 1978. (Naughton, 2006)” “After correcting for population growth, per capita household consumption grew only by 2.3 percent annually, according to the official statistics. (Naughton, 2006)” “Moreover, the urban–rural difference was significant: urban wage growth at 3 percent was significantly above rural wage growth of 1.8 percent. (Naughton, 2006)”

A second clear failure at the time was the lack of employment creation. The service industry was neglected by the government for a long time, and the new built industries required a high capital investment. The number of jobs in agriculture grew by 2 percent each year during the whole period. “By 1978 the agricultural labour force was 70 percent larger than it had been in 1952. (Naughton, 2006)” As a result, underemployment, particularly in rural areas, remained a serious problem.

The industry construction in China was focused on required intensive capital and advanced technology. Those huge projects usually need many years to build its complicated, large scaled facilities. Before the operation of these industrial facilities, all the investment was being hold. It brought China big challenges when building too many projects like this during the same period of time. In a way, China’s goal and plan for industry development was too high. “By concentrating on capital- and technology-intensive heavy industries and neglecting labour intensive consumer goods industries, the Chinese were pouring scarce resources into difficult undertakings while ignoring opportunities to exploit relatively ‘easy’ projects. (Naughton, 2006)” Although these challenging projects created a solid basis for China’ heavy industry, a more balanced model would be more appropriate and rational.

*3. Positive impacts during the socialist era*

The human capital was a legacy from socialist era. Although suffered from 10 years culture revolution, Chinese people were in better healthy condition and became better educated than before. “Strong entry-level health care institutions in the countryside were built up during the same period. (Banister, 2004)” “The result was that life expectancy at birth climbed to 60 for the overall period 1964–1982, according to our best estimates. (Banister, 2004)” “This was quite high for a country at China’s income level, and up from about 50 in 1957 and perhaps as low as 30 in the early years of the twentieth century (Banister, 2004)”

The 1982 census showed that two thirds of people were literate, and people’s working skills have been improved. The previous system have provided the poorest people in the society a relatively good support in education, health guarantee and working skill training.(except during the famine) And the human capital base was a critical node for China’s next step in becoming a big economy later after several decades’ catching up.

### 2.3 Problems and challenges

After almost 30 years of exploration, China finally came to a point where the new leaders were able to make a historic transformation. The existing traditional socialist system was abandoned to a large extent. Instead, a remarkable Chinese type of socialist development model which combined many characteristics of a market economy was set up. Nowadays, the young generation in China is no longer familiar with the command economy. Rather the planned economy has become part of a faint memory of the old days in peoples' memories. Until today, China has had more years working through a market transition than it had years under a planned economy system. Although there were occasional failures and mistakes, China adapted to the new efficient market economy model. China still has a long way to go in reforms to move towards an ideal development model, and the development policies towards economy, environment and energy use are far from complete at this moment, neither will they ever be perfect. However, at the same time, China as one of the biggest economies in the world surprised the world by its incredible progress over the past 35 years. Those high economic growth figures, for a sustained amount of time, did bring new problems and challenges alongside, though.

The past 35 years since the start of China's market transition in 1978, are commonly recognised as the most influential time for the current situation in China. The origins of many achievements, problems, and challenges nowadays can be found when looking back at the past 35 years, no matter whether economic, energy or environmental in nature.

This section will first sketch a basic framework of China's development since the market transition process, interpreting the characters of China's development model during the past 35 years. Secondly, it will indicate the current challenges and problems with respect to the previous years' market transition legacy. Thirdly, it will interpret the necessity for implementing new policies in order to cope with current problems and challenges.

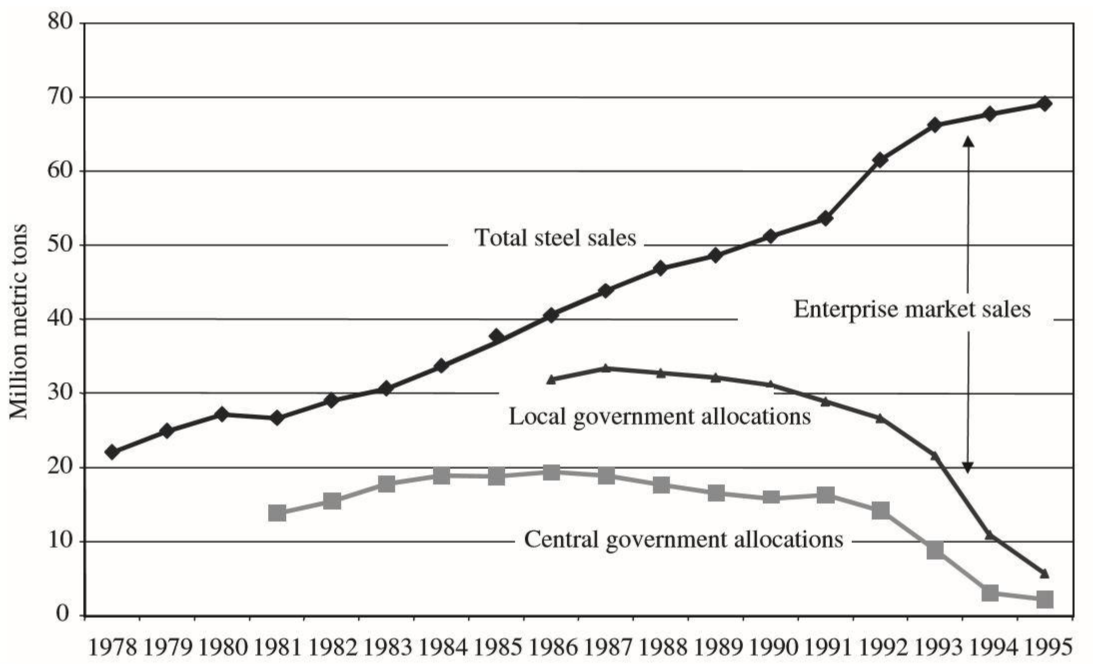
#### 2.3.1 Market transition

China's market transition was obviously different from the transition paths experienced by other socialist countries. In some East European socialist countries, the previous systems collapsed in one night and reformers tended to abolish all of its Socialist history, in order to move to the modern market economy as soon as possible. This was not the path that Chinese leaders have chosen. China's reformers viewed China in an accurate way: as a low-income developing country. They took China from there. Notwithstanding this accurate assessment of where China was coming from, unmet demands can be found easily in China's economy because of the underdeveloped point where China came from and because of some of the negative effect of the previous economic model.

China's reformers took their first strep of reform on countryside, where they lowered the quantities of grain procured, lowered the tax and raised the price of grain. The unmet demand of grain was imported from other countries. This policy given China's farmers a breath and resulted in dramatic success. "By 1984 grain output had surged to 407 million metric tons, more than one third higher than in 1978. (Naughton, 2006)" Since then, China was no longer a country short of food and industrial construction was not be hold back due to shortage of agricultural production.

After the success of agriculture sector, the reform was expanded to industrial and commercial parts. Reformers made policies to shift power and resources from central government individual parties in the market. In order to stimulate the activity of market, the reformers lowered entry barriers in these sectors. Many factories and companies were set up – non state firms, private firms and foreign invested firms all became part of the market. The industry production showed more flexibility.

*Figure 7 Steel production during 1978 to 1995 (Million metric tons)*




During this period of time, China's modern market was formed. However, its lack of effective administration, especially for the large number of tiny firms in market which has strong impact on the country together, became a hidden trouble for future development.

**Table 1** *Comparison of reform policies during two periods of time*

| 1980s reform | 1990s reform |
|---|---|
| Zhao Ziyang: cautious, consensual decision-making | Zhu Rongji: Rapid, personalized decision-making |
| Introduce markets where feasible; focus on agriculture and industry | Strengthen institutions of market economy; focus on finance and regulation |
| Dual-track strategy | Market unification, unite dual tracks |
| Particularistic contracts with powerful incentives | Uniform rules: "level playing field" |
| Competition created by entry; no privatization | State-sector downsizing; beginnings of privatization |
| Decentralize authority and resources | Recentralize resources, macroeconomic control |
| Inflationary economy with shortages | Price stability, goods in surplus |
| "Reform without losers" | Reform with losers |

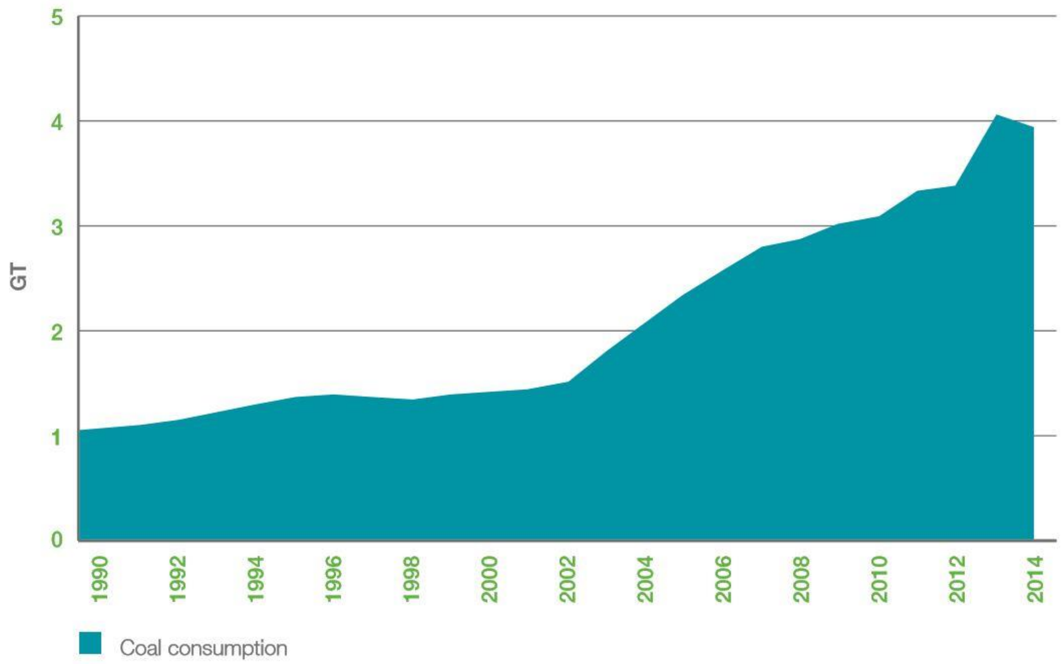
### *2.3.2 Challenges and problems*

After 35 years of reform since 1978, China has obtained unprecedented achievements but the conflicts in the current development model become more and more fierce. It is widely agreed in the common view that China has arrived at a "crossroad" where changes are supposed to be made in economic, environmental, energy and other sectors. Both China's top leaders, intellectuals and foreign researchers argue that the decreasing returns and emerging problems and challenges prove the previous development model is no longer able to support China to go to a next stage or is not sustainable to do so.

Some scholars argue that China is approaching its tipping point where economic growth is at a standstill, environment is seriously polluted and social welfare is not guaranteed. Some even argue that China is going to collapse or fall apart soon. Maybe some of these voices are not rational or not objective enough, however all these voices are targeting at China's development method and are worth mentioning.

In fact, China's chairman Xi Jinping has once repeated the word of former prime minister Wen Jiabao, criticising that China's current development model is "unstable, unbalanced, uncoordinated, and unsustainable." As we can see from the figure below, China's coal consumption started to rise significantly from 2002, in the past few year, the coal consumption increased sharply from 2012 to 2013. However, later in 2014, the consumption fell back and started to show a downturn trend. This situation can be seen as the effect of China's "New Normal".

*Figure 8 China's coal consumption from 1990 to 2014*




Source: (International Energy Agency, 2015)

The main challenges and problems concerning China's development now can be summarised as follows:

- China's economic growth is slowing. Economic growth is highly dependent on domestic investment which mostly goes to infrastructure. This leads to accumulating reconstruction and excessive production capacity. The share of ineffective growth is increasing in economic growth as a whole. Exports is another main engine for economic growth. It is mainly given by the low labour cost advantage of China. However, after implementing "single child" policy for a long time, China's population shows a significant aging trend. Meanwhile, some other developing countries such as India is showing an increasing advantage as a manufacturing basement with lower labour costs and improved basic facilities. Losing advantage as the world's factory seems like an unavoidable trend for China.

