The Market for Energy in China

by
Shu-Kam Lee

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Abstract

Since 1979, China embarked on an economic reform to modernize the country. The reform was so successful that China was able to grow by an impressive rate of 9 percent per annum between 1979 and 1997. The rapid development of the economy leads to a drastic increase in demand for energy. Since China has the largest population in the world, its energy demand is nothing but huge. Each year, for example, China needs to install as much as 10,000 MW of new electricity generation capacity, which equals the current capacity of Netherlands. This increase in demand for energy, which is likely to continue, will have implications for global energy markets, the world price of energy and for the global environment as emissions of greenhouse gases grow rapidly.

Against this background, there is an urgent need for the country to better manage the energy sector so that the market can function in an orderly manner. To tackle this issue, I single out three important energy problems to study. First, I will examine the current situation of the energy imbalance in China. Second, I will forecast how rapid the energy demand will grow in future so that the deficit between the demand and domestic supply can be identified. Lastly, I will discuss some methods that can be used to manage the demand.

My finding shows that energy-capital and energy-material inputs are complementary, whereas the relationship of energy and labour is insignificant. In addition, the simulation exercises also reveals that a high energy pricing policy might not be effective in mitigating the demand and in encouraging firms to employ labour intensive techniques. Also, rising energy prices may bring spiral inflation and deterioration in the balance of payments and foreign resources. Therefore, government should act cautiously when increasing energy prices.

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" The LORD give wisdom, and from his mouth come knowledge and understanding." (Proverbs 2:6).

Chapter 1: Introduction

1.1 Background and Aims

Since the launch of economic reforms in 1979, China has successfully turned itself into one of the fastest growing economies in the world. The rapid economic expansion in turn has given rise to a steady rise in energy consumption[1]. The rise of the energy consumption after the reform was so drastic that China has surpassed the Russian Federation since 1994 and become the world's second largest consumer of energy after the United States (Sinton, 1996). In 1995, China produced 5,847.81 billion yuan of GDP and consumed 1,311.76 million tons of standard coal equivalent (SCE) [2] of energy.[3]

The importance of the energy sector is not limited only to the domestic economy. As observed by Wu and Li (1995), China has to rely increasingly on the external energy market for meeting its rapidly growing demand. As a result, China's energy imports soared 20-fold from only 2.61 million ton SCE in 1980 to 54.56 in 1995, whereas energy exports increase almost twofold from only 30.58 million ton SCE to 67.76. The rising gap between demand and indigenous supply inevitably needs to be met by increasingly greater amounts of energy imports. As

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[1] Note that the largest user of energy is industry. It accounted for about three-quarters of both total commercial energy and coal use in 1990. Whereas, the typical household consumes very little because most people are living in rural areas which are very poor. Therefore, the residential sector consumes only 12% of the total consumption in 1995.

[2] One standard coal equivalent (SCE) is 7,000 kilo-calories per kilogram.

[3] China Statistical Year Book (1996).

China's magnitude of energy trade (both exports and imports) is not small, the gap will invariably affect world energy trade and prices. Against such a backdrop, it is therefore essential to study China's energy development.

In spite of the fact that energy is fundamental and essential to the growth of the Chinese economy, not much research work have been devoted to the topic of energy imbalance in China. Among the existing studies[4], most are mainly qualitative analyses. By contrast, I attempt to employ some quantitative techniques to analyse China's energy consumption and pricing policies. One aim is to offer guidance towards formulating policy.

1.2 Outline of the Thesis

In order to achieve the above objectives, the thesis will be divided into four parts. Part A employs a descriptive approach to assesses China's ability to manage the energy sector. (Chapter 2). Part B and Part C are quantitative studies of energy issues. Part B predicts the demand for energy utilising a demand side approach (Chapter 3 to 4). Part C adopts a supply side approach to evaluate the role of government energy pricing policy in managing the energy industry (Chapter 5 to 7). Part D is a summary of the findings in the previous sections (Chapter 8).

[4] Such as Wu and Li (1995), Johnson (1995), China Statistical Information and Consultancy Service Centre (1990), Sinton and Levine (1994), Kambarra (1992), Nakajima (1992).

Before discussing the outline of the thesis, it is necessary to compare the demand side and supply side approaches. In the demand side set-up, the firm is treated simply as a consumer of various inputs. The demand equation is often specified by past experience and estimated by typical econometric techniques, such as general to specific approach, cointegration and an error correction model. Under this approach, specification and variables used in the model are freely chosen, and then tested down to the final preferred model. As this approach simply specifies the relationship between input demands and other exogenous variables, which normally includes input prices, output level and structural variables etc., the relevant price elasticities (i.e. price/cross price elasticities) are easily computed. For example, the estimated coefficients of the price variables in a double log-linear demand function are price elasticities, which can also be obtained from multiplying the ratio of quantity demanded to price with the price coefficients of a linear demand equation. Based on the estimated coefficients, one can forecast the future energy demand.

However, there are a number of problems associated with this approach. For instance, one may question critically which variables should be included in the demand equation. Furthermore, it is likely that too many explanatory variables would be introduced which gives rise to the so-called "degrees of freedom lost" problem. This problem is particularly serious when the sample size is relatively small.

In the second approach, the firm is treated as a supplier of a final good or service, so this kind of estimation is commonly referred to as the "supply side approach". The starting point is to specify an indirect profit function (cost function) which has a number of well-known production features.[5] After obtaining this function, one can use Hotelling's Lemma (Shephard's Lemma) to derive the output supply and input demand equations (conditional input demand equations), and then estimate them using sample data. The explanatory variables used in this model are therefore based on optimising theories and normally restricted to prices of all inputs and outputs for cost minimisation (or instead, price of output and input for profit maximisation). One obvious drawback of this approach is that it may exclude some variables that have important bearing on the energy demand. Typical examples are the structure of the economy - an economy that has a high composition of heavy manufacturing, is likely to consume more energy than the one with a small share of such industry. In addition, the price elasticities derived from this approach are more complicated than those obtained under the "demand side approach". Besides, different functional forms (such as translog and quadratic) and assumptions of firm behaviour (either profit or cost equation) might result in different input demand functions and price elasticity formulae. Hence, the first approach is much easier and more flexible in term of specification of the input demand functions and calculation of the elasticities, while the second approach has a more solid theoretical basis.

Beyond this, there is one more important difference between these two approaches. The first approach usually requires national time series data. On the

5 For example, an equi-proportionate change in output prices and all input prices does not alter the input mix or encourage the firm to produce more output i.e. the producer does not suffer from money illusion. In addition, this theory also requires that the derivative of the profit function with respect to the output and input price are homogenous of degree zero in output and input price. We will discuss the properties in later chapters.

other hand, it is more appropriate to use a pooled firm data set for the second approach, since it incorporates the rational choices of inputs by firm. Usually, these kinds of data are available only at the micro-level only. As I am able to obtain a set of surveys of firm data, the supply side approach becomes feasible as well. Since this data set was administrated by the State Statistical Bureau of China in 1989, it is believed that the statistics are relatively accurate. Nonetheless, it should be mentioned that this survey data set does not include energy consumption of each firm, and so it cannot be used in estimating energy demand in the first approach. Instead, I employ the national time series data from 1952 to 1994 to estimate energy demand. On the contrary, the second approach can be employed with survey data because it only needs the data 'share of the energy expenditure in profit', which is available in the firm data set. Unfortunately, the observation period of this data set is only 1985-88 and so the energy deficit period was not covered. Consequently, this problem cannot be taken into account in this data set. However, the empirical findings from the second approach still can be projected to conduct energy policy analysis on energy insufficient problems. All in all, these two approaches have their own relative strong points and so, both of them will be used.

1.2.1) Part A: Descriptive Approach to Energy Imbalance in China

In Chapter Two, I consider the problem of China's energy imbalance problem. In the first part, I discuss what policies the government has initiated to overcome this problem in the past decade. Next, I try to find out the problems that China still needs to confront in the future and to evaluate the possible remedial policies for the energy deficit. This chapter contains a general discussion on the demand and supply of energy.

1.2.2) Part B: Demand Side Approach to the Prediction of Energy Insufficiency

Chapters Three and Four assess the severity of the energy imbalance.[6] To do this, it is necessary to specify an energy demand model. Since energy is one of the production factors, an energy demand function is commonly treated as one of the input demand functions. The important relationships are those between the demand for energy and prices of energy and other factors.

In Chapter Three, I use the vector error correction (VEC) model to forecast China's future energy demand. Although there are other studies that have forecast future demand for energy, they are flawed by the problem of spurious regressions, which occurs when time-trend-driving variables may appear to be correlated in finite sample regression, even though there is no true relationship among them.

[6] Due to the availability of the data, it has not been easy to estimate and forecast China's energy supply until now.

Moreover, to perform forecasting, the traditional approach requires us to predetermine the future values of the exogenous variables, which means that forecast values are subject to the subjective assumptions about the future values of the explanatory variables. However, VEC model can overcome these problems. Hence, I employ this technique to analyse the energy consumption behaviour and generate its ex-ante forecasts to the year 2000.

In Chapter Four, I model the demand for coal. In contrast to developed countries, coal is the major energy source of China.[7] My purpose is to identify the major factors that determine coal demand. To achieve this, I apply the cointegration and error-correction models to model Chinese coal consumption data. Since the error correction approach is a single regression which is quite different from the vector error correction approach employed in Chapter Three, it requires us to make some assumptions about the future values of the exogenous variables. Because of these particular characteristics, it is possible for us to assess the impacts of how the changes in exogenous variables will affect the energy

7 China's energy consumption depends on energy resource availability and production in China. The production of high quality energy, such as petroleum, natural gas and electricity, still cannot meet the rapidly increasing demand. Although crude oil, natural gas and hydropower contribute important shares of current energy components, coal still maintains the dominant position in primary energy supply and consumption of China. In the 1950s, coal composed about 95% of commercial primary energy. Along with the exploration of big oil fields like Daqing and Shengli from the beginning of 1960s, the share of oil and gas have increased a lot, achieving around 28% in the middle of 1970s combined with hydropower. While from 1980, the development of oil and natural gas became more and more difficult, coal has increased its share in the energy supply since then. The annual growth rate of coal consumption was 5.6% in 1980s, higher than that of primary energy consumption. Coal consumption was 1140 million tons in 1995, accounting for 74.6% of the total energy consumption. Coal is not only the dominant source of energy, but also is an important raw material of the chemical industry.

imbalance. The availability of this model would allow us to evaluate the effectiveness of controlling those variables in managing the coal demand in China.