- "High levels of industrial investment leads to high energy consumption. Production of steel is based on coal fire and such construction material as cement consumes a lot of energy as well. (Stern, China's "New Normal": structural change, better growth, and peak emissions, 2015)"

- State owned companies become the biggest monopolies in the market, the priorities in resource allocation and lack of competition lower their efficiency. As a result, more resources are wasted and many private companies cannot survive because of the lack of resources. This phenomenon is especially obvious in some key industries such as energy, telecommunications and transportation.

- Environment is nowadays becoming a hot topic which became the subject of close public attention in China. Meanwhile, China has one of the world's worst environment condition. Pollution is found everywhere in China, including polluted rivers and lakes, water resources, air pollution which cause increasing number of cancer deaths. Apart from greenhouse gas emissions and climate change there is also a big population problem. And the inefficient energy usage is the main problem that Chinese government has to tackle in order to lower GHG emission.

- Technological innovation is another sector where China find its challenges. The technology sector is recognised as a critical node for China to overcome over the bottleneck of underdeveloped way of economy development. No matter whether we discuss the economy, energy or the environment, technological development is the most important long-run driver for change and progress. For example, in economy sector, if China wants to rely less on domestic investment and export, China needs more Chinese companies with innovation skills to beat the market. In environment and energy sector, technology improvement is the key point for forming a better energy consumption structure and a higher level of sustainability.

Apart from all these problems and challenges listed above, there are still many other issues that we cannot list here, such as inequality between countryside and city, corruption, imperfections in legal system, low level of urbanization, etc. In this research, we will focus on the issues which are more directly related to our research questions.

### *2.4 Policy shock: China's "New Normal"*

The conception of the "New Normal" was initially used by China's current chairman Xi Jinping during a visit to Henan Province in May, 2014. In the beginning ceremony of APEC in November, 2014, Xi Jinping gave a systematic explanation of the meaning "New Normal" for the first time. In the Central Economic Working Conference in

December, Xi Jinping explained the main task and current trend of the “New Normal”. Since then, the “New Normal” started to become a key word in government’s goal and standard in future work.

The main characteristics and goals of the “New Normal” model can be summarised from Xi Jinping’s previous speeches, and can be categorised in the following way:

1. Slowing down the speed of growth, from very high speed to medium high speed.
2. Upgrading the structure of the economy, increase demand of the service industry, domestic consumer demand and make them the main engine for economic growth. Lessen the income gap between the countryside and cities, and increase citizen’s incomes.
3. Adjust the engine for economic growth: from investment driven to innovation driven growth.
4. Reduce $CO_2$ emissions, improve the environmental and air quality. Achieve the sustainable economic development.

The “New Normal” model sketched by Xi Jinping is a far-sighted decision that displays significant strategic thinking. The “New Normal” development model indicates upcoming changes in China’s future development. It takes the domestic and international macroeconomic situation into consideration, and combines it with China’s current challenges and goals in the near future. This new development model shows the expectation of “slowing down the speed and enhance the quality of economic development”. To be more specific, it covers aspects including switching the speed of economic growth, switching the engines of economic growth, reallocating of resources, industry structure upgrading and welfare sharing, etc. Understanding the “New Normal”, implementing it and adapting to it will be the critical steps for China’s development in the new era.

The three characters and goals of the “New Normal” listed above are relatively broad standards. However, in the practical implementation, the content contained in the “New Normal” could trickle down into each sub-industry and each detailed part of Chinese sustainable (economic) development.

Let’s look at each of the abovementioned goals one by one. First, a switch in the growth speed from very high speed to medium high speed is announced. This seems like a contradiction at first sight if one knows of the economic performance of China over the past 35 years. During the past 35 years since market reform, the growth speed of China’s economy has been at a two digit rate most of the time. Influenced by the global financial crisis in 2008, growth of China’s economy has slowed down to an extent (7.7 percent in 2012 and 2013). From experiences of other countries, a decrease in economic growth is a common phenomenon which tends to happen when a country or a region's income reaches a medium level. This happened to countries like Japan, South Korea and Germany after the Second World War. These countries started as industry-driven economies and have accelerated their economic step to catch up with other more developed countries. After high levels of growth in the 60s and 70s, their economic growth generally slowed down. From an international perspective, after the global financial crisis in 2008, the international economy showed that under decreasing aggregate demand the economic global structures were adjusting. The weakness of the economic situation in developed countries decreased external demand for China's manufacturing products. From a domestic perspective, after 30 years of large scale of intense exploration and construction, restrictions towards energy, environment and resources started to emerge, the export-oriented production powerhouse and investment driven high speed growth model has started to sputter and may no longer be applicable. In order to overcome over this bottleneck in economic development, a "New Normal" model may be totally necessary. Generally, due to the economic growth potential of China, a slowdown of the economy could be expected based on historical evidence. But this does not necessarily mean the quality of the economy and efficiency should be lower. On the contrary, the "New Normal" is aiming at the formation of a model of economic growth with better quality and higher efficiency. Before China's urbanisation reaches a peak, keeping economic growth at the higher end of 'medium-level' growth is promising.

Secondly, switching the industry structure that drives growth, from low-value added sectors to medium and higher value-added sectors is a challenge. This is also the main task in the "New Normal" model. China's industrial development model has been one of high investment, high resource intensiveness and relatively low output, and finds itself at the middle and bottom ends of global value chains (i.e. the 'Made in China' final assembly role). The 30 years of "shirts, slippers and toys" economy is coming to an end, and the "steel, cement and glass" economy is approaching its peak. At this moment, due to overcapacity in China's traditional industries, traditional population benefits are becoming less advantageous. The "Lewis Turning Point" is approaching China with an accelerating speed. The "New Normal" model is focused on increasing technological innovation power, promoting the combination of technology and industry to add value to China's new industry chain. The statistics of 2013 showed that the added value of China's service industry represented 46.1 percent of GDP for the first time, and it was also the first time the service industry outperformed traditional industries. In 2014, the value added from the service industry constituted 46.6 percent. By implementing the "New Normal" policies, China's industry is aiming at a smaller scaled, intelligent, professional system. The previous underdeveloped, low efficient, high energy and resource consuming system will be gradually phased out. Meanwhile, new industry, service industry, small and micro sized firms will perform as important characteristics in this procedure.

Thirdly, the “New Normal” model will pay more attention to the environment protection and improvement while developing. Considering China’s tough environment situation and increasing importance of sustainability in the global stage, the “New Normal” model is designed to make better use of energy. Long term project towards hydroelectric power, photovoltaic power, nuclear electricity will become a more significant combining part of China’s energy consumption, and traditional coal fired power will be phased out. Meanwhile, underdeveloped capacities will be phased out to achieve higher energy efficiency. (Zhanbin, 2015)

China’s “New Normal” is a full scope model which covers almost every sector. However, there is no official “New Normal” plan released as a whole yet. However, we can find some measures China has already taken which can be proven by the change in figures. With this, we can sketch a potential plan and direction of China’s next step in the “New Normal” plan and focus this research on the economy, environment and energy aspects and their macroeconomic impacts.

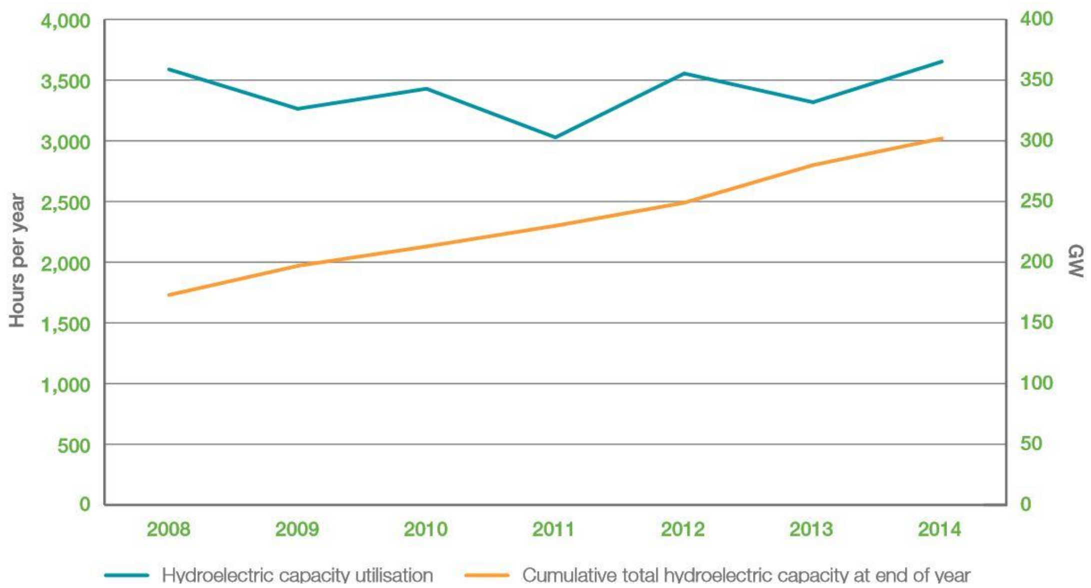
**Growth rate**

The most obvious change of the “New Normal” model is the slowing down of the GDP growth. During 2000 to 2010, China’s GDP growth rate was 10.5 percent on average while during 2012 to 2014, it was 7 to 8 percent. In the IMF’s latest forecast, China’s growth would be slowed down to 6.8 percent in 2015 and 6.3 percent in 2016. And during 2020 to 2030, it would be 4 to 6 percent on average. (IMF, 2015)

**Electricity Generation**

Replacing coal fired energy by other green energy is the main idea of the “New Normal”, it has close relation with both structural change and future energy use. China has shut down many coal fired power plants with low efficiency and high pollution. Instead, some higher efficient plants have been set up. During the past year, tight regulation has been established towards coal consumption. China has shifted its financial support to new energy deployment. China has invested 83.3 billion dollars which equals to almost one third of the global investment in 2014. And in 2004, this figure was just 3 billion dollars. (IBRD.IDA, 2015) 60 GW electricity generation capacities was installed in 2014 and these capacities are all coal free. Wind power, solar power and natural gas became the main types of resources.

*Figure 9 China's hydroelectricity utilisation and increase*




Source: (International Hydropower association, 2015)

**Industrial Adjustment**

In 2014, China's steel production was at its lowest growth rate of only 1.2 percent. Cement growth rate was 2.3 percent. (NBS, 2015a) In the first quarter of 2015, cement production declined by 3.4 percent while steel declined by 1.7 percent. This is because of China's "New Normal" policies led to a decreased demand for construction and manufacturing. Coal consumption in steel manufacturing declined by 1.5 percent and in construction it declined by 0.2 percent (according to the data by China Coal Industry Association). The Chinese government is expecting further percentage reductions per annum through 2015. (Fang, 2014) With this plan, industrial emission will be sharply reduced since steel and cement production represent about 70 percent of the industrial emissions in total.

**Potential Policies**

Apart from the existing trends and plans, there are also some potential policies which can be beneficial in achieving China's "New Normal" goal. Such as adjusting the coal tax, green finance and technological innovation into a green economy. Taking the coal tax as an example, China has restored its tariff on coal imports. However the tariff are still relatively low. In near future, it is possible for China to establish a more complex coal tax system which also covers coal using procedures. Whether this would go against the WTO remains to be seen, but if well framed as part of an environmental policy, prospects are good. Increasing the tax rate to a reasonable level is also a promising method. These potential policies will be taken into consideration in the modelling section of this research.

# 3 Methodological approach

## 3.1 Literature overview of similar policy questions

The research on macroeconomic impacts of energy, environment and economy policies usually concentrates on analysing the return on investment of policies. For example: Lorna A. Greening has done research studying the rebound effect that technology policies have on energy efficiency. (Greening, 2000) The research usually adopts Computable General Equilibrium (CGE) models as the main modelling approach. However, this research is often primarily focused on economic impacts of (environmental) tax policies and less on energy consumption, energy efficiency, different types of emissions, and different social and environmental effects. There are number of industrial policy analyses carried out, but mostly as a sub-part of a cross-sectoral analysis.

The Chinese government – as we deduced in the previous chapter – has set out a few policy goals that China is envisaged to meet in the coming years as explained in detail in the previous Chapter. In summarised form, these are:

- A peak of GHG emissions in 2030
- A slow down GDP growth but keep it at a dynamic rate
- Structural improvement of economic growth
- Raise the non-fossil fuel share of primary energy consumption

There is an important distinction that sets this research apart from other – earlier – research done. This may have an important influence on the final results of the "New Normal" policy question. In some of the studies, policy makers are assumed to be fully aware of all the information and resources that are allocated and used with close to a 100 percent efficiency. If this is assumed, any policy will cause losses compared to that perfect world. In other words: if the policy shifts the producing quantity away from the efficient level, losses follow. If such assumption does not exist (i.e. the starting point is not an optimal one), policies could possibly be able to achieve a higher efficiency in the end. "The improvement in performance may come from an awareness effect, as discussed below as a feature of the CCAs, or from the formal modelling of induced technological and preference change, as in the hybrid modelling reported in (Jaccard, 2004) and (McFarland, 2004). (Barkera, 2007)"

Parry used a numerical CGE model and made comparisons between the costs of implementing 8 policy methods to cut down CO2 emissions. "A carbon tax, two energy taxes, and both narrow-based and broad-based emission permits and performance standards have been examined. (Parry, 1999)" He showed that the pre-existing tax pushed up the costs of all policies.

A CGE model was introduced in 2003 to analyse the potential impact of economic policy on the economy and technology. "They found the policies that decrease the energy consumption are different from those that aim at reducing the growth rate of energy inputs. (Smulders, 2003)" "Although these policies may stimulate innovation, they unambiguously depress output levels. (Smulders, 2003)." Here the trade-off between growth and the environment is made very obvious.

In a research in 2006, the author interpreted previous methodologies that have been applied to analyse cost of policies in previous research. "They assumed the aggregate capital was fixed and sectoral capital completely mobile between sectors. (Barkera, 2007)" "The concept 'shadow taxes' was used to represent the effect of regulation in a static CGE model with a 10 year projection. (Barkera, 2007)" Statistics from the Energy Information Administration's, National Energy Modelling System of the United States were applied to measure the quantity of energy that had been saved by implementing new policies. The first method was to cut a fixed quantity of energy consumption over all sectors and calculate the impacts. The second method set the policy to implement a non-uniform quantity reduction of energy in each sector – equivalent to setting a carbon tax or permit system. The economic cost of the first policy was found to be much higher than the cost of the second one. In fact, the second method showed a higher proficiency result which caused lower economic costs upon policy implementation. Apart from this, they also showed the method of how they transfer energy saving policies into "shadow tax". In their opinion, the policies changed the real cost of energy as inputs and lowered the efficiency overall. Because of this, manufacturers tend to reduce the energy consumption and move the emphasis to other aspects such as labour and capital investment. "Because in some cases policies might not only shift input usage along a production frontier but also lead to inefficient use of the existing technology. (Pizer, 2006)" In the conclusion, it showed the cost of implementing policies are much higher than levying carbon taxes or establishing permit requirements when achieving the same GHG emission goal.

The main method and aim is to transfer the impacts of policies on energy saving, environment protection and structural improvement from specific sectoral studies to macroeconomic scale and further analyse its broad effects. "... in interpreting economic simulation modelling studies that refer to the putative shortcomings of energy-efficiency policies, it may not be apparent to non-specialists that the models are typically not demonstrating these shortcomings but rather assuming them, and then illustrating the numerical consequences. (Sanstad, 2006)" "On the other hand, however, these equilibrium models can be used to estimate in reduced form the aggregate benefits of bottom–up policies if the detailed technological information is available from some other source. (Sanstad, 2006)" The difference of methods was explained by Sanstad. (Sanstad, 2006)

In 2006, a research applied CGE model to analyse the policy on energy efficiency which covers two industrial sectors. (Roland-Holst, 2006) The result of this research showed unremarkable effects on industrial output and employment in the US, and the effect was positive for semiconductors but negative for cement. (Roland-Holst, 2006)

The methods applied are not extremely different. The differences shown on the surface are mainly due to the different forms of policies and the mechanism beneath it. If the policies are designed roughly, then the results from modelling tend to illustrate a loss in many sectors. If the policies give incentives to induce users to behave smartly and choose a low cost way of transformation, then the costs tend to be relatively low.

In 2010, Barker and Serban Scrieciu did a research on modelling the low climate stabilisation with the E3MG model. Instead of using the CGE model as most previous studies did, the E3MG model was applied. The model was also able to detail the links between economics, the environment and energy in a much more elaborate way than was done in the CGE models previously. The authors used the E3MG model to analyse the impact of a policy package that aimed to achieve a low-stabilization target by 2100. The research found the low-carbon transition was likely to result in an increase of macroeconomic benefits. This finding is not common and is rarely found in studies based on the CGE model. (Barker and S. S, 2010) Other research that was done with the help of the E3MG model is introduced more specifically in Section 3.3.2.

## 3.2 Choosing the E3MG model

By studying the earlier literature and methodological approaches toward analysing economic and environmental policies and their impact on growth and the environment, we propose to choose to continue working with the E3MG model instead of the CGE models. Why would we choose for the E3MG model?

**The wide geographical coverage:**
The scope of application of the E3ME model is broad and E3MG even broader. The E3ME model contains specific descriptions for every single member country of European Union and also covers the main big countries in the world in terms of the size of economy. The E3MG model is expanded to include 53 global regions that in total cover the entire world economy.

**Sectoral disaggregation:**
The E3MG model is a detailed model. It makes the integration of complicated

scenarios in the model possible. Policies and situations usually differ from region to region, country to country. There are 69 economic sectors in Europe and 43 sectors for other parts of the world. The disaggregation is divided by product, industry, energy (fuel) user, etc. It includes crops, animals, fishing, coal, basic metals, real estate, electrical equipment, etc. The E3MG model is designed to cover these characteristics while modeling. Additionally, the result (the impacts of policies) can be also presented in a detailed way, which means the parties who enjoy benefits or suffer a loss can be indicated in terms of the implementation of a specific policy. In this research, we are not going to go into details of sectoral disaggregation, since this research will focus on the macro-results. The character of sectoral disaggregation used in the E3MG model makes it possible to simulate the implementation of the complex “New Normal” scenario. The impact of the “New Normal” policy can be presented in a specific way, for example through the gains and losses at macro-level, but also at sectoral level.

**Flexibility**

The E3MG model is designed on an econometric and empirical basis. This feature gives the model the advantage that it can estimate policy performance in the near future and in medium term grounded in empirical evidence. Meanwhile, assessments over more than a decade’s period are also possible by applying the E3MG model. Since the mechanism of this model is not based on rigid estimation which can be commonly found in other modeling methods, it provides higher flexibility and applicability for practical use. This means it is suitable for analysing the “New Normal” policy since the model is not based on rigid assumptions which is common for other models. This advantage enables the research to obtain relatively accurate results, especially when the policy covers many sectors and variables.

**E3 Linkages**

Due to the E3MG model’s hybrid character, the model has two ways of giving internal feedback to itself while modeling. “As the interactions between economy, energy demand/supply, material consumption and environmental emissions are nonlinear. (Cambridge Econometrics, 2014)” “It is an incomputable advantage comparing to those models that have only 1 way of delivering internal feedback or even ignore the interactions totally. (Cambridge Econometrics, 2014)” Because the E3MG model is designed to analyse energy, environment and economic impacts, it is highly applicable for our research. The model is focused on the interlinkages between these three blocks which is exactly what the “New Normal” is about.

The E3MG model has been under development for many years. For the energy sector, the E3MG model invokes top-down mechanism to estimate its demand. The model lists 22 groups of main energy consumers, and the main energy consumed is categorised into 4 types: coal, fuel, LNG and electricity. “The energy demand can be recognised as outputs in E3MG model and their corresponding inputs are economic activity, relative prices, and measures of technology. (Barker, 2015)" The E3MG model produces all its outputs at the same time under the constraint that the sum of energy consumption for each consumer equals the total consumption. Previous studies that used the E3MG model in their research are discuseed in the next section.

## 3.3 Previous analyses using the E3MG model

From the literature review in section 3.1, one could get the impression that the CGE model has been used much more than the E3MG model to look at impacts of policies for the economy, the environment and energy. This is likely to be true. However, during the past decade, the E3MG model has also been applied in many studies. And the E3MG model has been upgraded following practical applications. Until today, the E3MG model has been used by European Commission and other research institutions to analyse the policy impact at the European level.

In 2012, E3MG model was used by Soocheol Lee in studying the impact of tax reform in Japan. The research has simulated 4 scenarios to assess the performance of carbon tax in meeting Japan's Copenhagen pledge, which was reducing the emission to 75 percent of 1990 level. One scenario was designed to achieve the 25 percent reduction target, the other two had different emphasis in revenue recycling. The result showed that the baseline scenario had limited influence in emission reduction. As a result, GDP and employment were also not influenced significantly. In other scenarios, GDP and employment fell because the emission reduction targets were more ambitious. However, the research also found out, the loss in GDP and employment are likely to be compensated only if the revenue is recycled appropriately, so that the loss can be offset. (Lee, 2012)

In 2010, A.S. Dagoumas and T.S Barker conducted research to analyse the macroeconomic impact of different pathways on achieving emission reduction targets in England, especially the impact on GDP and investment. There were 4 scenarios with different levels of emission reduction target. The reduction target of different pathway were set at 40 percent, 60 percent, 80 percent reached by 2050. By making these scenarios, the research found out that all reference scenarios gave better result in terms of the change in GDP compared to the baseline. And it further concluded that there was not always such trade-off between GDP growth and emission reduction. (Dagounmase, 2010)

In the year of 2010, European Commission applied E3MG model in analysing the target of "moving to a 30 percent GHG target for 2020 (European Commission, 2010)" In that analysis, three scenarios were set up. The Baseline reflecting trends and already implemented policy measures as of spring 2009. The reference scenario reflecting full implementation of the Climate and Energy Package; A 30 percent Reduction Commitment scenario that represents a 25 percent domestic GHG reduction scenario in 2020 in the EU. In the result, it showed that in order to achieve the baseline, reference and reduction, EU has to reduce the GHG emission for 4 percent, 9 percent and 13 percent respectively. The change in system costs, investment, and annual fuel expenses in order to achieve the 25 percent emission reduction targets were also indicated.

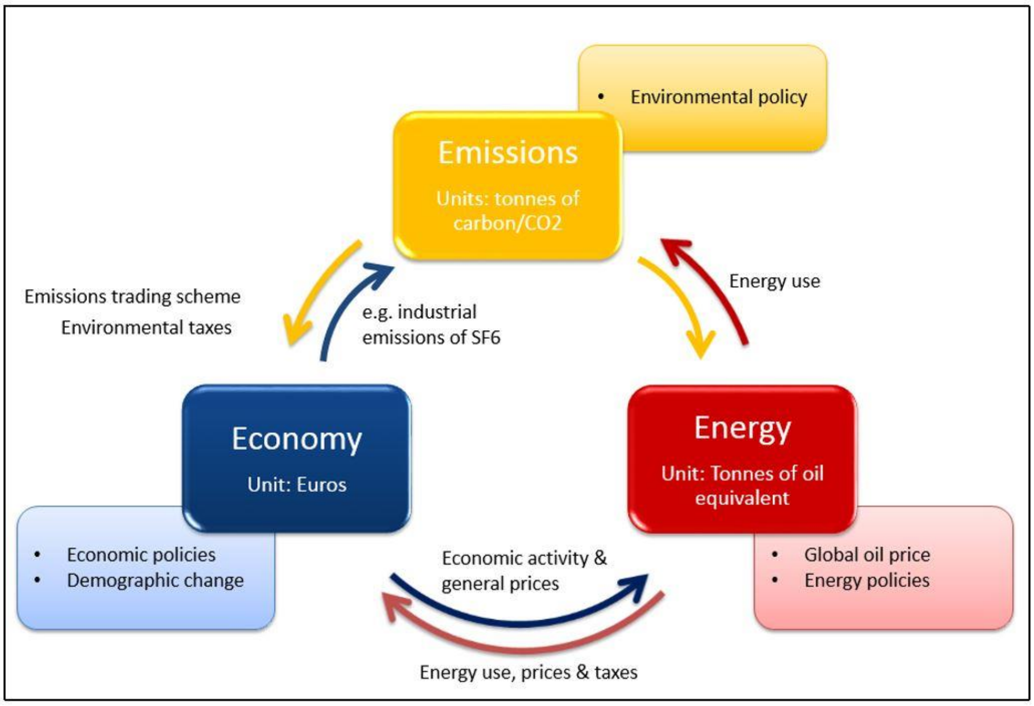
## 3.4 The E3MG model

### 3.4.1 E3MG model introduction

The Energy, Environment, Economy Model at the Global level, also known as E3MG model is developed by Cambridge Econometrics and the University of Cambridge. The E3MG model is a global level macro econometrics tool that is designed to examine the landmark changes in society over years (up to 2050). The model intrinsically links energy, environment and economics – hence E3 – together. That is exactly why this model is very well suited to analyse the research question of this thesis: to look at the economic, environmental and energy effects of China's "New Normal". The interaction between each module can be illustrated in following picture:

The figure below shows the main modules of our modelling process and its mechanism. Each box in the figure contains its own database, this data has been collected by experts of statistical offices for Cambridge Econometrics. Use of the E3MG model and associated data thus gives us the great convenience of getting access to large amounts of high quality data that are already pre-formatted for use by the E3MG model.