1.2.3) Part C: Supply Side Approach to the Evaluation of Energy Pricing Policy

The Forecasts by econometric techniques from Chapters Three and Four can verify the qualitative analysis in Chapter Two whether China will suffer from energy shortfall in the next century. If so, it is necessary to implement energy policies to alleviate this problem. Chapter Two has evaluated the effectiveness of such policies. However, the analyses are mainly qualitative approaches and the findings may be different if the studies are based on quantitative techniques. On the other hand, increasing energy prices is currently the major instrument in China to mitigate demand. However, its impact on the economy and energy consumption is controversial.

Therefore, in the following chapters, I evaluate the energy pricing policy in managing the energy sector by the "supply side approach". Chapters Five, Six and Seven regard the estimation of input demand functions and of own price and cross price elasticities, aiming to investigate the complementarity/ substitutability among energy and other input factors such as capital and labour, and hence evaluate whether a high-energy pricing policy can solve energy insufficiency. The findings are of strong interest to the Chinese energy sector. It is because the use of a high price policy may lead to different possible outcomes. For instance, an increase in energy price could result in declines in capital formulation and perhaps in lowering labour productivity growth. The economy may shrink as a result. In the alternative situation, the high pricing regime could encourage more rapid capital formation and so achieve the goal of energy conservation with more desirable and productive outcomes. Therefore, the effects of rising energy prices on energy saving and output growth are ambiguous. This ambiguity is hinged on the substitution/complementary relationship among energy and other (non-energy)-input factors. The evaluation of the effects of a higher pricing policy will provide an important lesson, especially when such policy is implemented to narrow the future energy insufficiency.

The input demand functions and relevant elasticities can be derived from traditional translog profit models. However, the traditional methods ignore the effect of rationing on such derivations. As rationing occurs frequently in Chinese enterprises, applying rationing behaviour to Chinese data may therefore be strongly desirable. In light of this, I modify the traditional method and derive the price elasticities by introducing a virtual pricing approach. During the observation period (1985-88), energy deficit has not emerged as an important constraint. However, most Chinese firms were likely suffered from insufficient material inputs over this period. Therefore, in order to take this problem into account, material inputs are chosen ex ante as rationed input whereas energy is treated as a variable factor without rationing. Nevertheless, for the period after 1992, energy has changed to become a rationed input as energy deficit has become serious. Unfortunately, I cannot find a data set that has 1990s information and hence cannot choose energy as a rationing constraint in my model. Nevertheless, the exercise conducted in this thesis illustrates how rationing can be modelled and such useful information as price elasticities be derived. More importantly, the results also can be used to project energy policy analysis in later period when energy imbalance occurs.

In Chapter Five, I begin by reviewing the literature on the controversy between capital and energy. I then explain why rationing should also be an important factor. After that, I review and compare different methods that can be used to derive input demand functions. From the review, I argue why the dual approach and translog profit function is suitable for this study. In this chapter, the advantages and drawbacks of this approach will be presented in detail.

In Chapter Six, I explain how the elasticites are derived from a translog profit function. In the first section, the elasticities are derived in the traditional way which is under the assumption that there is no rationing in the economy. As rationing is currently occurring in China, I incorporate the rationing behaviour in deriving the elasticities. Following this argument, I explain and compare how the two approaches i.e. the auxiliary constraint and the virtual pricing approaches-can deal with the rationing. After this comparison, I conclude that the virtual pricing approach is more appropriate to derive the elasticities under rationing. The derivation of the elasticities is presented in the last section.

Chapter Seven adopts the translog profit function to the firm data set to derive relevant price elasticities. At the beginning, I introduce the survey data and explain how the translog profit function can be formulated in my energy model. After that, I discuss the adopted econometric technique. The estimates of the translog profit equation then are substituted into the formulae derived in Chapter

Six so as to obtain the elasticities with rationing and without rationing. From the signs of the elasticities, I can examine the relationship between energy and other inputs and hence evaluate the effects of raising the energy price policy on the economy. With the figures of energy forecasts obtained in Chapter Two and Three, different policy options are evaluated and their findings provide more understandings on the effect of a high price policy towards managing energy insufficiency.

1.2.4) Part D: Conclusion

Chapter Eight summarises this study under the three aspects which are mentioned above, i.e., to assess the ability to manage the energy sector, to predict the size of the imbalance between supply and demand, and to evaluate the role of government's energy pricing policies in China.

Chapter 2: An Overview of Energy Market in China[1]

2.1 Introduction

After many years of hard effort to manage the rapid growth of energy demand, energy remains a major input constraint in China. The most severe imbalance began to occur in some sectors after the early 90s resulting in considerable disruption to the economy as factories in many cities had to be closed several days a week in order to mitigate the electricity shortfall. At present, although the imbalance is apparently less severe than several years ago, it is far too early to conclude that the problem is totally solved as the economy is expected to continue to grow at a relentless rate into the foreseeable future. Against this backdrop, the problem of energy constraint will inevitably remain a dominating issue in the formulation of the energy policy. In view of this, this chapter will attempt to examine this particular issue. First, in the next section, I will evaluate the experience of the country in handling this problem. Despite some important achievements towards overcoming the energy imbalance, China still needs to face a number of formidable problems in the years to come. In section three, therefore, I will attempt to point out some of the important issues that remain to be solved. Based on this discussion, I attempt in section four to propose some policy prescriptions for managing the problems. The final section draws out the major points of this chapter.

[1] This chapter is to a large extent based on the paper in Energy Policy (Chan and Lee, forthcoming)

In order to better understand the major issues facing China, it is beneficial to start by examining the future energy balance of the country. As China approaches the end of this century, the planned output targets laid down by the government for coal, oil, gas, hydro-electricity and nuclear energy in the year 2000 are summarised in Table 2.1. Aggregating them into a common unit, namely million tons of standard coal equivalent (Mtce, hereafter), implies that the Chinese energy producers are planning to supply a total of 1,380 Mtce by the year 2000. According to one official estimate, China will need around 1,500 Mtce at the same year. Consequently, a deficit of 120 Mtce is expected to occur as the country approaches the end of this century. Among all the major fuels, the shortfall of oil will be the most severe. In order to close this gap, 43 Mtce of oil is needed to be imported. At the current international price of US$20 per barrel, this would amount to US$4.2 billion. In order to secure external supply, the government plans to procure about 22 Mtce of oil through bilateral agreements with such countries as Kazakhtsan and Turkmenistan. The remaining shortfall of 20 Mtce to 25 Mtce will be made up by conventional imports.[2] In 1996, China recorded a trade surplus of US$ 16.6 billion. Therefore, the deficit of energy balance will be kept at a manageable level over the next few years.

[2] Source: South China Morning Post, 6th April 1997, Money Section, p.2.

Table 2.1: China's energy supply and demand in the year 2000 and 2010

	Energy supply in the year 2000 (Mtce)[1]	Energy demand in the year 2000 (Mtce)[2]	Energy supply in the year 2010 (Mtce)	Energy demand in the year 2010 (Mtce)
Coal	1,000	1,064	1,285[3]	1,373
Oil	241	284	276[4]	358
Gas	33	40	93[5]	80
Hydro-electricity	100	97	142[6]	143
Nuclear electricity	4	-	30[7]	-
Others		7		47
Total	1,377	1,495		2,001

Sources: 1) *People's Daily*, 20th March 1996 and Yan (1994), p.11-12. 2) The demand estimates for both 2000 and 2010 are from Zhou Fengqui (1996). 3) Yan (1994), p. 66. 4) Zhou Yongkang (1996). 5) Same as 4. 6) Wu and Wang (1995). 7) Same as 4.

2.2 The experience of mitigating the Energy Constraint

To maintain China's energy imbalance at a manageable level is by no means an easy task, as the country's GDP experiences a phenomenal growth rate of 9.6 percent between the start of reform in 1979 and 1995. Such growth rate puts enormous pressure on energy supply. In order to overcome the energy insufficiency, the Chinese government has initiated a number of policies, some of which have been quite successful in narrowing down the deficit.

2.2.1) The Rapid Rise of Small Coal Mines

One of the key energy policies that the government has undertaken after the reform is to encourage the local initiative to expand coal supply. The government adopts this policy because the mine ownership is very diverse in China. In 1979, 55 per cent of output came from the state-owned coal mines. A further 31 per cent of production came from state mines owned locally at provincial, prefectural and county levels. The remaining 14 per cent of output was obtained from village-owned coal mines. In comparison, the national coal mines tend to be larger and more highly mechanised than small rural coal mines in the villages. However, the rural mines grew at a spectacular rate after the reform. In 1993, for example, village coal mines account for 35 percent of the total coal output, while the national and local state own mines produce around 40 and 25 percent respectively. To sum up, the emergence of the small coal mines enables the country to achieve the goal of producing 1.4 million tons of raw coal by the year 2000, which many considered unattainable when the government first announced this target in the 1980s.

The development of small coal mines helps not only to increase the supply of coal, but also alleviates the transport bottleneck which caused severe energy constraint in the late 1980s. The country is vulnerable to such bottlenecks because the distribution of coal deposits is geographically very unequal in China; nearly 80 percent of them are concentrated in three provinces: Shanxi, Shaanxi and Inner Mongolia, which locate in the north and north-west of the country. However, the major consuming centres are in the east and south. As a result, large amount of coals have to be transported long distances before reaching their consumers. This situation has resulted in a significant strain on the coal-carrying capacity of the rail system. In the worst years, many businesses around the country were idle due to lack of electricity, while large piles of coal sat unused outside the mines. Transport bottlenecks have been alleviated in part by the proliferation of small coal mines which scatter more evenly around the country. As a result, the largest three coal abundant provinces accounted only 34.3 percent of total coal output in 1993. The rise of local coal suppliers therefore significantly reduces the demand for coal from large coal mines.

2.2.2) Relieving the Capacity Constraint

The second major factor which has contributed significantly to narrowing down the energy imbalance is the rapid build up of electricity generation capacity. This relieves considerably the energy constraint because China has not only experienced deficit of energy inputs, but also insufficiency of electricity generation capacity. In order to alleviate this gap, the government sets the development of power industry as a first priority. As a result of the rapid development of small coal mines, this allows the government to shift greater proportions of investment from the coal to power industry. In 1995, for example, almost 60 percent of the government's investment in the energy industry went to the power industry, while only 13.6 percent was given to the coal extraction industry (State Statistical Bureau, 1996). In comparison, the power and coal extraction industries absorbed 29.8 and 48.3 percents of all the energy investment in 1985, respectively. The commitment to the power industry is undoubtedly strong. Currently, the government aims to upgrade the power system. For example, the government plans to increase power capacity to 290 Gigawatt (GW) by the year 2000. To achieve this target, 16 GW of new capacity is expected to be added each year in the present ninth Five-year Plan (1996-2000). In terms of growth rate, the power industry will rise by 7 percent annually; this is almost twice the growth rate of the entire energy sector. Equally important for handling the energy imbalance, the government plans to join up the existing six cross-provincial transmission grids into a single system so that surplus electricity can be transferred readily to deficit areas. Among the first to be connected are the northern and northeast regional grids. By the year 2003, when the first part of the Three Gorges hydroelectricity project in central China will be completed, the transmission grids will allow 100 billion Kwh of electricity be transmitted each year from the Three Gorges to the consuming centres in the eastern provinces along the coast. It is planned that a national grid will be completely formed around 2020.[3]

2.2.3) Getting Prices Right

Price changes have been one of the most significant results of the reform. In the centrally planning system before the reform, the prices of fuel were treated as an accounting unit with no direct bearing to the cost of providing the resources. Such practices have given rise to a great deal of problems after the reform. First, since the price signals are distorted, consumers are unlikely to make correct decisions. This is

[3] Source: *Tai Kung Pao*, 4th April 1997, p.C7.

particularly worse when the prices of energy are significantly fixed below their opportunity costs.