*Figure 10 Interaction of E3 Components*




The "E3MG model analyses policy impact by combining accounting balances and behavioural relationships. (Cambridge Econometrics, 2014)" Because behavioural relationships are complicated and polytrophic, the preferable way is to simulate the behavioural relationships on the basis of historical time- series data. The E3MG model has 29 variables estimated from the relationships and 47000 equations to forecast the results. In this section, the E3MG model and its equations will be presented in detail, because it is important to understand the working of the model.

As a basis for understanding the equations that follow, the below conventions for some notations will be explained.

"(.) means the subject before the it is a vector and all the elements are denoted with the dot. (Cambridge Econometrics, 2014)"
"(.,.) means the subject is a matrix (Cambridge Econometrics, 2014)"
"(^) means the vector is converted to a diagonal matrix (Cambridge Econometrics, 2014)"
"(.,.)' means the matrix is transposed (Cambridge Econometrics, 2014)"
"(-1)(-2) etc. means there is period lag for variable (Cambridge Econometrics, 2014)"
"LN(V) the natural logarithm of variable V (Cambridge Econometrics, 2014)"
"DLN(V) the change in LN(V) (Cambridge Econometrics, 2014)"
"MATP(M1(.,.),M2(.,.))

Matrix multiplication of variable matrices M1 and M2. (Cambridge Econometrics, 2014)"

"ECM error term from long-run cointegrating equation that gets used (after lagging) in the dynamic equation. (Cambridge Econometrics, 2014)"

The equations are presented in following sections.

## The Aggregate Energy Demand Equations

Co-integrating long-term equation:

$$LN\big(FRF(.)\big) = \mathrm{BFRF}(.,10) + \mathrm{BFRF}(.,11) * \mathrm{LN}(\mathrm{FR0}(.)) + \mathrm{BFRF}(.,12) * \mathrm{LN}(\mathrm{PFRP}(.)) + \mathrm{BFRF}(.,13) * \mathrm{LN}(\mathrm{FRTD}(.)) + \mathrm{BFRF}(.,14) * \mathrm{LN}(\mathrm{ZRDM}) + \mathrm{BFRF}(.,15) * \mathrm{LN}(\mathrm{ZRDT}) + \mathrm{BFRF}(.,16) * \mathrm{LN}(\mathrm{FRK}(.)) + \mathrm{ECM} \quad [\text{Equation } 1]$$

Dynamic equation:

$$DLN\big(FRF(.)\big) = \mathrm{BFRF}(.,1) + \mathrm{BFRF}(.,2) * \mathrm{DLN}\big(\mathrm{FR0}(.)\big) + \mathrm{BFRF}(.,3) * \mathrm{DLN}\big(\mathrm{PFRP}(.)\big) + \mathrm{BFRF}(.,4) * \mathrm{DLN}\big(\mathrm{FRTD}(.)\big) + \mathrm{BFRF}(.,5) * \mathrm{DLN}(\mathrm{ZRDM}) + \mathrm{BFRF}(.,6) * \mathrm{DLN}(\mathrm{ZRDT}) + \mathrm{BFRF}(.,7) * \mathrm{DLN}\big(\mathrm{FRK}(.)\big) + \mathrm{BFRF}(.,8) * \mathrm{DLN}\big(\mathrm{FRF}(-1)\big) + \mathrm{BFRF}(.,9) * \mathrm{ECM}(-1) \quad [\text{Equation } 2]$$

Definitions:

"BFR0 is a matrix of parameters (Cambridge Econometrics, 2014)"

"FR0 is a matrix of total energy used by 22 energy users for 53 regions, th toe (Cambridge Econometrics, 2014)"

"PFR0 is a matrix of average energy prices for 22 energy users and 53 regions, euro/toe (Cambridge Econometrics, 2014)"

"PRYR is a matrix of average producer prices in the economy as a whole (2005 = 1.0, local currency) (Cambridge Econometrics, 2014)"

"FRY is a matrix of activity for 22 energy users and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)"

"FRTD is a matrix of R&D by 22 energy users for 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)"

"ZRDM is global R&D in machinery, m euro at 2005 prices (Cambridge Econometrics, 2014)"

"ZRDT is global R&D in transport, m euro at 2005 prices (Cambridge Econometrics, 2014)"

"FRK is a matrix of investment by 22 energy users for 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)"

Equations 1 and 2 demonstrate the total energy used by energy user on a long term basis and dynamic basis respectively. The long term energy consumption is the total consumption of 22 energy users and 53 regions. The equations demonstrate the sum of natural logarithm of activity, price ratio, R&D by energy user, R&D in machinery, R&D in transport, investment by energy users and the error from long-run co-integration multiplied by each of their matrix of parameters. By calculating the logarithm, corresponded energy consumption can be derived. By multiplying the corresponding matrix of parameters, the consumption of each parameter can be known.

Additionally, for equation 2, a lagged change in energy use and lagged error correction are taken into consideration in order to adjust to period lag of each parameter.

**The Aggregate Consumption Equations**

Co-integrating long-term equation:

$$\begin{aligned} LN(RSC) = {} & BRSC(11) + BRSC(12) * LN(RRPD) + BRSC(13) * LN(RRLR) \\ & + BRSC(14) * LN(CDEP) + BRSC(15) * LN(ODEP) + BRSC(16) \\ & * LN(RVD) + ECM \end{aligned}$$

[Equation 3]

Dynamic equation:

$$\begin{aligned} DLN(RSC) = {} & BRSC(1) + BCR(2) * DLN(RRPD) + BRSC(3) * DLN(RRLR) + BRSC(4) \\ & * DLN(CDEP) + BRSC(5) * DLN(ODEP) + BRSC(6) * DLN(RVD) \\ & + BRSC(7) * LN(RUNR) + BRSC(8) * DLN(RPSC) + BRSC(9) \\ & * DLN\big(RSC(-1)\big) + BRSC(10) * ECM(-1) \end{aligned}$$

[Equation 4]

Definitions:

“BRSC is a matrix of parameters (Cambridge Econometrics, 2014)”

“RSC is a vector of total consumers’ expenditure for 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)”

“RGDI is a matrix of gross disposable income for 53 regions, m euro at current prices (Cambridge Econometrics, 2014)”

“RLR is a matrix of long-run nominal interest rates for 53 regions (Cambridge Econometrics, 2014)”

“EX is a vector of exchange rates, local currency per euro, 2005=1.0 (Cambridge Econometrics, 2014)”

“RPOP is a vector of regional population for 53 regions, in thousands of persons (Cambridge Econometrics, 2014)”

“CPOP is a vector of child population for 53 regions, in thousands of persons (Cambridge Econometrics, 2014)”

“OPOP is a vector of old-age population for 53 regions, in thousands of persons

(Cambridge Econometrics, 2014)”
“RUNR is a vector of unemployment rates for 53 regions, measured as a percentage of the labour force (Cambridge Econometrics, 2014)“
“RPSC is a vector of the real consumer price inflation for 53 regions, in percentage terms (Cambridge Econometrics, 2014)”
“RPSC is a vector of consumer price inflation for 53 regions, in percentage terms (Cambridge Econometrics, 2014)”
“RVD is the cumulative sum of investment in dwellings for 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)”

Equations 3 and 4 are used to demonstrate the aggregate consumption equations. The real consumers’ expenditure is presented by the natural logarithm of total consumer’s expenditure. Equations 3 and 4 sum up the results of the natural logarithm of gross disposable income, real price of consumption, real rate of interest, total consumer price deflator, child dependency ratio multiply the matrix of parameters in each sector. Same as the previous equations, for the dynamic equations, the change in natural algorithm is used instead of LN (V) and period lag is corrected by the last two items in equation 4.

Additionally, RRPD, PRCR, RRLR, CDEP and ODEP represent real gross disposable income, real price consumption, real rate of interest, child dependency ratio respectively. The equations used to derive them are listed below:

$$RRPD = (RGDI * EX/RPSC)/RPOP$$

[Equation 5]

$$PRCR = VCR(.)/CR(.)/PRSC$$

[Equation 6]

$$RRLR = 1 + (RLR - DLN(PRSC))/100$$

[Equation 7]

$$CDEP = CPOP/RPOP$$

[Equation 8]

$$ODEP = OPOP/RPOP$$

[Equation 9]

**The Industrial Investment Equations:**

Co-integrating long-term equation:

$$LN(KR(.)) = BKR(.,10) + BKR(.,11) * LN(YR(.)) + BKR(.,12) * LN(PKR(.)/PYR(.)) + BKR(.,13) * LN(YRWC(.)) + BKR(.,14) * LN(PQRM(5,.)) + ECM$$

[Equation 10]

Dynamic equation:

$$DLN(KR(.)) = BKR(.,1) + BKR(.,2) * DLN(YR(.)) + + BKR(.,3) * DLN\left(\frac{PKR(.)}{PYR(.)}\right) + BKR(.,4) * DLN(YRWC(.)) + BKR(.,5) * DLN(PQRM(5,.)) + BKR(.,6) * LN(RRLR) + BKR(.,7) * LN(YYN(.)) + BKR(.,8) * DLN(KR)(-1) + BKR(.,9) * ECM(-1)$$

[Equation 11]

Definitions:

"BKR is a matrix of parameters (Cambridge Econometrics, 2014)"

"KR is a matrix of investment expenditure for 69/43 industries and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)"

"YR is a matrix of gross industry output for 69/43 industries and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)"

"PYR is a matrix of industry output price for 69/43 industries and 53 regions, 2005=1.0, local currency (Cambridge Econometrics, 2014)"

"PKR is a matrix of industry investment price for 69/43 industries and 53 regions, 2005=1.0, local currency (Cambridge Econometrics, 2014)"

"PQRM is a matrix of import prices for 69/43 industries and 53 regions, 2005=1.0, local currency (Cambridge Econometrics, 2014)"

"PRSC is a vector of consumer price deflator for 53 regions, 2005=1.0 (Cambridge Econometrics, 2014)"

"YRLC is a matrix of wage costs (including social security contributions) for 69/43 industries and 53 regions, local currency at current prices (Cambridge Econometrics, 2014)"

"YREE is a matrix of employees for 69/43 industries and 53 regions, in thousands of persons (Cambridge Econometrics, 2014)"

"RLR is a vector of long-run nominal interest rates for 53 regions (Cambridge Econometrics, 2014)"

"YYN is a matrix of the ratio of gross output to normal output, for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)"

Equations 10 and 11 demonstrate the industrial investment on the long-term basis and its dynamics. Equation 10 sums up the results of natural logarithm of real output, relative price of investment, real average labour cost, real oil price effect multiply their related matrix of parameters. However, for the dynamic equation, it uses the real rate of interest, actual normal output, lagged change in investment. The period lag has been adjusted by the last item.