In view of this, the authority began to rectify energy prices. For example, a two tiered system was introduced in 1985 under which oil producers were allowed to sell their above quota output at a price higher than the state-administered price. As shown in Table 2.2, the above quota price of crude oil remained substantially higher than the government-administered price, although the gap started to narrow in the early 1990s. Later on, the government took another major reform step by introducing a market price to the second tier in 1993. Although the two-tiered price structure remains intact, the market price has not since departed significantly from the international price.

Table 2.2: The domestic oil price structure of China.

	Plan			Market
	Low		High	
1985	100		555	
1990	167		555	
1991	201		589	
1992	201		589	
1993	205		535	1000
1994		700		1232
1995		700		1250

Source: Bi (1994) and Chao (1996).

The long-term objective of the government is to raise planned prices to international market levels before the end of the century. In moving towards this goal, the price for the first tier, which is normally sold to government-subsidised sectors, was raised to between 880 yuan and 964 yuan per ton in early 1997.[4] The second-tier crude, which is sold at market prices, remains at an average of 1,200 yuan per ton. Following this, the authority plans to introduce an additional price increase of 200 yuan per ton to the first-tier crude oil in 1998, effectively ending the two-tiered system. Since the first tier crude oil represents about 80% of onshore production, a great majority of oil consumers will increasingly need to face international prices. The determination to rectify the previous pricing policy will minimise the inefficiency of consumption caused by the arbitrarily held down energy prices.

In addition to causing consumption inefficiency, the adverse impacts of arbitrarily held down prices are particularly notable for the national coal mines. Table 2.3 shows the amount of economic losses that state coal mines suffered over the last eight years. The implementation of the price increase has reversed the trend of the losses suffered by the coal industry. From a loss of 6.2 billion yuans in 1991, the loss in profit of the national coal mines fell to 1.0 billion yuan in 1995.

Table 2.3 Economic losses (billion yuans) of state coal mines in China.

Year	1988	1989	1990	1991	1992	1993	1994	1995
Loss	-1.8	-3.7	-6.1	-6.2	-5.3	-3.3	-2.0	-1.0

Sources: *China's Statistical Yearbook* and *China's Economic Yearbook*, various issues.

[4] Source: *Asian Wall Street Journal*, 2nd April, 1997, p. 25.

2.2.4) Improving energy consumption efficiency

Another major factor which helps reduce the energy imbalance is the improvement in energy consumption efficiency. In contrast to the pre-reform period during which the energy intensity (energy consumed per unit of output produced) climbed steadily, it declined consistently after the reform, which enables the country to save a substantial amount of energy. For example, during the recently elapsed Eighth Five Year Plan (1991-1995), the economy grew at an annual rate of 12 percent, while energy consumption increased by a mere 5.5 percent. As a result, the demand elasticity ratio fell to as low as 0.46 (5.5%/12%) in these five years. In comparison with the elasticity ratio of the Fifth Five-Year Plan (1976-1980), which equals 1.0, it is clear that the energy intensity has been greatly improved after the reform.

This remarkable performance can be attributed to the following changes. First, under the reform, firms are given greater incentives to be more cost sensitive. For example, they are allowed to retain part of their profits after the reform. Also, firms' investment has to derive from bank borrowing instead of government allocations. These types of new policies naturally lead most firms to place a greater emphasis on cutting cost which includes energy expense. Second, the emergence of township enterprises (TVP) also helps reduce the demand for energy. One of the most spectacular changes after the reform is the rapid growth of the non-state sector. Between 1984 and 1994, for example, the growth of industrial output in non-state enterprises was double that of state-owned enterprises. In the non-state sector, about

4/5 of the output was produced by TVP. More important, not only have TVP grown faster than the state-owned enterprises, they are also more efficient; the total factor productivity for SOEs is estimated to be only one third to one half the corresponding rate for non-state enterprises (Broadman, 1995, p.13). As a result, TVP represents a major source of energy saving. Third, the introduction of energy price reform also plays a significant part in increasing energy efficiency. Subsequent to the energy price rise, the amount spent on energy inputs has become more important. As Chinese firms have become more market oriented at the same time, price reform would help stimulate the consumers to be more efficient in using energy.

2.3 Remaining Problems Ahead

2.3.1) The Growing Oil Deficit

The energy balance looks much less optimistic when the forecast is extended to the next decade. Several problems deserve policy-makers' attention. In particular, the total energy supply is expected to grow at a rate significantly smaller than demand. This is particularly noticeable in the oil sector because the forecast for oil supply in 2010 is 276 Mtce which is nine percent more than that of 2000. At the same time, however, the demand for oil will rise to 358 Mtce, exceeding the supply by 30 percent. This will imply that China will need approximately 82 Mtce of imports (or 2.3 million barrels a day), which more than doubles the estimated imports for the year 2000.

Several reasons contributed to this acute imbalance. The most important one is that, in contrast with natural gas production, almost two-third of the entire country's oil output comes from the three largest oil fields: Daiqing, Shengli and Liaohe. Unfortunately, all these fields have passed their growth periods. For example, Daiqing and Shengli were first discovered in 1959 and 1961, respectively. Because of these discoveries, China was able to achieve self-sufficiency in oil in 1965. However, Daqing's oil production reached its peak in 1976 and since then its output was restricted to 50 million tons per year. So far, Daiqing has discovered 5 billion tons of oil-in-place from which 1.4 billion tons have been extracted. In 1997, Daiqing's management anticipates extracting another 2 billion tons from the oil field so that the existing annual output of 50 million tons can be more or less achieved at least through to the year 2010.[5] This will mean that oil developers could get about one third of their oil-in-place. Shengli, the number two oil field in the country, has experienced a similar development history. Its output rose steadily until 1988 when it reached a yearly output of 33 million tons. After reaching the peak, its output stabilises at the 30 million tons level.

[5] See *Tai Kung Pao*, Hong Kong, 4th March, 1997, p.C3.

Table 2.4: Oil and natural gas production of major Chinese oil fields in 1995.

	Oil output (million ton)	As percentage of total oil output	Natural Gas (billion metre)	As percentage of total gas output
Daiqing	56.0	36.6%	2.29	13.1%
Shengli	30.0	19.6%	1.29	7.4%
Liaohe	15.5	10.1%	1.75	10.0%
Xinjiang	7.9	5.2%	0.88	5.0%
Huabei	4.7	3.1%	0.31	1.8%
Zhongyan	4.1	2.7%	1.10	6.3%
Henan	1.9	1.2%	0.04	0.2%
Zhongyuan	4.1	2.7%	1.10	6.3%
Jilin	3.4	2.2%	0.18	1.0%
Tarim	2.5	1.6%	0.14	0.8%
Changqing	2.2	1.4%	0.10	0.6%

Source : *China Petroleum News*, 10 January, 1996.

As the country was unable to find new large oil fields in the past decade, oil producers have been struggling to maintain their current levels of oil production. However, the demand for oil has been growing relentlessly due to a combination of increased plastics and fibre demand which is estimated to consume roughly 7% of total crude supplies, and a sharply higher consumption of refined products, especially in the transport sector (e.g. autos, trucks and aircrafts) which is the largest consumers of crude oil. As a result, China is confronting a sharply increasing demand for crude oil against a flat to gradually rising domestic crude supply. To accommodate the deficit, industry has depressed the reserve-to-production to a historically low level for acquiring additional oil.[6] This leads to the allegation that the Chinese oil producers have been over-producing to meet their domestic needs at the risk of depleting their reserves and causing serious damage to their oil wells' reservoirs.[7] Unless the country discovers new oil basins to replenish the existing large oil fields, the prospect of a rising oil deficit gap will become increasingly likely as the country enters the next century.

2.3.2) The Uncertainty of Coal Supply

Since, 1990, China has surpassed the US and become the largest coal producer in the world. From then on, coal output continued to rise by about 4 to 5 percent per year. In 1995, China produced 10.5 Mtce of coal. As the government sets the target for the economy to grow annually by 8 percent before 2000 and 7 percent in the following ten years, the demand for coal is expected to rise by 4 to 5 percent annually if the present income elasticity of demand ratios remain unchanged. By 2010, demand will rise further to 18 Mtce. Concerns can be raised about the advisability of an existing strategy that relies heavily on the supplies of small coal mines. The most important one is related to the sustainability of small coal mines, whose importance is expected to decline in the twenty-first century. As shown in Table 2.5, analysts in China predict that the relative contribution of the small coal mines will significantly reduce as time goes on. This is not surprising since most small mines tend to exploit comparatively small, shallow basins with

[6] As reported in Lu *et al.* (1995), p.5, the reserve-to-production ratio has dropped considerably from 15.2 in 1986 to 13.6 in 1992.

[7] See, for example, Mamdouh (1995).

limited scope of expansion over the long run. Most of the existing small mines operated before the 1990s would be exhausted soon after 2000. (Ma, Zhu and Sheng (1996), p. 16). Unless more investments are forthcoming in the state sector, the fading out of small coal mines may weaken the supply ability of the coal industry in China.

Table 2.5: The relative shares of different types of coal mines in China.

Year	national state coal mines	local state coal mines	village-owned coal mines
1979	56%	29%	15%
1985	46%	26%	27%
1990	44%	28%	27%
1993	41%	25%	35%
2000	50%	25%	25%
2010	55%	25%	20%

Source: *Rural Statistical Yearbook of China*, *Energy of China* and *Statistical Yearbook of China*, various issues. The forecast figures are obtained from Nie (1994), p. 63.

How did the state investment change over the last several years? As shown in Table 2.6, the shares of state investment in both the energy sector and coal industry have been declining quite drastically. For example, in 1995, the energy sector accounts only for 18.6 percent of total government investment, which is almost 34 percent smaller than that of 1990. In comparison, the reduction to the coal industry is even more notable; the share of coal industry drops by more than one half, from 5.8 percent in 1990 to 2.6 percent in 1995.

Table 2.6: The share of state investment in the energy and coal industries. (%)

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995
Energy	23.1	23.7	27.8	28.3	26.3	22.0	19.6	18.2	18.6
Coal	4.3	3.9	4.8	5.8	5.4	4.1	3.2	2.4	2.6

Source: *Statistical Yearbook of China*, various issues.

Clearly, the rapid rise of small coal mines allows China to have a breathing space, but there is little room for complacency as the country has become the world largest producer. In particular, many of these small coal mines have never been prospected. In addition, the recovery rates of many of these mines are as low as 10 to 15 percent, resulting in massive wastage. As a result, their potentials are not clearly known. As demand for coal continues to grow relentlessly, relying on small coal mines is clearly not a sustainable policy.

2.3.3) Little Progress In Reforming State-Owned Enterprises

Taking the above two points together implies that the country must require considerable investment for meeting future demand. However, it is questionable whether the government could find sufficient funding if moribund state-owned enterprises (SOEs) remain unable to improve their unsatisfactory performance, which are manifested in a variety of indicators. For example, although the SOEs currently account for over one-third industrial output, they consume nearly three-quarters of the industrial investment. Although this could be the result of a higher concentration of capital intensive industrial in SOE sector, the value added per worker is about half of the non-state industrial sector. If the stock of unsold inventories- which stands at the level of US$ 60 billion or 8% of China's GDP in 1996[8]- was removed from the valuation of output, value added per worker in SOEs would be much lower.

In view of their unsatisfactory performance, the government has tried to reform SOEs by adopting a "contract responsibility system" in the late 1980s. This involved a system of contracts whereby enterprises agreed to turn over a set level of profits to the state. After completing this requirement, the enterprise was to be given certain autonomy. Since these contracts typically lasted only for three years but many management decisions need many years to be felt, there is no guarantee that managements will work for the long-term interest of firms. Probably because of this, China decided to phase out the contract responsibility system and replace it by a shareholding system in late 1993. The obstacles have been far greater than anticipated, however. Since the state remains as a dominant shareholder in the new system, the incorporation does not change to a significant extent the working relationship between managers and owners, i.e., the state.[9] Thus far, the enterprise reform remains one major part of the reforms that has met with little success.

The adverse impacts of this failure are far-reaching to energy sector. The World Bank estimates that the government needed to subsidise as much as 4 % of China's GDP to its SOEs in 1995 (The World Bank, 1996, p.18). Also, the number

[8] Source: *Asian Wall Street Journal*, 9th April 1997, p.8.

[9] Interested readers can refer to Chan (1996) who discuses why the shareholding system does not work very well for those Chinese SOEs listed in the Hong Kong Stock Exchange.

of loss-making enterprises has grown steadily from 26 percent of SOEs in 1992 to 44 percent in 1995. Unless the government is able to find a solution, the need to continue the subsidisation of the state sector on a large scale will hamper considerably the government's ability to provide funding for many desirable energy projects.

2.3.4) Intensifying regional deficits

The fourth factor that may worsen the energy deficit is associated with the unbalanced regional development pattern of the country. Prior to 1978, Chinese development strategy was dominated by preferential development of heavy industry. After 1978, however, the strategy was shifted to an emphasis on the development of the coastal regions so that they can serve as the growth poles for stimulating economic growth in the interior provinces. In pursuing this policy, the government has deliberately increased investment in the coastal regions at the expense of the interior. For example, Chai (1996) reports that in the years between 1979 and 1992 the coastal region's investment in fixed assets rose by almost 10 percentage points whereas that of the western region actually declined.[10] As a consequence, the growth rates of most of the coastal provinces are often among the highest in the country. Such a development has far-reaching implications to the energy balance of the country. As mentioned before, the geographical distribution of coal mines is highly uneven in China: nearly 80 per cent of large coal mines are concentrated in

[10] One can refer to Chai (1996) for detail.

the north and north-west, while the major consuming centres locate along the coast. The unbalanced development which favours the coastal regions inevitably increases the strain on the coal-carrying capacity of the rail system.

This problem is further aggravated by the newly adopted investment policy of the government. As a result of decentralisation which took place after the reform, the tax revenue of the central government as a percentage of GDP has been significantly reduced. The central government finds it increasingly difficult to fund all the new electricity generation projects. In order to attract other sources of funding, the government has adopted what is commonly known as the "high-in, high-out" investment policy. The main principle of this policy, as stipulated in the recently promulgated "Electricity Law", is to allow domestic and foreign investors to charge prices higher than the government-administered prices for recovering their investment costs. The consequence of this policy is clear; nearly 86 per cent newly approved coal-fired electricity plants in 1996 are planned to be built in the coastal regions.[11] This is not surprising as they are the regions which are able to afford higher prices. However, the unbalanced development pattern of growth, if not mitigated in the near future, will increase the traffic congestion and hence intensify the regional energy imbalance.

[11] Source: *South China Morning Post*, 6th April, 1997, Business Section, p.2.

2.4 Some Policy Prescriptions

In order to handle the energy imbalance, both supply and demand policies are necessary. On the supply side, for example, China must intensify its efforts to discover new oil fields. At present, China has two major unexplored oil basins that may have large potential reserves. One of these is the South China Sea which is believed to have deposits equivalent to 8 Daqing oilfields, although recent offshore discoveries have been modest. However, since this is also the area where the border disputes are most intense, the uncertainty about its future potential is substantial. Another potential source is the Tarim Basin, which locates in the westernmost province, Xinjiang. The latest geological survey indicates that Tarim will be one of the most important sources of oil and gas for China. In 1996, the five operating oil fields in Tarim allows China to produce 3.15 million tons of crude oil, making Xinjiang the eighth largest oil producing province in the country. Although the output of Tarim basin is still moderate, its potential of becoming one of the major oil producer is great as the Chinese government estimates that the oil reserves in the basin may be as large as 11 billion tons of oil and 8.4 trillion cubic meters of natural gas. So far, only 1.4 billion tons of oil and gas have been verified. In spite of the fact that Tarim basin is the largest under-explored oil basin in the world, its location makes it extremely harsh for exploration. Part of the difficulty of oil exploration and development in Tarim is that oil deposits tend to be found very deep, and wells there have to be drilled up to an average depth of 4,000 meters. In addition, Tarim is a notoriously difficult area to work in. For example, work normally needs to stop for about three months every year, from late spring, because of shifting sands and sandstorms.

Because of these particular geographical conditions, the exploration programme in the Tarim Basin will be the largest and most expensive in China's history. The involvement of foreign investment would lessen the risk and cost involved. On the surface, the Chinese government has made a lot of efforts to attract foreign investment. For example, the area available for foreign exploration has increased to 960 million square kilometres, representing almost one-quarter of its entire territory. By the end of 1996, 0.15 million square kilometres have been contracted to foreign oil companies. Despite this, foreign companies made little headway in the exploration work of Tarim since it has been opened to outsiders in 1994. Up till now, most foreign companies have been confined to the fringes of the region and have failed in their search for oil. For the 4.3 million tons of oil extracted in 1996 from the region, virtually all have been produced by Chinese companies. The inability to find oil in Tarim frustrates many foreign companies. As a consequence, British Petroleum stopped work in early 1995. This was followed by an Amoco-led consortium which dropped out of third-round bidding for the Tarim in the middle of 1996. The reluctance displayed by foreign companies can be ascribed to the lack of a clear policy framework for attracting foreign investment. Two examples serve to clarify this point. The first one is related to the pricing policy of oil. Before the recent price reform, the entire price making process was highly opaque. It was not clear at all how the authority determined its oil prices. Such a practice increased the risk of investment and thus reduced the interest of foreign companies. Another more recent example is related to the provision of information and data that associate with Tarim. Until very recently, virtually all of data are provided by the China National Petroleum Corporation. However, very few data have been released to outsiders so far.[12] Clearly, this policy is anything but conducive to attract foreign investment.

In addition to above supply policy, the government should also strengthen its role in the coal industry, as the existing policy of relying on the small coal mines may not be sustainable. To do that, it is necessary for the government to increase its investment in state mines. Unfortunately, for a developing country, capital is always one of the most limiting constraints. In theory, this constraint can be partially relieved by using capital efficiently. In reality, however, producers in China often do not use their capital in such a desirable manner. For example, it is reported that, out of the existing 210 million tons of oil-refining capacity in 1996, 30 million tons are idled due to excess capacity.[13] This problem occurs frequently after the central government has decentralised part of the investment decision-making power to lower-level governments, whose investment behaviour are expected to be optimised by the introduction of a financial market. Since the reform of the financial sector remains at an early stage, duplication of investment often occurs. To increase of the efficiency of capital utilisation, the continuation of the financial reform ought to deserve top priority in the reform agenda.

[12] For detail, see Murphy and Seidlitz (1997).

[13] Source: *People's Daily*, 10th March 1997, p.2.

Apart from the supply side, demand side management is equally important in the context of China. This is because energy consumption per unit output in China is 3 to 4 times that in developed countries. In particular, energy consumption for major manufacturing industrial products is 40 percent higher than those in industrial countries (Zhou, 1996). Since the industrial and transport sectors consume about 70 per cent of total energy in recent years, there is a great potential for energy conservation in China, particularly within manufacturing industry. Chinese energy consumption can be conserved in the following ways. First, demand can be reduced by changing the economic structure. Before the reform, the development of tertiary industry had been arbitrarily held back because the government adopted a forced industrialisation strategy. Until now, the low-consumption service sector constitutes only a small proportion of the economy, whereas the high-energy consumption sector makes up the largest proportion. By removing those policies that discriminate against the service sector, the demand for energy would reduce and the well-being of the society would be increased. Second, energy demand can be reduced by increasing the efficiency of consumption, particularly of heavy energy users. Typical examples are fans and pumps which currently use over one third of electricity. In addition, upgrading the small, old coal-fired plants can also save significant amounts of energy. Third, in some energy intensive industries where the small enterprises produce a significant share of output, it is possible to conserve energy by raising the scale of production of these small firms. This type of saving will be most significant in the cement industry where small township enterprises account for almost one-fourth of the total output.

2.5 Conclusion

The Chinese economy has grown spectacularly since the economic reform in 1979. As a result of this, the economy has begun to be plagued by energy deficit, to varying degrees. In order to overcome this problem, the government has initiated a number of policies, some of which have been quite successful in narrowing the energy deficit. For example, as many energy projects need many years for construction, careful planning is essential for handling the deficit problem. In addition, the commitment to pay more attention to the economic incentives of both consumers and producers, such as price reform, also plays potentially important part in solving the problem.