**The Extra-EU Import and Export Volume Equations**

Extra-EU import volume equations are applied to analyse the situation of China, as a non-EU country.

Co-integrating long-term equation:

$$\begin{aligned} LN(QEM(.)) = {} & BQEM(.,12) + BQEM(.,13) * LN(QRDI(.)) + BQEM(.,14) \\ & * LN(PQRM(.)) + BQEM(.,15) * LN(PYH(.)) + BQEM(.,16) \\ & * LN(EX) + BQEM(.,17) * LN(YRKC(.) * YRKS(.)) + BQEM(.,18) \\ & * LN(YRKN(.)) + BQEM(.,19) * SVIM + ECM \end{aligned} \qquad [Equation\ 12]$$

$$\begin{aligned} DLN(QEM(.)) = {} & BQEM(.,1) + BQEM(.,2) * DLN(QRDI(.)) + BQEM(.,3) \\ & * DLN(PQRM(.)) + BQEM(.,4) * DLN(PYH(.)) + BQEM(.,5) \\ & * DLN(EX) + BQEM(.,6) * DLN(YRKC(.)) * (YRKS(.)) + BQEM(.,7) \\ & * DLN(YRKN(.)) + BQEM(.,8) * DSVIM + BQEM(.,9) * LN(YYN(.)) \\ & + BQEM(.,10) * DLN(QEM)(-1) + BQEM(.,11) * ECM(-1) \end{aligned} \qquad [Equation\ 13]$$

Definitions:

“BQEM is a matrix of parameters (Cambridge Econometrics, 2014)”

“QEM is a matrix of internal imports for 69/43 industries and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)”

“PQRM is a matrix of import prices for 69/43 industries and 53 regions, 2005=1.0, local currency (Cambridge Econometrics, 2014)”

“EX is a vector of exchange rates, local currency per euro, 2005=1.0 (Cambridge Econometrics, 2014)”

“QR is a matrix of gross output for 69/43 industries and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)”

“QRM is a matrix of imports for 69/43 industries and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)”

“QRX is a matrix of exports for 69/43 industries and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)”

“YRKC is a matrix of ICT technological progress for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)”

“YRKN is a matrix of non-ICT technological progress for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)”

“YRKS is a matrix of skills for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)”

“SVIM is zero for the external trade equations (Cambridge Econometrics,

2014)"
"YYN is a matrix of the ratio of gross output to normal output, for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)"
"V- indicates a current price version of the variable (Cambridge Econometrics, 2014)"

Equation 12 calculates the import volume by adding up the results of natural logarithm of home sales, import price, price home sales by home producers, exchange rate, ICT and non-ICT technology progress multiply their related matrix of parameters. Actual/normal output and lagged factors are calculated additionally in equation 13 for analysing the change.

**The Industrial Hours- Worked Equations**

The E3MG applies the number of employees as a unit in presenting the employment results instead of person-hours. In order to generate the employment result in numbers of employees, industrial hours-worked equations will be needed.

Co-integrating long-term equation:

$$\mathrm{LN}\big(\mathrm{YRH}(.)\big) = BYRH(.,8) + BYRH(.,9) * LN(YRNH(.)) + BYRH(.,10) * LN(YRKC(.) * (YRKS(.)) + BYRH(.,11) * LN(YRKN(.)) + ECM$$

[Equation 14]

Dynamic equation:

$$\mathrm{DLN(YRH(.))} = \mathrm{BYRH}(.,1) + \mathrm{BYRH}(.,2) * \mathrm{DLN(YRNH(.))} + \mathrm{BYRH}(.,3) * \mathrm{DLN(YRKC(.) * YRKS(.))} + \mathrm{BYRH}(.,4) * \mathrm{DLN(YRKN(.))} + \mathrm{BYRH}(.,5) * \mathrm{LN(YYN(.))} + \mathrm{BYRH}(.,6) * \mathrm{DLN(YRH)}(-1) + \mathrm{BYRH}(.,7) * \mathrm{ECM}(-1)$$

[Equation 15]

Definitions:
"BYRH is a matrix of parameters (Cambridge Econometrics, 2014)"
"YRH is a matrix of average hours worked per week for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)"
"YRKC is a matrix of ICT technological progress for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)"
"YRKN is a matrix of non-ICT technological progress for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)"
"YRKS is a matrix of skills for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)"
"YRNH is a matrix of normal hours worked per week for 69/43 industries and 53

regions (Cambridge Econometrics, 2014)"
"YYN is a matrix of the ratio of gross output to normal output, for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)"

Equation 13 and equation 14 show the average hours worked and the change in average hours worked. Equation 13 considers normal hours worked while combining the impact of technology progress. Equation 14 takes into account also the actual/normal output by calculating the natural logarithm of the matrix of the ratio of gross output to normal output. Lagged change and error has been corrected by the last two items in the equation.

The export volume is calculated under similar rules, however the equations are slightly adjusted. The external export volume equations are listed below.

Co-integrating long-term equation:

$$\begin{aligned}\mathrm{LN(QEX(.))} = {} & \mathrm{BQEX(.,10)} + \mathrm{BQEX(.,11)} * \mathrm{LN(QWXI(.))} + \mathrm{BQEX(.,12)} \\ & * \mathrm{LN(PQRX(.)/EX)} + \mathrm{BQEX(.,13)} * \mathrm{LN(PQRE(.)/EX)} + \mathrm{BQEX(.,14)} \\ & * \mathrm{LN(YRKC(.) * YRKS(.))} + \mathrm{BQEX(.,15)} * \mathrm{LN(YRKN(.))} \\ & + \mathrm{BQEX(.,16)} * \mathrm{SVIM} + \mathrm{ECM}\end{aligned}$$

Dynamic equation:

$$\begin{aligned}\mathrm{DLN(QEX(.))} = {} & \mathrm{BQEX(.,1)} + \mathrm{BQEX(.,2)} * \mathrm{DLN(QWXI(.))} + \mathrm{BQEX(.,3)} \\ & * \mathrm{DLN(PQRX(.)/EX)} + \mathrm{BQEX(.,4)} * \mathrm{DLN(PQRE(.)/EX)} + \mathrm{BQEX(.,5)} \\ & * \mathrm{DLN(YRKC(.) * YRKS(.))} + \mathrm{BQEX(.,6)} * \mathrm{DLN(YRKN(.))} \\ & + \mathrm{BQEX(.,7)} * \mathrm{DSVIM} + \mathrm{BQEX(.,8)} * \mathrm{DLN(QEX)(-1)} + \mathrm{BQEX(.,9)} \\ & * \mathrm{ECM(-1)}\end{aligned}$$

**The Industrial Employment Equations**

Co-integrating long-term equation:

$$\begin{aligned}LN(YRE(.)) = {} & BYRE(.,10) + BYRE(.,11) * LN(YR(.)) + BYRE(.,12) \\ & * LN(LYLC(.)) + BYRE(.,13) * LN(YRH(.)) + BYRE(.,14) \\ & * LN(PQRM(5,.)) + BYRE(.,15) * LN(YRKC(.) * YRKS(.)) \\ & + BYRE(.,16) * LN(YRKN(.)) + ECM\end{aligned}$$

[Equation 16]

Dynamic equation:

$$\begin{aligned}\mathrm{DLN(YRE(.))} = {} & \mathrm{BYRE(,.1)} + \mathrm{BYRE(,.2)} * \mathrm{DLN(YR(.))} + \mathrm{BYRE(,.3)} \\ & * \mathrm{DLN(LYLC(.))} + \mathrm{BYRE(,.4)} * \mathrm{DLN(YRH(.))} + \mathrm{BYRE(,.5)} \\ & * \mathrm{DLN(PQRM(5,.))} + \mathrm{BYRE(,.6)} * \mathrm{DLN(YRKC(.) * YRKS(.))} \\ & + \mathrm{BYRE(,.7)} * \mathrm{DLN(YRKN(.))} + \mathrm{BYRE(,.8)} * \mathrm{DLN(YRE)(-1)} \\ & + \mathrm{BYRE(,.9)} * \mathrm{ECM(-1)}\end{aligned}$$

[Equation 17]

Definitions:
“BYRE is a matrix of parameters (Cambridge Econometrics, 2014)”
“YRE is a matrix of total employment for 69/43 industries and 53 regions, in thousands of persons (Cambridge Econometrics, 2014)”
“YR is a matrix of gross industry output for 69/43 industries and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)”
“YRH is a matrix of average hours worked per week for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)”
“YRLC is a matrix of employer labour costs (wages plus imputed social security contributions) for 69/43 industries and 53 regions, local currency at current prices (Cambridge Econometrics, 2014)”
“YRKC is a matrix of ICT technological progress for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)”
“YRKN is a matrix of non-ICT technological progress for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)”
“YRKS is a matrix of skills for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)”
“PYR is a matrix of industry output prices for 69/43 industries and 53 regions, 2005=1.0, local currency (Cambridge Econometrics, 2014)”
“YREE is a matrix of wage and salary earners for 53 regions, in thousands of persons (Cambridge Econometrics, 2014)”
“PQRM is a matrix of import prices for 69/43 industries and 53 regions, 2005=1.0, local currency (Cambridge Econometrics, 2014)”

Equation 16 and equation 17 demonstrate the total employment and change in total employment. Equation 16 generates the result by adding up results of natural logarithm of real output, real wage costs, hours worked, real oil price, ICT and non-ICT technological progress. For calculating changes in total employment, a lagged change and error term have been are added in equation 17 (these are the last two items).

**Price Index**

The price index is derived by the industrial price equations in the E3MG model. The equations for Industrial Price can be seen below:

Co-integrating long-term equation:

$$\mathrm{LN(PYH(.))} = \mathrm{BPYH(.,9)} + \mathrm{BPYH(.,10)} * \mathrm{LN(YRUC(.))} + \mathrm{BPYH(.,11)} * \mathrm{LN(PQRM(.))} + \mathrm{BPYH(.,12)} * \mathrm{LN(YRKC(.)} * \mathrm{YRKS(.))} + \mathrm{BPYH(.,13)} * \mathrm{LN(YRKN(.))} + \mathrm{ECM}$$

[Equation 18]

Dynamic equation:

$$\mathrm{DLN(PYH(.))} = \mathrm{BPYH(.,1)} + \mathrm{BPYH(.,2)} * \mathrm{DLN(YRUC(.))} + \mathrm{BPYH(.,3)} * \mathrm{DLN(PQRM(.))} + \mathrm{BPYH(.,4)} * \mathrm{DLN(YRKC(.)} * \mathrm{YRKS(.))} + \mathrm{BPYH(.,5)} * \mathrm{DLN(YRKN(.))} + \mathrm{BPYH(.,6)} * \mathrm{LN(YYN(.))} + \mathrm{BPYH(.,7)} * \mathrm{DLN(PYH)(-1)} + \mathrm{BPYH(.,8)} * \mathrm{ECM(-1)}$$

[Equation 19]

Definitions:

"BPYH is a matrix of parameters (Cambridge Econometrics, 2014)"

"PQRM is a matrix of import prices for 69/43 industries and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)"

"YR is a matrix of gross industry output for 69/43 industries and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)"

"YRKC is a matrix of technological progress for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)"

"YRKN is a matrix of non-ICT technological progress for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)"

"YRKS is a matrix of skills for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)"

"QR is a matrix of gross output for 69/43 industries and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)"

"QRM is a matrix of imports for 69/43 industries and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)"

"QRX is a matrix of exports for 69/43 industries and 53 regions, m euro at 2005 prices (Cambridge Econometrics, 2014)"

"YYN is a matrix of the ratio of gross output to normal output, for 69/43 industries and 53 regions (Cambridge Econometrics, 2014)"

"QYC is an input-output coefficient matrix (Cambridge Econometrics, 2014)"

"YRLC is a matrix of labour costs for 69/43 industries and 53 regions, local currency at current prices (Cambridge Econometrics, 2014)"

"YRT is a matrix of net taxes for 69/43 industries and 53 regions, local currency at current prices (Cambridge Econometrics, 2014)"

"V- indicates a current price version of the variable (Cambridge Econometrics, 2014)"

Equation 18 and equation 19 show the industrial price and the change in price. Equation 18 covers unit cost, import price, ICT and non-ICT technology index in order to derive the result. The dynamic equation shown by equation 18 also calculates the actual/normal output, lagged change and error term.