Although the energy gap has been reduced to a manageable level in recent years, China still faces a multitude of challenges. In particular, since the economy is expected to grow robustly, the government must continue to expand the energy supply. Inevitably, the investment needs arising from the oil, coal and electricity sectors are huge. To generate enough funding, the government needs to reform its existing polices on such sectors as state-owned enterprises, financial markets and foreign investment. These investment needs can be reduced by spending more effort on energy saving. Rationalising the economic structure, upgrading the obsolete heavy energy users and raising the scale of production of small enterprises could improve the energy efficiency substantially.

Chapter 3: Forecasting the Demand for Energy in China[1]

3.1 Introduction

China has engaged in economic reforms since 1979, the general aim of which has been to quadruple its 1980's national income by the year 2000. Experience shows that one of the major obstacles to achieving this objective is the frequent occurrence of energy imbalance. Probably as a consequence of the increasing importance of this sector in the national economy, great effort has been spent in China on the study of energy demand. An earlier report on these efforts comes from Smil (1989, Chapter 4), who documented seven separate forecasts that had been conducted by economists. Their estimates differed quite widely, ranging from a maximum of 2.40 billion tons of standard coal equivalent (SCE) to a minimum of 1.39 billion tons to be demanded by the year 2000.[2] These studies largely followed two main types of approaches: Intensity analysis and regression model. Invariably, the high estimates came from those which used intensity approach in the early 1980s. This is not surprising as the country's energy intensity was relatively high before the reform and saw a drastic fall in the subsequent years. Early intensity analysis which did not foresee this change would naturally

[1] This chapter is to a large extent based on the paper in The Energy Journal (Chan and Lee, 1996)

produce particularly high estimates. A later forecast conducted by Cai (1990, Chapter 2), who combined both regression and intensity approaches, has produced a more moderate increase. Cai forecast that the Chinese energy demand will rise to 1.45-1.68 billion tons of SCE by the end of this century, depending on different assumptions about the efficiency gains on energy consumption. In view of the importance of the energy forecast towards making investment plans, this chapter attempts to throw some light on how the Chinese energy demand will change as the country's development process continues.

In contrast to the previous papers, my analysis is based on two increasingly popularised econometric techniques, cointegration and vector error correction model. This popularity is due to the pioneering works of Granger (1983, 1986, and 1988) and Engle and Granger (1987) on cointegration. The reasons for adopting these approaches in estimating energy demand are twofold. First, earlier econometric studies have been subject to the potentially serious econometric problem of spurious regression, which arises when variables that are driven by time trends may appear to be correlated in finite sample regression, even though there is no true relationship existing among them. The problem arises in many previous studies as it has always been assumed that economic variables are stationary, in terms of having constant unconditional means and variances. But, in reality,

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[2] The heat content of standard coal equivalent is 7,000 kilo-calorie per kilogram.

many economic variables are typically driven by trends that are varying stochastically over time. Regressing variables of this nature are therefore likely to produce unreliable outcome, i.e., spurious result.[3]

A more acceptable methodology is the use of cointegration. Granger and Engle (1987) and Granger (1983) argue that although trend-driven variables do not exhibit stationarity, one or more of their linear combinations may be stationary or cointegrated, which implies a long-run equilibrium relationship. Furthermore, Engle and Granger (1987) suggest using error correction models when the regression variables are cointegrated. In making the present forecasting, I adopt the VEC model as it can provide some unparalleled advantages. First, it is possible to combine the long-run equilibrium and the short-run error-correction dynamics within a single model. Second, since most of the economic variables employed in energy demand estimation, such as income and price, are likely to be endogenous, estimating energy demand by single equation may produce simultaneity bias and hence lead to unreliable forecasts. This problem can be overcome with the help of the VEC model, which models data in a system form and hence does not require assumptions about the exogenous variables.

[3] An excellent survey on this can be found in Bentzen and Engsted (1993).

3.2 Methodology and Model Specification

The important characteristics of the VEC model can be illustrated through its described formulator, which normally starts with a vector autoregressive (VAR) model of the form given below:

$$X_t = \sum_{i=1}^{p} \Pi_i X_{t-i} + e_t \qquad (3.2.1)$$

where X_t is a vector of stochastic variables, p is the number of lags that will generate a white noise process, Π_i is a parameter matrix that measures the long-run effect of the respective lag levels of X on its current level, and e_t is a column vector of a long-run random disturbance term assumed to be idd$\sim N(0,\Sigma)$. An error-correction mechanism (ECM) can be introduced to (3.2.1) by re-writing the equation into the following form:

$$\Delta X_t = \Pi X_{t-p} + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + e_t \qquad (3.2.2)$$

where Δ is the first difference operator. The coefficients Π and Γ_i for i = 1,2,...,p-1 in (3.2.2) are determined from the coefficients Π_i, i = 1, 2,...,p of the VAR in (3.2.1). More explicitly

$$\Pi = -I + \Pi_1 + \Pi_2 + \ldots + \Pi_p$$

and

$$\Gamma_i = -I + \Pi_1 + \ldots + \Pi_i \qquad (i = 1,\ldots,p-1)$$

where I is an unit matrix. Clearly, the error-correction model in (3.2.2) is expressed as a traditional first differenced VAR model except for the term ΠX_{t-p}. Normally, X_{t-p} is referred to as the error-correction term while Π is the error correction coefficient matrix. Intuitively, the presence of X_{t-p} in the equation reflects the correction of the short-run disequilibrium of the variables by their long-run relationship. In equation (3.2.2), the information of the long-run co-movement of the variables is summarised in Π, the long-run parameter matrix. Whether the variables do move together in the long-run, i.e., whether a long-run equilibrium path exists among the variables, can be investigated by the Johansen's multivariate cointegration test, (Johansen, 1991). The number of cointegration vectors (or long-run relationships) is determined by the rank of the long-run impact matrix. Three distinct cases of interest may occur. First, if the rank of Π is equal to n, where n is the number of variables in X_t, the vector process X_t is stationary. Second, in a situation where Π is a null matrix, its rank is zero. This implies no long-run relationship among the variables and the whole system will reduce to a first-differenced model. Third, for the more general cases where the rank of Π, say $r < n$, there exists a representation of Π such that the following restriction will hold:

$$\Pi = \alpha \cdot \beta' \tag{3.2.3}$$

where β is the $n \times r$ matrix of cointegration vectors, α is an $n \times r$ matrix. The elements of α measure the speed of adjustment of the variables with which they attach. Quite appropriately, the matrix α is called the adjustment matrix.

When the cointegrating restrictions (3.2.3) are imposed, (3.2.2) becomes

$$\Delta X_t = \alpha\beta' X_{t-p} + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + e_t, \tag{3.2.4}$$

The matrix $\beta' X_{t-p}$ constitutes a set of r error correction mechanisms separating out the long and short-run responses in the model. Although, the error-correction representation is not the only possible parameterisation of a dynamic model with cointegrated variables, it has the advantage that all of the variables (dependent and independent) in the representation are stationary. This means that the standard asymptotic theory can be used to conduct statistical inference.

In my study, the vector X_t comprises four variables, Q_t, Y_t, P_t and M_t, where Q_t is energy consumption in year t, Y_t is national income, P_t is the price of energy, M_t is an indicator of structural variation. In this model, the structural variation is represented by the share of the heavy industry in national income.

In formulating a model for analysing the demand behaviour of the Chinese energy industry, there are some methodology issues that need to be dealt with. For example, in the literature, there are two major methods by which different energy sources are aggregated: Btu and Divisia approaches. Each of them has its own merits.[4] Since China does not publish its price statistics for its individual energy inputs, the Divisia approach has not been adopted in the present study.

Following the conventional analysis, I include national income and energy price in the vector X_t. Similar to other socialist countries, China uses the concept of national income to measure its aggregate economic activities. This is defined as the total income earned in the production of material goods. Normally, it comprises five major sectors: industry, agriculture, construction, commerce and transportation. Non-material services, such as passenger transportation and government administrative services, are excluded from this accounting device. Viewed in this light, GDP is a better variable to reflect the level of economic activity. However, since GDP is only available after the mid-1980s, I use national income instead. In addition to these two independent variables, I include the variable M_t on the grounds that heavy industry has long been one of the major energy consumers of the country. For example, during the years between 1985 and 1993, heavy industry consumed around 53 per cent

[4] For a detailed comparison on how these two methods affect the

of total energy. This arises because China followed Stalinist forced-industrialisation strategy before the reform, by emphasising the development of heavy industry. Although the share of heavy industry in the national income has been declining since the reform, it started to rise again in the latter part of the 1980s. This arises because resources had not been adequately allocated to heavy industries, especially the materials and energy industries, in the early stage of reform. As a result, this led to the shortfall of producer goods such as basic materials, steel, and electricity.[5] Consequently, the heavy industry began to receive more investment at the end of 1980s. In view of its importance, I include the variable M_t in the estimation.[6]

3.3 Data Sources

All of the data used in the analysis are obtainable from the *Statistical Yearbook of China*. The variable national income is taken directly from the *Statistical Yearbook of China*. For the remaining variables, I have undertaken the following procedures. The total energy consumption comprises four major energy inputs consumed in

energy elasticities, see Nguyen (1987).

[5] For a detail analysis, see Zhou and Chen (1993).

[6] In addition to the above variables, I have also tried other variables. They are, for example, weather, population, size of urban areas proxied by the urban population, share of industrial output in the national income. All of these variables are not, however, significant or in correct sign.

China: Coal, petroleum, electricity and natural gas. In order to apply the Btu aggregation method, I have converted the physical quantities into thermal unit by using conversion factors provided by the World Bank (1984, p. 159). For example, Chinese coal on average has around 5,000 kilo-calories per kilogram. In terms of standard coal equivalent, a ton of average coal is equivalent to 0.715 ton of standard coal equivalent. To calculate the price for Btu aggregation approach, I follow Nguyen (1987)'s approach in which he divided the sales value by total heat content. Since China does not have the figures of sales values, I use the output value of the energy sector instead by assuming that these two sets of data differ by a constant proportion. The data of M_t are obtained from the following procedures. In the *composition of the total national income* series, I can obtain the share of industrial output in the national income and in the *ratio of gross output value of industry* series I can have the share of heavy industry's output in the total output. By multiplying these two sets of figures, it is possible to derive the share of heavy industry output in the national income.

3.4 Model estimation

To examine the time series property of the data, I conduct the augmented Dickey-Fuller (ADF) unit root tests on the stationarity of the levels and then first differences of the four variables. In essence, testing whether a variable Z_t is integrated is equivalent to test for the significance of G_2, i.e., H_0: $G_2 = 0$, in the following regression:

$$\Delta Z_t = G_0 + G_1 t + G_2 Z_{t-1} + \sum_{i=1}^{k} \delta_i \Delta Z_{t-i} + e_t \tag{3.4.1}$$

where t is a linear time trend. The result of this test is reported in Table 3.1. Note that the *t*-statistics cannot be referred to the critical values in the standard "*t*" table since under the null hypothesis the Z variable is non-stationary. Instead, the Mackinnon (1991)'s critical values have to be applied in this occasion. The use of linear time trend in the equation depends on the resulting statistical significance. Only the series $\log(Q_t)$ has not been introduced with the trend.

Table 3.1: Augmented Dickey-Fuller Test on levels and first differences of the lags of the energy consumption, national income, real energy price and structural variation.

series	level	first difference
$\log(Q_t)$	-1.76	-5.06**
$\log(Y_t)$	-1.85	-5.16**
$\log(P_t)$	-1.86	-3.61*
$\log(M_t)$	-2.73	-4.28**

Notes: (1) */** denote rejection of hypothesis of a unit root at 5%/1% significant level respectively.
(2) The value of k is determined by using the Akaike's criterion.

The ADF tests indicate that the null hypothesis that the level of each series is generated by a random walk process should not be rejected, whereas the hypothesis of a random walk in the first difference of each series is rejected. This means that all of the series are integrated of order one and so the model cannot be estimated by standard regression technique. Viewed in this light, the VEC model is a better alternative. However, since the VEC specification only applies to cointegrated series, I need to perform cointegration tests before applying the VEC model to the Chinese energy data. To investigate his, I apply the maximum likelihood approach developed by Johansen (1991). The result of this test is reported in Table 3.2.

Table 3.2: Cointegration Test Series: $\log(Q_t)$, $\log(Y_t)$, $\log(P_t)$ $\log(M_t)$

Eigenvalue Number	Likelihood Ratio	5% Critical Value	1% Critical Value	Hypothesised of Cointegrated Equations(s)
0.50787	53.426	47.21	54.46	None*
0.34903	26.483	29.68	35.65	At most 1
0.23479	10.190	15.41	20.04	At most 2
0.00001	0.0005	3.76	6.65	At most 3

Note: * denotes rejection of the hypothesis at 5% significance level.

As shown in Table 3.2, there is at most one cointegration equation at 5% significance level. Having established this result, I can estimate the long-run demand relationship with the help of Johansen's maximum likelihood approach (Johansen, 1991), the result of which is given in the following equation:

$$\log(Q_t) = 7.127 + 0.706\log(Y_t) - 0.9083\log(P_t) + 1.2079\log(M_t) + U_t$$

$$(3.6) \qquad (12.30) \qquad (-2.10) \qquad (12.13)$$

(3.4.2)

Years 1953-1993. *t*-statistics are in parenthesis. As shown in equation (3.4.2), all the coefficients are significant with correct signs. The long run elasticity of income, price and structural variation are 0.706, -0.908 and 1.208 respectively. As compared to other countries' estimates, we have relatively low income elasticity in the Chinese energy sector.[7] However, this may not be surprising because before the reform took place in 1979, the energy price was arbitrarily held down by the Chinese government so as to stimulate industrial development. This policy was partially rectified during the reform as the government could not continue to subsidise the profit-losing energy industries. Probably due to the price changes and other reform policies which stimulates the incentive of energy consumers to be more cost conscious, the energy consumption efficiency has been greatly improved after the reform. This leads to a drastic fall in

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[7] As documented by Bentzen and Engsted (1993), many energy studies show long-run elasticities about unity, or above.

energy intensity[8] and may also explain the low value of income elasticity.

To proceed further, I compute the error term u_t of equation (3.4.2), which together with the differenced variables can be fed into equation (3.2.2) for the estimation of the VEC model. Table 3.3 shows the result:

Table 3.3: Estimated Vector Error-Correction Model: 1953-1993

	Equation 1 ΔQ_t	Equation 2 ΔY_t	Equation 3 ΔP_t	Equation 4 ΔM_t
constant		0.038*		
U_{t-1}	-0.762**	-0.462**	0.067	-0.882**
ΔQ_{t-1}		-0.224	0.064	
ΔQ_{t-2}		-0.208		
ΔY_{t-1}	0.716**	0.839**		0.343
ΔP_{t-1}	1.870**	1.159**	0.603**	1.437**
ΔP_{t-2}	-2.497**	-1.074*	0.608**	-1.269
ΔM_{t-1}	0.387**		-0.100	0.461**
ΔM_{t-2}	0.233	0.175	-0.109**	
$\overline{R}^2$	0.447	0.467	0.581	0.479
LM(2)	0.540	2.055	0.250	0.225
ARCH(2)	0.451	0.232	0.099	0.063
C.F.(1980)	2.020	0.681	7.306**	0.831

Notes:

1. U_t is the error-correction term of equation (3.4.2).
2. **/* denotes that the parameter is statistically significant at 1%/5% significance level respectively.
3. $\overline{R}^2$ is the coefficient of determination adjusted for the degrees of freedom. LM (2) and ARCH (2) are Lagrangian multiplier tests for second order autocorrelation[9] and second order autoregressive

[8] For more detail on this point, see Lin (1992).

[9] The result shows that the null hypothesis of the LM test in this study is not rejected, i.e., there is no serial correlation up to lag order 2. Unlike the Durbin-Watson statistics for AR(1) errors, the LM test may be used to test for higher order ARMA errors, and is applicable

conditional heteroscedasticity(ARCH)[10] respectively.The multiplier test is set at second order because the highest lag order of the above model is equal to two. C.F. (1980) is Chow forecast test[11]with break point setting at year 1980. All statistics are F-values.

In formulating the error-correction mechanism, the lag length of U_t corresponds to the length of response (adjustment) to a deviation from the long run path. To be compatible with economic theory, the lag length of the disequilibrium error has to be set at a low value. In estimating the above model I fix the lag length of U_t equal to 1.[12] On the other hand, the random errors e_t have to be free from autocorrelation, the usual practice is to allow for relatively long lags for the differenced variables, since these might approximate the possible autocorrelation structure of the error terms. However, imposing long lags will reduce degrees of freedom. In reconciling these opposing demands, I set the value of p equal 2. In selecting the

whether or not there are lagged dependent variables. Therefore, it is recommended to use whenever we are concerned with the possibility that the errors exhibit autocorrelation. See Godfrey (1988) for detailed discussion.

10 The test statistics reveals that the conditional variance of the error term is not serially correlated with the past squared values of the error term, i.e, the null hypothesis that there is no autoregressive conditional heteroscedasticity (ARCH) in the residuals is not rejected. See Engle (1982) for detail.

11 The test shows that there is no large difference between the actual and predicted values, which implies that the estimated relation over the estimation and prediction periods is stable.

12 See Thomas (1994) for details.

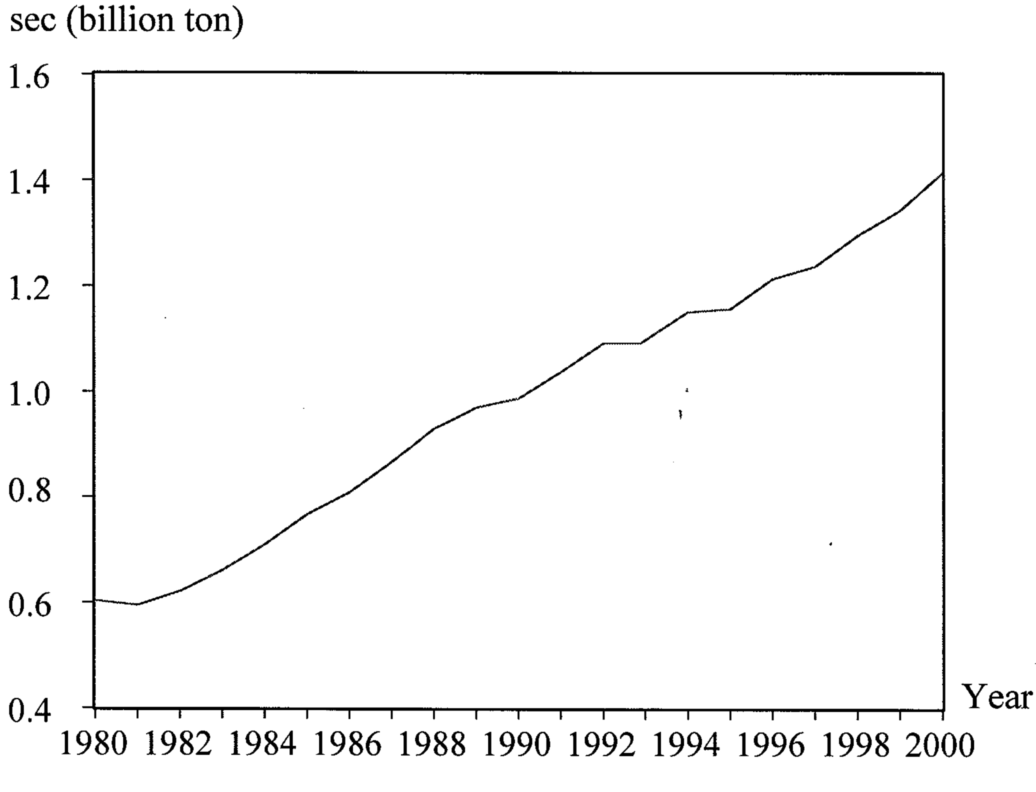
final form of the model, all those variables that have relatively small t-values (less than one) are then discarded.

3.5 Energy Forecast

Before applying the above model to forecast the energy demand, it is important to check its stability. Since a parametric econometric model is completely described by its parameters, model stability is equivalent to parameter stability. The CUSUM of squares test (Brown, Durbin, and Evans, 1975) can be conducted to investigate the stability of the model's parameters. In general, if the CUSUM of squares test statistic moves outside the critical values of 5% significance, the null hypothesis would have to be rejected, thereby implying parameter or variance instability. In addition, I may plot the feasible recursive estimates of all the coefficients to test for their stability. If the coefficient displays significant variation as more data are added to the estimating equation, it is also a clear indication of instability. The above two tests indicate that, in general, the model in Table 3.3 is stable.

Having established the stability, the VEC model in Table 3.3 is then applied to estimate the energy changes until the end of this century. Because the change in any variable is assumed to be a function of its own past changes as well as past changes in other variables, a VEC system is a natural vehicle for generating *ex ante* forecasts that use only information available prior to the forecast period. In other words, the use of the VEC model does not require me to make any assumptions about the values of exogenous variables. The outcome of the forecast is reported in Figure 3.1. In presenting this figure, I have used the standard coal equivalent as the unit for measuring the heat content. By so doing, it is possible to compare with the planned supply target of the government.