### 3.4.2 E3MG scenario preparation

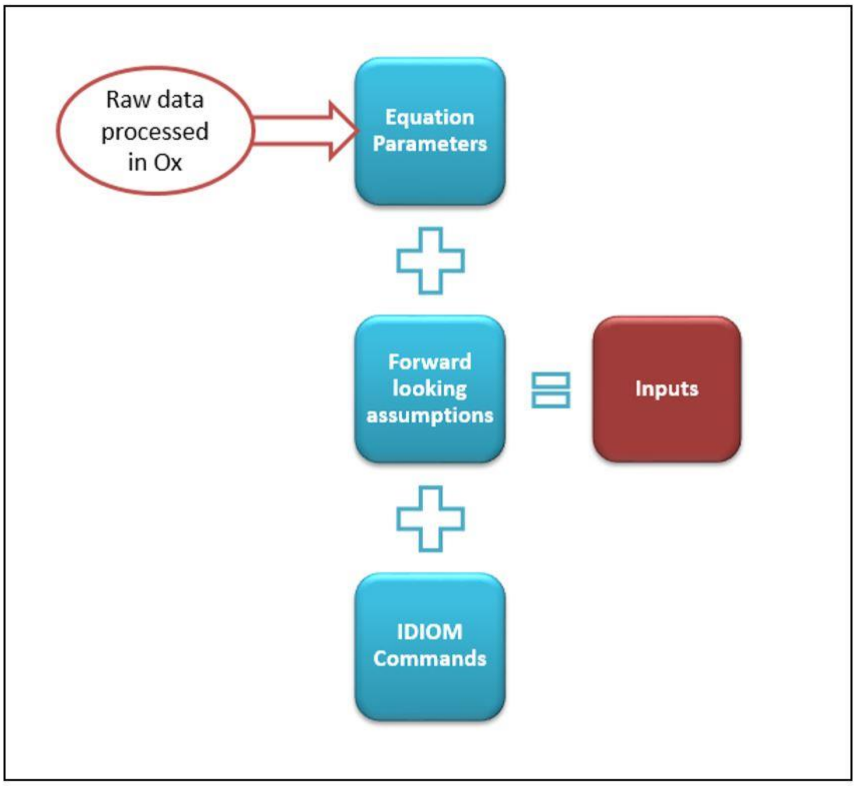
China's "New Normal" development strategy is aimed to achieve a better development pattern by making structural change in traditional industrial structure and implementing explicit policies on energy use and limiting greenhouse gas emission. It is believed that China's coal consumption is approaching its maximum level in the coming years. In line with China's commitments to peak its greenhouse gas emission in 2030, China's "New Normal" policies need to establish a complicated and specific mechanism to achieve all these goals.

The E3MG model, combined with the advantages of econometric techniques and characters of CGE models, is able to provide estimations of long term results which include its economy, environment and energy indicators towards specific policy changes. E3MG model is specialised in the long term analysis with its equations used to derive the outcomes under the long term restrictions. The long term forecasting combines the function of an error correction model, which functioned to adjust the impacts that dynamic relationships bring to the result.

Therefore, the E3MG model is an ambitious modelling tool with a skill to analyse the impact of complicated policy packages, which extends the capability of methodology from applying economic theory to deriving practical econometric impacts. Provided all these characters and capabilities, the E3MG model is an ideal model to apply in analysing the economic, environmental and energy impacts of China's "New Normal" policy.

The E3MG model consists of three functioning units. "One accounting framework of the economy, based on ESA95, coupled with balances for energy and material demands and environmental emission flows. (Cambridge Econometrics, 2014)" "A database covering a time period since 1970, and sectoral disaggregation at the NACE 2-digit level. (Cambridge Econometrics, 2014)" And "an econometric specification of behavioural relationships in which short-term deviations move towards long-term trends. (Cambridge Econometrics, 2014)"

*Figure 11: Inputs of E3MG*




As it is illustrated in the figure above, in the model establishing stage, there is no one single software that can satisfy all the requirements of the E3MG model, so the data processing is done by several software programmes correspondingly.

When implementing the model, we will basically deal with three main components, which are the energy, environment and economy modules (as specified in the presentation of the equation structure above).

In order to fit the “New Normal” policy into the E3MG model, it is necessary for us to extract the critical information from the “New Normal” policy that is related to each sector. For example, in economy sector, the information about the tax rate, growth in government expenditure, interest rate and exchange rate are usually required. For energy sector, we need to know the world oil price and new regulations in energy industry. By processing the “New Normal” policy into extracted information, these information will be fit into the model as exogenous inputs.

In the economy sector, the “New Normal” policy tends to slow down the economic growth, lower the expenditure on low value added and highly polluted industry, lower the interest rate and exchange rate in order to compensate for the decrease in structural improvement;

In energy sector, the “New Normal” policy tends to implement stricter regulation on energy use, especially coal fired energy. After the concept of the “New Normal” was announced by Xi Jinping, the government plan for 2015 aimed to cut energy intensity by 3.1 percent and extend the usage of green energy. Additionally, import tariffs of multiple types of coal have been introduced since tariffs have been levied again since 2014 and there is a possibility that the “New Normal” policy will introduce the carbon tax to China in the near future;

In terms of the environment sector, the GHG emission reduction goal can seem as one of the main targets of the “New Normal” policy in environment protection sector, peaking China’s GHG emission in 2030.

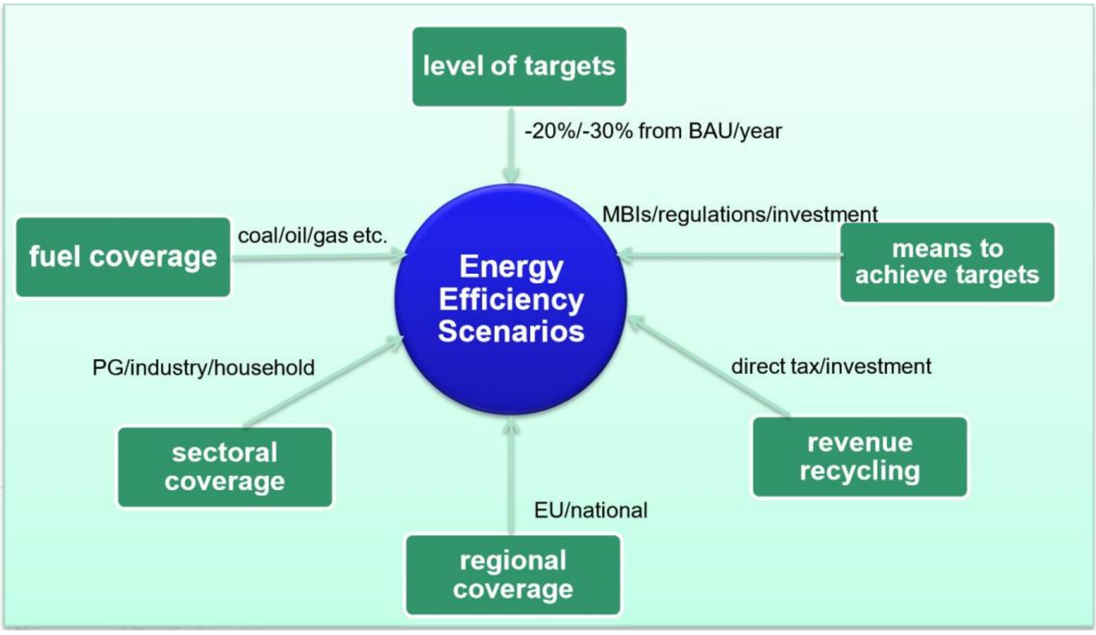
All these inputs listed above will be explicit in data preparation section. After inserting these exogenous factors into E3MG model, the model will process these factors. Economy module will analyse the economic activities and generate a general price level. Energy module will receive the general price level and generate the prices of the specific type of energy consumed. The energy module will pass on its results to emission module and the emission module will further provide information for the economic module. This closes the system of equations in order to analyse the policy change.

### 3.4.2 E3MG scenario definition

Scenario formulation is a critical part in the E3MG model because it defines how we simulate policy targets and present important indicators that the “New Normal” policy contains into E3MG model ‘language’. Normally, the E3MG model contains more than one scenario whereby a baseline scenario is always the indispensable starting point.

The E3MG model is able to make projections with a given package of figures but it is more commonly used in policy analysis. The policy analysis in the E3MG model is usually operated by the use of a baseline scenario and related policy scenarios. All these scenarios can be linked to each other. By comparing the differences in results derived from each scenario with the baseline, the impacts that each policy would have at a specific moment in the future can be assessed.

*Figure 12 Factors in scenario design*




Source: (Pollitt, 2013)

**The baseline scenario:**

In most cases, the results of the E3MG model scenarios are illustrated as the percentage difference compared to the baseline. This way of presenting results implies that not only the policy scenario – i.e. the "New Normal" policy – is important, but also how the baseline is defined matters. This always implies assumptions as to how the future may look like – which implies there are error margins that need to be taken into account. However, based on conclusions from previous studies that have used the E3MG model, values related to baseline scenario have proven to be robust. Nonetheless, they have a significant influence on the results of the analysis. Examples of circumstances that show the reason why results of baseline scenarios are important for the final results of the E3MG analyse are:

- When there is a scenario target to achieve a specific emission reduction (i.e. a 30 percent lower $CO_2$ emission in 2030 compared to China's 1990 level). The baseline scenario needs to work out the amount of effort that needs to be spent in order to achieve the target, so that other reference scenarios can estimate the corresponding efforts referring to the baseline result.
- If there is a scenario that leads to an increase in the energy price (e.g. China decides to levy a 1 percent tax on coal use), the baseline scenario will provide reference to the scenario, so that the relative impact of increased energy price will be demonstrated.

**Scenarios for “New Normal” analysis:**

1. The **baseline scenario** is designed to hold the line of trends and policies at China’s level during 2000-2010. The average **GDP growth** was 10.5 percent on average. The overall investment share of GDP and high capital allocation in **heavy industry** is set to be high (especially steel and cement). The investment in service industry and in manufacturing industry which has a higher added value is relatively low. And there is the assumption of high **consumption of coal** as an energy resource that will continue.

2. The **“New Normal” or “Peak 2030” scenario** is designed in line with the “New Normal” trend. Since there are no detailed official targets announced by the government, assumptions regarding this scenario will be made based on the latest trends. The average **GDP growth** slows down to around 7 percent annually. The scenario assumes a lower investment share of GDP in heavy industry. There is an Increase of investments in service industries and in manufacturing industries which have a higher added value. Lower **consumption of coal** as an energy resource is assumed. And the scenario ensures that **China’s GHG emissions peak** in 2030. (We assume an emission target reduction from 16.5 GT to 13.8GT, based on the relevant forecasting result) (Stern, China's "New Normal": structural change, better growth, and peak emissions, 2015).

**Table 2** *Summary of scenario*

| Scenarios | Emission reduction goal | Policy measures | Revenue recycling |
|---|---|---|---|
| **Baseline** | No | Tariff, no carbon tax | No |
| **Peak 2030** | Peak CO2 emission in 2030. (Between13.8 GT and 16.5 GT) | Tariff and carbon tax | tax revenues are used to reduce government debt |

**Table 3** *Table 3 Possible E3MG carbon tax input (RMB Yuan/ toe*

| Year | Baseline Scenario | Peak 2030 | | |
|---|---|---|---|---|
| | All energy types | Coal | Fuel | Natural Gas |
| **2010-2014** | error | 9 | 13.84 | 9.77 |
| **2014-2018** | error | 11 | 17 | 12 |
| **2018-2022** | error | 13.37 | 20.66 | 14.6 |
| **2022-2026** | error | 16.25 | 25 | 17.7 |
| **2026-2030** | error | 20 | 30.53 | 21.55 |

(Notes: Figures based on 1 Euro= 6.8 RMB, the value is set to be “error” for years without carbon tax )

## 3.5 Data

The E3MG model is a software based econometric model, the software is designed in a user friendly way. But it requires a large number of data resources. Given this fact, data preparation becomes a critical procedure in implementing the model in our research. As said before, there is no official plan that has been released as a complete quantitative picture, giving exact figures of the future targets for China’s “New Normal” policy (until now). The scenario data in this research will be derived from historical figures, current policy trends and potential policies. For the necessary data which is absent in the existing policies, we will make assumptions based on the available information.

### 3.5.1 Process of gathering the raw data

The following software is necessary in data processing:

- Fortran: “The Fortran 95 programming language is used in writing source code for E3MG model. (Cambridge Econometrics, 2014)” “It is compiled using the Intel Fortran compiler. (Cambridge Econometrics, 2014)”
- IDIOM: This software is functioned as pre-complied set of Fortran, and it enables users to make changes of the input without changing the source code.
- DOS: “The model is usually run from a command line, using cmd batch files. (Cambridge Econometrics, 2014)”
- Visual Basic: “This visual basic language allows the model to be run without requiring any programming expertise. (Cambridge Econometrics, 2014)”
- Ox: “The Ox is applied to process data, estimate parameter and manipulate the results. (Cambridge Econometrics, 2014)”

### 3.5.2 Data inputs

In order to work out detailed sectoral outputs, extensive and specific data inputs are needed in the E3MG model. The following databases will be used to feed into the E3MG model:

- A time series database covering 1970-2015.
- Data for baseline forecast
- Multiple sectoral data
- Bilateral trade data

- Data about emissions, energy consumption and energy prices
- Material data

All these data will have to be processed by Ox software before fitting it into the E3MG software. In the following paragraphs, we will collect and list all the necessary data resources for analysing the China's "New Normal" policies with the help of the E3MG model.

**Times-series economic data:**
China's Investment
China's Gross Value Added Manufacturing (The World Bank Group, 2015)
China's Research and Development Spending (The World Bank Group, 2015)
China's Household Expenditure for different product
China's Import
China's Export
China's Employment
China's Current Labour Cost
China's Average Working Hours

"Apart from this data, time series data on macro level such as China's GDP, household incomes, exchange rates, tax and interest rates, and unemployment rate are also needed. (Cambridge Econometrics, 2014)" This data can be also obtained from The World Bank database. Normally, for the time series data, the E3MG model uses data from Eurostat, AMECO as primary source because it was initially designed to serve European countries. However, as China is a non-European country, the data on China is more limited. In order to expand the data sources, we will use the OECD's STAN database, the World Bank database, the Asian Development Bank database, etc. The gaps in data will be compensated by the national data.

**Table 4** *China's GVA Manufacturing, R&D and Household consumption*

| Type | 2011 | 2012 | 2013 | 2014 | Unit |
|---|---|---|---|---|---|
| **Gross Value Added Manufacturing** | 32 | 31 | 31 | 31 | % of GDP |
| **R&D Spending** | 1.76 | 1.84 | 1.98 | - | % of GDP |
| **Household final consumption expenditure** | 36.6 | 37.7 | 36.6 | 36 | % of GDP |

Source: (IBRD.IDA, 2015)

**Table 5** *China's Unemployment, Labour Cost and Average Working Hour*

| Type | 2010 | 2011 | 2012 | 2013 | Unit |
|---|---|---|---|---|---|
| **Unemployment** | 4.2 | 4.3 | 4.5 | 4.6 | % of total labor force |
| **Labour Cost** | 109.1 (2012) | 108.4 (2013) | 105.7 (2014) | 104.5 (current) | Yuan |
| **Average Working Hour** | 8.66 | 8.66 | 8.66 | 8.66 | Hours per day |

Source: (The World Bank, 2014) (Trading Economics, 2015)

**Cross sectional data:**

The cross sectional data refers to data that does not have time series character and data that normally does not change over a period of time. The cross sectional data is illustrated by input-output tables which include:

- China's Domestics Production in different sections
- China's imports in these sections

This data will be used to calculate the coefficients which shows the amount of inputs needed to produce the same amount of output.

**Bilateral trade data:**

Bilateral trade data includes 4 dimensions: time, origin, sector and destination. China's bilateral trade data with be obtained from the OECD and the International Trade Centre.

**Table 6** *Product imported by China from 2010-2014 (partially E3MG inputs)*

| | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|
| **Mineral fuels, oils, distillation products, etc** | 188,965,812 | 275,766,337 | 313,066,988 | 315,232,252 | 316,660,509 |
| **Iron and steel** | 25,326,244 | 28,380,643 | 23,280,399 | 21,335,562 | 21,179,186 |
| **Electrical, electronic equipment** | 314,282,498 | 350,954,252 | 381,520,999 | 439,417,537 | 425,097,326 |
| **Plastics and articles thereof** | 63,704,657 | 70,198,652 | 69,424,491 | 72,390,786 | 75,195,997 |

| | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|
| **Cotton** | 10,619,616 | 14,730,025 | 18,681,444 | 17,229,073 | 12,758,667 |
| Overall Import | 1,396,001,600 | 1,743,394,900 | 1,818,199,200 | 1,949,992,315 | 1,962,085,985 |

Source: (International Trade Centre, 2014)

**Energy and emissions data:**

The energy data for E3MG is normally collected from the International Energy Agency, and the energy consumption data for countries is usually time series data on a yearly basis. However, as China is currently not a member of the International Energy Agency, we will collect the missing data from the national data base or other data resources.

In order to analyse the impact of China's "New Normal" policies, we choose coal, fuel, natural gas, and electricity as the four main types of energy to study. There is one point where we are supposed to pay special attention: double counting needs to be avoided in data collection. For example, the coal consumed to generate electricity should not be calculated again when assuming the coal fired power generating plant.

Energy price can be presented with and without tax, in line with the E3MG model's instruction in energy data collecting, we will follow these rules:

- "Tax will be assumed as zero when data are missing for all the years. (Cambridge Econometrics, 2014)"
- If data are missing for the last few years, the tax will be assumed as same as the last year's data.
- If data is missing for the first few years, the tax will be assumed to rise 5 percent per year until the first year that data is available.
- We do not consider subsidies as part of the "New Normal" policy (which means that negative values will be ignored.)

**Table 7** *China's Energy Consumption* **(Enerdata, 2015)**

| Energy Type | 2010 | 2011 | 2012 | 2013 | 2014 | Unit |
|---|---|---|---|---|---|---|
| **Oil Products** | 399 | 418 | 438 | 452 | 465 | Mt |
| **Natural gas** | 106 | 129 | 144 | 166 | 181 | bcm |
| **Coal, lignite** | 3000 | 3305 | 3397 | 3577 | 3473 | Mt |
| **Power** | 3626 | 4052 | 4326 | 4656 | 4833 | TWh |

For emission data, we will collect it in a time series format from the OECD. The GHG emission data can be disaggregated by energy users.

**Materials data**

For analysing China's "New Normal", the materials data will be mainly collected from the OECD. Material data includes mainly exports and imports of consumed materials.

# 4 Results and Analysis

In this Chapter, we will present the results of the quantitative research stemming from the use of the E3MG model looking at the potential impact of China's New Normal on the economy, environment and energy.

**GDP Growth and $CO_2$ Emissions**

In China's "New Normal" policy, the mechanism of scenarios we have established was not by setting CO2 emissions constraints. Instead, the emission levels are forecasted as the result of assumed future economic growth, structural improvement, energy efficiency and etc. All the changes towards these factors caused by the "New Normal" policies or relevant assumptions of policy changes will affect the energy production and consumption patterns. In this research, it considers the economic and energy conditions that with high possibility lead to a peak CO2 emission in 2030.

In order to elaborate the results, it is necessary to understand the key relationship between economic growth, energy consumption and CO2 emissions:

$$Em = \left(\frac{Em}{En} \times \frac{En}{y}\right) \times y$$

"Em" refers to CO2 emissions;
"En" refers to energy consumed;
"y" refers to economic output

If the value of $\frac{Em}{y}$ falls by b percent and output increases by c percent, (1) indicates that:

(2) The rate of growth of $\mathrm{Em} = (\mathrm{c} - \mathrm{b})\%$
By which it means emission increase if c>b, decrease if c<b
To be more specific, growth rate Em equals c-b

(3) $-\mathrm{b} = -(\mathrm{f} + \mathrm{g})$

"f" refers to rate of growth of $\frac{\mathrm{Em}}{\mathrm{En}}$;

"g" refers to rate of growth of $\frac{\mathrm{En}}{\mathrm{y}}$

However, there may still be an interaction relationship between b and c. (Stern, China's "New Normal": structural change, better growth, and peak emissions, 2015) For example, if the economy is dynamic, there might be a high investment and growth which leads to higher R&D investment. Otherwise, if the value of b decreases, it might mean the economy lacks R&D investment, which could result in a slower growth rate.

The estimated economic growth for China's economic growth is presented in the table below:

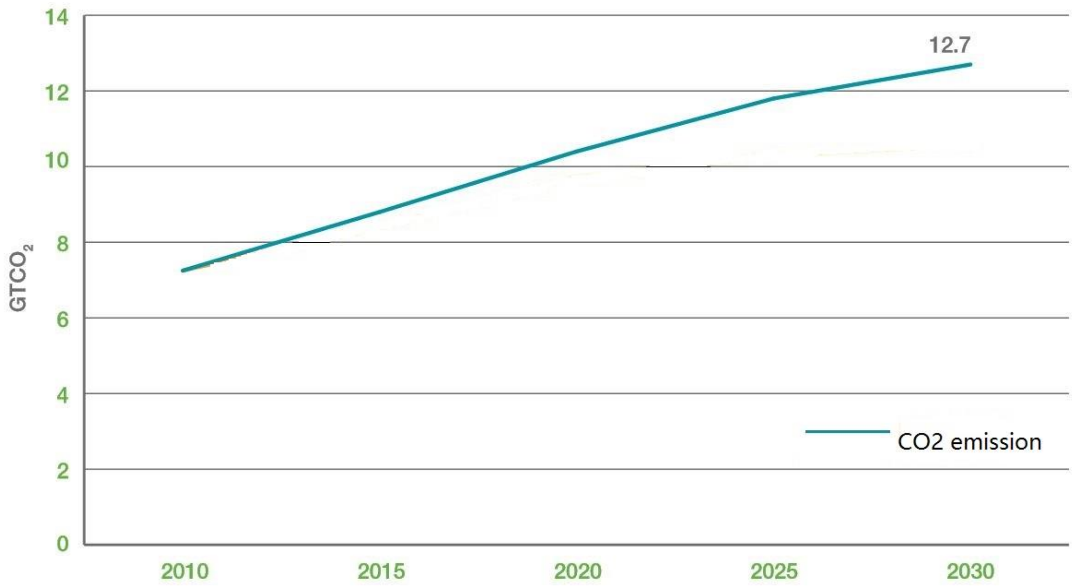
**Table 8** *Results of E3MG model 2030*

| 2030 | | Base | Scenario | Change in percentage |
|---|---|---|---|---|
| **Carbon price** | € /tCO2 (2005) | 0 | 168.1196 | |
| **GHG emissions** | mtCO2 | 17547.04 | 14277.69 | -18.6 |
| **Final energy consumption** | th toe | 2372073 | 2132016 | -10.1 |
| **GDP** | € m 2005 | 10718185 | 10423186 | -2.8 |
| **Consumption** | € m 2005 | 3764951 | 3508588 | -6.8 |
| **Investment** | € m 2005 | 4698458 | 4684730 | -0.3 |
| **Exports** | € m 2005 | 7409360 | 7382608 | -0.4 |
| **Imports** | € m 2005 | 6827134 | 6824502 | 0.0 |
| **Employment** | thousands | 1250745 | 1249284 | -0.1 |
| **Price index** | 2005=1.0 | 1.367 | 1.46 | 6.8 |

**Gross Domestic Product (GDP)**

As we can see from the results, the GHG emission of baseline scenario is predicted to be 17.547 MT in 2030 – that is: the expected level of GHG emissions without a change in policy. If the "New Normal" is simulated, pushing for a GHG emissions peak in 2030, we see that this implies a total amount of GHG emissions of 14.278 MT. The GHG emission of Peak 2030 scenario is 18.6 percent lower compared to the business-as-usual baseline scenario. In the baseline, Chinese GDP is estimated to be 10.7€ trn while the Peak 2030 scenario shows an expected GDP of 10.4€ trn. This boils down to a 2.8 percent difference: with the "New Normal" policy, Chinese GDP will be 2.8 percent lower in 2030 that it would be otherwise. This outcome can be understood intuitively if we recall that the difference between the "New Normal" and the baseline scenarios is a different estimated growth rate for China (i.e. GDP), resulting in different levels of GHG emissions. The extent to which China achieves the GHG reduction emission is highly related to China's economic growth in the next decade. This finding corresponds to the conclusion of a report jointly done by Tsinghua and MIT towards energy and climate in China. In the report, it proved with a modelling exercise that "It would not be possible for China to peak its CO2 emission in 2030 if China's GDP growth rate keep staying higher than 5 percent per year on average over the 2020-2030 period. (Zhang Xiliang, 2014)" The challenge with these predictions – as also shown above when looking at the link between dynamic innovation (and thus potentially more energy- and GHG-reducing new policies and inventions) and growth – is evident. If Chinese economy innovates, growth may not have to be reduced as much (or at all) and still the “New Normal” could still be achieved.