Figure 3.1: Forecast of energy demand in China: 1994-2000



As shown in the above figure, Chinese energy demand will continue its prevailing uprising trend as it approaches the end of this century. My model forecasts that the energy demand will rise to 1.42

billion tons of SCE at the year 2000, which roughly equals the government planned supply target of 1.4 billion tons.[13]

3.6 Conclusion

As the economic variables used in my model are not stationary, I choose the cointegration method to model the consumption behaviour of the energy sector in China. The results indicate that not only price and income are important, the share of heavy industry's output is also a significant demand determinant. My estimation also reveals that China has relatively high price elasticity but a low income elasticity. In addition, the vector error correction model shows no sign of instability. In the light of this, I employ the estimated model to forecast the change in energy demand for the period of 1994-2000. The model predicts that the energy demand displays a steady increase as the country approaches the end of this century, reaching the level of 1.42 billion tons of standard coal equivalent at the year 2000. This roughly equals the supply target of the country.

[13] The official supply target is revealed in Li (1991).

Chapter 4: Forecasting Coal Demand in China[1]

4.1 Introduction

In contrast to many developed countries where petroleum is the major source of energy supply, coal has remained the dominant source of energy input in China and accounted for more than seventy per cent of the total energy consumption in the early 1990s. Therefore, I will model and forecast the demand for coal. Unlike Chapter Three, this chapter concentrates on single regression models, which allow us to evaluate the effectiveness of controlling the explanatory variable in managing the coal demand in China.

In the literature, there have been a number of single equation studies on aggregate U.S. petroleum consumption.[2] As pointed out by Jones (1993), these studies of the US petroleum industries typically employ an arbitrarily pre-determined specification, such as a partial adjustment model or some kind of a distributed lag structure on price alone. This initial specification is rarely justified, except possibly to cite its previous success in similar work. In view of this, Jones advocated the use of Hendry's general-to-specific modelling approach as it is free of the prior subjective prejudices of the researcher for a

[1] This chapter is to a large extent based on the paper in Energy Economics (Chan and Lee, 1997)

[2] Single equation studies of aggregate U.S. petroleum consumption includes, for example, Brown (1983), Bopp (1984), Gately and Rappoport (1988) and Brown and Phillips (1989), (1991).

particular specification. In substantiating his claim, Jones employed a set of US petroleum consumption data to examine the extent to which the general-to-specific approach would differ from other commonly used models, including the partial adjustment model, a single static model and the polynomial distributed lag (PDL) on price. By comparing the forecast errors of these models, he concluded that Hendry's general-to-specific modelling approach is seen to provide a data-acceptable restricted model that out-performs the alternatives.

On the surface, the general-to-specific approach has the merit of avoiding the mis-specification error. However, an alternative method of employing the single equation Error Correction Model (ECM) (Bentzen and Engsted, 1993) has two advantages. First, in comparison to general-to-specific approaches, the variables in a typical ECM representation will normally be far less highly correlated. This facilitates the testing-down procedure because, with low standard errors, the normal *t*-statistics in an estimated ECM will provide a good guide to which differenced variables should be eliminated. Thus ECM is easier than Hendry's general-to-specific approach arriving at a sufficiently parsimonious final preferred equation. Second, in contrast to such conventional dynamic model as the partial adjustment model, the ECM does not impose restrictions that require the ratio of the short-run and long-run price elasticities be identical to the ratio of the short-run and long-run income elasticities (Johnson, 1992).

As revealed in Table 4.1, all variables employed in this chapter are nonstationary. Hence, to avoid spurious results, I will attempt to model the coal demand of China by using the cointegration analysis and ECM. There are, however, two approaches to estimating the ECM: They are the Engle-Granger two step procedure and Hendry's type of testing down. Asymptotically both methods should yield a valid ECM and hence arrive at the same estimated model (Granger, 1986). However, in small samples, an ECM obtained from the Engle-Granger procedure may not necessarily correspond to the type of model derived from the Hendry's testing down. In view of this, one cannot say, a priori, which method is preferable. As a result, both of these methods will be employed in this study and their forecastibility will be compared in order to differentiate their performance in modelling coal consumption behaviour in China. In addition to these two approaches, I have also included the general-to-specific approach for forecastibility comparisons. These alternative estimates over the same sample period provide some indication of how the cointegration analysis differs from those of the general-to-specific approach.

This chapter is arranged in the following manner. In the next section, the method of single equation ECM will be presented. This will be followed by the application of these methods to the Chinese coal consumption data in the third section. In addition, an ex post forecast comparison analysis will be carried out in order to discriminate the performances of the three chosen models. The best performing model will be used for making forecast of Chinese coal demand by year 2000 in the fourth section.

4.2 Single Equation Error Correction Model(ECM)

To illustrate an ECM, let us use the following simple equilibrium equation:

$$y_t = \alpha + \beta x_t, \tag{4.2.1}$$

where y_t is a dependent variable and x_t is a vector of independent variables. If y_t and x_t were in equilibrium, then the balance $y_t - \alpha - \beta x_t$ will equal zero. However, $y_t - \alpha - \beta x_t$ will be non-zero when disequilibrium occurs. In fact, this quantity measures the extent of disequilibrium between y_t and x_t and hence is known as the disequilibrium error. In case where disequilibrium occurs, y_t can be assumed to be related to values of x_t and the lagged values of y_t and x_t , one simplest form of which is

$$y_t = \gamma + \delta_0 x_t + \delta_1 x_{t-1} + \tau y_{t-1} + u_t \ , \tag{4.2.2}$$

where u_t is the disturbance term. Subtracting y_{t-1} from both sides of equation (4.2.2) and regrouping the resulting equation yields

$$\Delta y_t = \delta_0 \Delta x_t - \mu(y_{t-1} - \alpha - \beta x_{t-1}) + u_t, \tag{4.2.3}$$

where μ, α and β assume the values of $1-\tau$, $\gamma/(1-\tau)$ and $(\delta_0+\delta_1)/(1-\tau)$; Δ represents the first difference. Equation (4.2.3) shows that the changes in $\boldsymbol{y}_t$ depend on the change in $\boldsymbol{x}_t$ and the lagged values of the disequilibrium error, which implies that when $\boldsymbol{y}_{t-1}$ is greater than its equilibrium value, the value of $\boldsymbol{y}_t$ will be decreased in the subsequent period. The model thus measures how the value of $\boldsymbol{y}_t$ is corrected for the disequilibrium error. From (4.2.3), it is clear that δ_0 and β measure the short-run and long-run parameters while μ measures the speed of adjustment towards long run equilibrium. We have assumed a simple relationship in (4.2.2) but in practice, this equation contains higher lag-orders as explanatory variables so as to make $\boldsymbol{u}_t$ white noise. When higher order lagged variables are introduced, equation (4.2.3) is required to be modified into the following form:

$$\Delta \boldsymbol{y}_t=\sum_{i=1}^{k-1}\psi_i\Delta \boldsymbol{y}_{t-i}+\sum_{i=0}^{k-1}\delta_0\Delta \boldsymbol{x}_{t-i}-\mu(\boldsymbol{y}_{t-k}-\alpha-\beta \boldsymbol{x}_{t-k})+\boldsymbol{u}_t. \qquad (4.2.4)$$

4.3 Data Sources.

The variables coal consumption q_t and national income y_t are directly obtainable from the *Statistical Yearbook of* China (various issues), the latest version of which is 1995. p_t is the retail price of coal deflated by the overall retail price index. The construction of the share of the heavy industry output in the national income has been mentioned in Section 3.3.

4.4 Empirical Results

The energy demand equation to be estimated in our study is as follows:

$$q_t = \beta_0 + \beta_1 y_t + \beta_2 p_t + \beta_3 m_t + u_t, \qquad (4.4.1)$$

where q_t = coal consumption in year t;
y_t = national income;
p_t = real retail price of coal;
m_t = a variable proxy for structural variation. In this model, m_t is the share of heavy industry's output in the national income;
u_t = the disturbance which is assumed to have the conventional properties.

Lower case letters denote the natural logarithm of variables so that each coefficient estimated is an elasticity. In order to compare the forecastibility, all the three models are run between the years 1953-90, leaving the last four observations (1990-94) for carrying out the post-sample forecast error comparison.

4.4.1) Engle-Granger's type ECM

As stated in Chapter Three, before conducting the Engle-Granger's type ECM analysis, it is necessary to conduct the Augmented Dickey-Fuller (ADF) unit root tests on the stationarity of levels and the first differences of the four variables. The results in Table 4.1 indicate that the variables under examination are integrated of order one. This supports our earlier conjecture that they form a non-stationary time series. Next, we test whether the variables are cointegrated by using Johansen (1991)'s cointegration test. Table 4.2 reports the result of this test.

Table 4.1: Augmented Dickey Fuller Test for years 1953-1990

Series	Level	First difference
q_t	-1.7015	-3.4764*
y_t	-2.9602	-4.7787**
p_t	-2.4428	-6.3186**
m_t	-3.3329	-4.1685*

Notes: (1) * and ** represent rejection of hypothesis of a unit root at 5 and 1 per cent significant level respectively.

(2) As the model is based on annual data, the estimation therefore starts from k = 1. Also, since there is no sign of serial correlation in the residuals after introducing one lag to the independent variables, the estimation terminates at k = 1.

(3) The t-statistics cannot be referred to the critical value in the standard "t" table since under the null hypothesis the dependent variable is non-stationary. Instead, the Mackinnon(1991)'s critical values have to be applied in this occasion.

(4) The use of linear time trend depends on the resulting statistical significance. Only the series q_t has not been introduced with a trend.

Table 4.2: Cointegration tests of the series q_t, p_t, y_t and m_t.

Eigenvalue Of Cointegration	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesised Number Equation
0.565562	54.88650	47.21	54.46	None**
0.353074	24.87325	29.68	35.65	At most 1
0.214122	9.194432	15.41	20.04	At most 2
0.014343	0.520099	3.76	6.65	At most 3

Notes: */** denote rejection of the hypothesis at 5%/1% significance levels respectively. The likelihood ratio test indicates there is only 1 cointegrating equation at the 5 % significance level.