*Figure 13 China’s CO2 forecast*




Source: (Zhang Xiliang, 2014)

The Peak 2030 scenario results in peaking CO2 emissions in 2030. From the E3MG model, we can conclude that the peak 2030 scenario’s economic growth rate at this moment is lower than the target 7 percent growth rate. As such, if China keeps on growing with 7 percent - given constant levels of technology – GHG emissions will not peak in 2030. The GDP growth rate forecasts for China from the World Bank and the IMF suggest that they are expected to be closer to 7 percent than to 5 percent (the peak 2030 growth rate suggestion by Zhang Xiliang (2014)). Furthermore, the “New Normal” has already commenced – there is no clear point when this new policy started to be implemented. As such, the “New Normal” transformation has already started and could well (not measured yet) be on the way. What remains vital in any case is that in order for China to play safe with the “New Normal” (i.e. minimising the risk that the “New Normal” will inhibit growth), the “New Normal” should also focus strongly on increasing the rate of innovation into energy-saving technologies and environmentally-friendly ways of production. In that way the link between growth and pollution is decoupled, raw material and energy use per final product will drop and higher growth rates, while still achieving the “New Normal”, can be maintained.

In the energy sector, final energy consumption of the baseline scenario is predicted to be 2372073 thousand toe in 2030. In the Peak 2030 scenario it decreases to

2132016 thousand toe in 2030. This implies a 10.1 percent difference in energy use, which is quite significant. These results indicate that the “New Normal” policy we simulated by “Peak 2030” scenario is potentially likely to cut back Chinese energy consumption to a large extent. Additionally, the carbon price in our E3MG model is predicted to be 168 Euros per tonne of CO2. Such carbon price is quite high, especially when looking at the current price. The reason for this is that the Future Technology Transformations for the power sector in the model are quite insensitive to carbon prices. Regulations on coal, plus subsidies would reduce the required carbon price substantially. Moreover, the E3MG model applied in this research does not instantly assume long-term adjustment so there are delays and lagged effects, which pushes the required price a bit up for 2030.

Apart from GDP (already discussed above) the E3MG model captures six other macroeconomic indicators that are relevant for our research: consumption, investment, exports, imports, employment and price index. Due to a different emphasis in the “New Normal” policy simulation, the macroeconomic indicators are affected in a different way compared to the baseline. We will discuss each of these variables below:

**Consumption**

The consumption estimation in the baseline scenario shows that in 2030 the total consumption in China is likely to be 3.8€trn. However, in the Peak 2030 scenario, the consumption is shown to be 3.5€trn. This is 6.8 percent lower compared to the baseline result. This decrease in consumption happens because the energy price is higher as a result of the new policy, which further leads to increases in prices of other commodities and services. The decreased consumption is likely to be part of the explanation why GDP drops in the Peak 2030 scenario. However, this is the side-effect of the new policy: it is helpful for reducing GHG emissions and the decrease is possibly compensated by other policy instruments.

**Price index**

In our model run, we set the price index for 2005 to be “1.0”. On this basis, the baseline scenario result leads to an index of 1.367 in 2030, while in the Peak 2030 scenario it is 1.46. The price index of the Peak 2030 scenario is therefore 6.8 percent higher than the baseline. The higher energy price is one of the main reasons why the price index is driven up.

**Investment**

In the baseline scenario, investment is estimated to be 4.70€m=trn while in the Peak 2030 scenario the estimated figure is 4.68€trn. That amounts to a 0.3 percent decrease compared to the baseline. As the “New Normal” policy is designed to lower heavy industry oriented investment, this is an expected result of our research. Actually a marginal drop of 0.3 percent while focus of the “New Normal” policy is to decrease heavy industry investment, implies that significant amounts of investment must be channelled to other sectors – otherwise the drop would be much higher.

**Employment**

Employment is not going to be affected by the “New Normal” policy compared to the expected baseline figures. The baseline scenario predicts there to be 1.251 billion employed in 2030. According to the “New Normal” policy Peak 2030 scenario, this number is 1.249 billion. This is a very marginal decrease in employment of 0.1 percent. The employment effect is not just about total numbers, however. If investment in heavy industry is declining, and some is channelled to other sectors, the stationary employment figure implies that – even with the E3MG Keynesian demand functions (that allow for less than full employment) – jobs shift from heavy industries to other sectors. And that there is enough demand to accommodate that shift. Thus achievements in other sectors will stand out as a consequence. These data suggest that the “New Normal” policy could support growth of the service industry and higher value added industries to create more jobs that are lost in – for example – heavy industry. Other instruments such as decrease the average working hours is also a possible policy instrument to be taken.

**Exports and Imports**

The export and import results from the E3MG model compare the “New Normal” scenario with the baseline scenario. The results are presented in the Table below.

**Table 9** *Example Export and Import Figures*

| | Baseline scenario | Peak 2030 scenario |
|---|---|---|
| Exports (€ trn) | 7.41 | 7.38 |
| Imports (€ trn) | 6.83 | 6.82 |

The scenario simulation shows that exports tend to decrease by 0.4 percent in Peak 2030 scenario and imports keep steady. This does imply that the Chinese trade surplus will diminish marginally because of the “New Normal” policy – as a consequence of the fact that imports do not change since in country from where China imports no policy changes are modelled. However, exports become more costly to produce due to higher energy prices and a focus on sustainable growth and production – reducing to a small extent the economic cost competitiveness of the Chinese economy. For the long-run, however, this may not be a problem, because other factors than cost competitiveness will matter in the future – e.g. sustainable production and re-use of materials through the circular economy.

# 5 Conclusions

China has been growing at an incredible pace over the past 30 years. Recently the growth engine has slowed down a bit, but nonetheless, the question is how future economic development for China will look like and inter alia what that means for sustainable development in terms of the environment and GHG emissions. To put it in a different way: there is economic growth and there is economic growth.

**Methodological approach**

This research has focused on what the potential impact of China's "New Normal" policy – a policy focused on more sustainable economic growth in the future – is in terms of energy, environment and economy. The idea for the "New Normal" came from the latest policy trend introduced by China's Chairman Xi Jinping. This new policy trend aims to provide opportunities to achieve a lower-steady-state growth but still dynamic economy, while giving more consideration to energy efficiency, environmental protection, CO2 emission reduction, etc. As the country's development is driven by the synergies between different the sectors. The energy sector, the environment and the economy interact with each other under the influence of exogenous policy changes. We have extracted the core elements from various sources and speeches to develop the parameters to analyse a potential policy package in terms of the "New Normal" trend and integrate it with China's future CO2 emission reduction targets. In this way the potential changes in energy, environment and the economy from the "New Normal" policy can be assessed. In short, based on various sources, including keynote speeches, our research concludes that the "New Normal" policy as: "slower economic growth, structural adjustment, switching economic growth from investment driven to innovation driven, reduce CO2 emissions and improve environment quality."

With its focus on energy- environment- economy analysis, the E3MG model is the best methodological tool we could use to analyse the E3 impact of the "New Normal" policy. Through the E3MG model, we stylised the "New Normal" policy to simulate a future situation based on the combination of historical data with the "New Normal" policy. The extensive and carefully maintained data in the E3MG database provided the model with the necessary empirical basis to avoid making forecasts based on the micro-theoretical optimal behaviour assumption. Compared to other models that are frequently used in policy analysis, the E3MG model were proved being able to provide a representation of complicated real-world behaviour.

Quantifying the "New Normal" has meant that we defined a baseline projection until

2030: the most likely future scenario without any policy change. We then modelled the “New Normal” scenario, which we called the ‘Peak 2030’ scenario after the ambition to have GHG emissions peak in that year. We defined the GHG gas reduction goals for 2030 by using policy instruments that levy a carbon tax and increase coal tariffs. The revenue from tax and tariffs were used to reduce government debt, so that the loss in economic growth would be partially compensated. The scenarios have set different levels of policy instruments to reduce CO2 emissions and promote economic growth. By comparing the ‘Peak 2030’ scenario results with the results of the baseline scenario, we quantified the potential impact of the “New Normal” policy – gaining some interesting insights.

**Research results**

The E3MG simulation suggests that the “New Normal” policy will indeed achieve ambitious GHG emission and environmental goals. Seeing through the “New Normal” policy would results in 18.6 percent lower GHG emissions and 10.1 percent lower energy consumption in 2030 than if nothing was done (i.e. the baseline). That is an absolute difference of 3.3 billion tonnes of CO2 per year by 2030. This is equivalent to the emissions of 1.4 billion litres of fuel each year, enough to drive around the earth (at the equator) 1619 times in a car (1 on 20) each year.

The energy and environmental results come at an impact on the economy, however. We recall that these ambitious environmental goals were reached by putting a tariff on coal use and by levying a carbon tax. GDP in 2030 will be 2.8 percent lower than without the “New Normal”. Consumption is expected to be 6.8 percent lower (due to higher prices by 6.8 percent). Exports will decline slightly (0.4 percent) while imports remain at the same level. Interestingly, investments are expected to decline only by 0.3 percent and employment by only 0.1 percent.

When interpreting these economic results, we need to realise that the E3MG model couples economics to environment through emission coefficients. If they remain fixed, lower emission levels imply that also GDP will be lower. However, decoupling of the economy from the environment would be possible if energy efficiency and the circular economy are greatly enhanced, implying that the ‘price’ of the environment in economic terms would decrease. Therefore, an important policy recommendation that stems from this research is that China should focus strongly on creating entrepreneurship and stimulate R&D into energy efficiency and the circular economy to further decouple emissions from economic growth. The stronger the decoupling, the lower the GDP ‘price’ China has to pay to achieve its environmental and energy targets. And before we reach 2030 is still 15 years away.

Another interesting observation is the fact that investments and employment only drop marginally. This implies that investments and jobs shift away from heavy industries but towards other sectors – towards those sectors that are not taxed, like services or other manufacturing sectors. The same goes for employment. This implies that the "New Normal" policy has a structural adjustment consequence away from polluting towards cleaner sectors as engines for economic growth and that it does not lead to a big drop in aggregate demand (which we can state because of the Keynesian demand structure of the E3MG model that does not assume full employment by definition). That means that the "New Normal" is indeed a true sustainable growth strategy.

**Areas for further research**

The use of the E3MG model in this research means that we have used a state-of-the-art model to look at the 3E impact of the "New Normal" policy. But we need to acknowledge that also the E3MG is just a model, with its limitations and restrictions. There are two limitations that we want to mention – and that would warrant areas for further research. First of all, a very important potential positive effect of the "New Normal" policy is not taken into account. If China is able to significantly reduce GHG emissions, pollution levels will drop which will have a positive effect on human health – less asthma, less other respiratory problems, lower health costs, and lower healthcare costs. This effect is not factored into the E3MG model but it could be significant. Another important point to note is that the E3MG results do not include additional power sector investments. The model assumes that crowding out takes place (i.e. there is no net increase in investments because private and public investments cancel on the aggregate). If we would have assumed that power sector investments would only partially crowd out other investments, we could see a small positive effect of the power sector on GDP and also employment.

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