The Johansen tests for cointegration indicate that there exists a long-run relationship among the four variables. Having established this result, we can begin the first step of Engle-Granger's method by using Johansen (1991)'s maximum likelihood approach to estimate the long-run parameters of the demand equation. The result is summarised in the following equation:

$$q_t = 5.988 - 0.802p_t + 0.854y_t + 0.838m_t + u_t, \qquad (4.4.2)$$

$$(-5.52) \quad (30.07) \quad (24.93)$$

where e_t is random error and (.) contains t-statistics.[3] All the three coefficients have significant correct signs. The long-run elasticities of price, income and structural shift are respectively:

[3] The intercept of the above equation does not have a t-statistic simply because this is a normalised value. For detail, see Johansen (1991).

$$\varepsilon_p^{LR} = -0.817, \qquad \varepsilon_y^{LR} = 0.842, \qquad \varepsilon_m^{LR} = 0.860.$$

Having obtained the values of long-run parameters, we can proceed to the second step of Engle-Granger's ECM by feeding those values into the disequilibrium error of equation (4.2.4). The equation to be estimated will be:

$$\Delta q_t = \sum_{i=1}^{k-1} a_i \Delta q_{t-i} + \sum_{i=0}^{k-1} b_i \Delta p_{t-i} + \sum_{i=0}^{k-1} c_i \Delta y_{t-i} + \sum_{i=0}^{k-1} d_i \Delta m_{t-i}$$

$$- \mu\{q_{t-k} - 5.694 + 0.817 p_{t-k} - 0.842 y_{t-k} - 0.860 m_{t-k}\} + u_t, \tag{4.4.3}$$

where Δ denotes the first-difference operator and $\{.\}$ represents the disequilibrium error. In estimating the above equation, the initial step is to set the value of k and then successively delete the most insignificant differenced variables. We have tried different values of k in estimating the above equation, the maximum k we have used is 3. After testing downing procedure, the best model performance is shown as follows:

Table 4.3: The estimated results of the Engle-Granger ECM, 1954-1990

Coefficient	value	t-statistics
b_0	-0.220	-1.97
c_0	0.763	7.77
d_0	0.514	6.38
μ	0.671	7.11

$\overline{R}^2 = 0.909$
DW = 1.86
SSR = 0.074
LM(4) = 0.000 [$\chi^2(4) = 9.488$]
LARCH(4) = 2.310 [$\chi^2(4) = 9.488$]
CF (break point = 1980) = 0.252 [$F_{0.05}(11,23) = 2.24$]

Table 4.3 shows the results of estimating Equation (4.4.3) for the period of 1954-1990. From a statistical point of view, the results depicted in Table 4.3 are satisfactory, $\overline{R}^2$ is reasonably high and there are no signs of residual serial correlation or auto-regressive conditional heteroscedasticity in the model. Since the model passes all the diagnostic tests we have conducted, this indicates that our choice of k is acceptable. Finally, the break point of the Chow forecast test is 1980, the year when the economic reform began to take place. The test statistic shows the statistical parameter constancy holds when the data extend over the period of reform. The short-run elasticities of price, income and structural shift are given by the estimated coefficients on the zero- lag terms. They are given by, respectively:

$$\varepsilon_p^{SR} = -0.220, \qquad \varepsilon_y^{SR} = 0.763, \qquad \varepsilon_m^{SR} = 0.514.$$

All of them are lower than their long-run parameters. Also, the value of the adjustment parameter is 0.671 which means that if the demand is 1 per cent out of its equilibrium, 67.1 per cent of adjustment towards its equilibrium will take place within the first year.

4.4.2) Hendry's Type ECM

Instead of applying equation (4.2.4) directly, Hendry's ECM normally starts with a unrestricted version of the ECM (see, e.g., Hendry, Pagan, and Sargan, 1984) as given by the following equation:[4]

$$\Delta q_t = \sum_{i=1}^{k-1} a_i \Delta q_{t-i} + \sum_{i=0}^{k-1} b_i \Delta p_{t-i} + \sum_{i=0}^{k-1} c_i \Delta y_{t-i} + \sum_{i=0}^{k-1} d_i \Delta m_{t-i}$$

$$-\mu q_{t-k} + \gamma p_{t-k} + \delta y_{t-k} + \phi m_{t-k} + u_t, \tag{4.4.4}$$

This is then followed by a testing down procedure in search of a suitably parsimonious final model. In contrast to the last model, both long-run and short-run elasticities are estimated together in this approach. Since equation (4.4.4) can be seen as a nested equation with the higher lagged order equation being nested within the lower order

[4] In fact, equation (4.4.4) is the unrestricted version of equation (4.4.3) because if we do not write the ***t-k*** variables of the latter equation into the disequilibrium error form, it will give us equation (4.4.4).

one, we can perform a restriction test to determine the value of k. In our model, we test for k=1 against k=2 and the resulting F statistic equals 1.810, falling short of the critical value of $F_{0.05}(4,23)$ which equals 2.80. Clearly, the restrictions are not rejected by the data. We therefore prefer the first order ECM and the result of the estimation of the model is:

$$\Delta q_t = 3.876 - 0.255\Delta p_t + 0.707\Delta y_t + 0.514\Delta m_t$$

(6.04) (-1.78) (4.15) (4.46)

$$- 0.646 q_{t-1} - 0.591 p_{t-1} + 0.549 y_{t-1} + 0.552 m_{t-1} + e_t \qquad (4.4.5)$$

(-6.45) (-3.58) (6.65) (5.72)

Estimation is undertaken for 1954 and 1990 with the following diagnostic statistics: $\overline{R}^2$ = 0.906, DW = 2.15, RSS = 0.067, LM(4) = 3.828 [$\chi^2(4)$=9.488], LARCH(4) = 7.1947 [$\chi^2(4)$ = 9.488], CF (break point = 1980) = 0.1955 [$F_{0.05}(11,17)$ = 2.41], (.) = t-statistics, [.] = critical values.

Similar to those of the Engle-Granger's type ECM, the evaluative statistics obtained from the Hendry's ECM have passed all the diagnostic tests, at 5 per cent significance level. The long-run elasticities of price, income and structural shift are obtained by transforming the t-1 lagged independent variables of equation (4.4.5) into the disequilibrium error form. By so doing the long-run elasticities of price, income and structural shift can be calculated as:

$$\varepsilon_p^{LR} = \gamma/\mu = -0.915, \quad \varepsilon_y^{LR} = \delta/\mu = 0.850, \quad \varepsilon_m^{LR} = \phi/\mu = 0.854,$$

while the short-run elasticities of these variables are given by the estimated coefficients on the zero- lag term:

$$\varepsilon_p^{SR} = -0.255, \quad \varepsilon_y^{SR} = 0.707, \quad \varepsilon_m^{SR} = 0.514.$$

Furthermore, the coefficient of the disequilibrium error in this case is 0.646, more or less the same as that derived from the Engle-Granger's approach (0.671). Thus both equations imply that roughly sixty per cent of any disequilibrium between actual and equilibrium coal demand in any one year is made up within the next year. It is interesting to note that the coefficients estimated from Hendry's ECM does not deviate significantly from those of the Engle-Granger's ECM. The estimated long- and short-run elasticities obtained from the two equations are of the same (first) order of magnitude, and the elasticities and adjustment coefficients are roughly the same. More importantly, both approaches lead to equations with similar lag structures, with approximately sixty per cent of the long-run effects being achieved after one year.

4.4.3) General-to-Specific Approach

The use of Hendry's general-to-specific approach to study the Chinese coal consumption normally commences with the general form of autoregressive distributed lag model (denoted ADL) as shown below[5]:

$$q_t = \alpha + \sum_{i=1}^{n_1} a_i q_{t-i} + \sum_{i=0}^{n_2} b_i p_{t-i} + \sum_{i=0}^{n_3} c_i y_{t-i} + \sum_{i=0}^{n_4} d_i m_{t-i} + u_t, \qquad (4.4.7)$$

where the four lag lengths (n_1, n_2, n_3, n_4) are initially set at the same maximum value. The selection of the maximum lag length is inevitably arbitrary as theory does not provide us with any restrictive guidelines (Beenstock and Willocks, 1981). In practice, the choice of the maximum lag length is made by use of F tests. In my case, the following F-test has been carried out in which the null is ADL(2,2,2) against the alternative that the maximum lag length is of order three, i.e., ADL(3,3,3). The test yields a F statistic of 0.863 [$F_{0.05}(4,19)=2.90$] implying that the null hypothesis is not to be rejected. The maximum lag length is thus set at 2.

Following this, the procedure progressively simplifies the general model by imposing data-instigated restrictions on the set of

[5] Although Table 4.1 shows that the variables are I(1), Table 4.2 reveals that all the variables are cointegrated with a unique cointegrating relationship. The OLS estimates of short-run and long-run parameters are therefore consistent and have normal asymptotic distribution, such that the t, F tests on these parameters are valid. See Pesaran and Shin (1995) for detail.

coefficients. Potential restrictions are usually identified by inspecting the magnitudes of individual parameter estimates, as well as their standard errors. For more practical details on how these potential restrictions are identified and verified, interested readers can refer to Hendry (1984) and, for a more updated example, to Jones (1993). The final restricted model in our case is as follows:

$$
\begin{aligned}
[q_t - m_t] = 4.837 &- \underset{(-14.61)}{0.064}[q_{t-2} - 3q_{t-1}] + \underset{(-2.74)}{0.405}[2y_t + y_{t-2}] \quad (7.43) \\
&-0.491y_{t-1} - 0.317[p_t + p_{t-1}] + 0.260[m_{t-1} - 2m_t] + e_t \\
&\quad (-2.67) \qquad (-5.73) \qquad (7.05)
\end{aligned}
\tag{4.4.8}
$$

The estimation period is between 1955 and 1990. The diagnostic statistics are $\bar{R}^2 = 0.991$, SSR = 0.056, DW = 1.50, LM(4) = 5.570 [$\chi^2(4) = 9.488$], LARCH(4) = 2.578 [$\chi^2(4) = 9.488$], CF (break point = 1980) = 0.540 [$F_{0.05}(11,15) = 2.51$]. In order to obtain the above model, the following six restrictions have been applied:

$$a_1 = -3a_2,\ b_0 = 2b_2,\ c_0 = c_1,\ c_2 = 0,\ d_0 = -2d_1 \text{ and } d_2 = 0.$$

A restriction test has been carried out in order to conform to these restrictions. The resulting statistic is equal to 0.363, which is distributed as F(6,24), falling short of its critical value of 2.51 at the 5 per cent significance level. The evaluative statistics of equation (4.4.8) show that the restricted ADL model displays no evidence of serial correlation and heteroscedasticity in its residuals. It is also stable over the reform period. To calculate the elasticities of demand, we need to derive the unscrambled coefficients of equation (4.4.8). The result is presented in Table 4.4.

Table 4.4: Unscrambled coefficients for restricted ADL model

	Number of lags			
	0	1	2	Σ
1955-90				
q_t	0	0.192	-0.064	0.128
p_t	-0.317	-0.317	0	-0.634
y_t	0.810	-0.491	0.405	0.724
m_t	0.480	0.260	0	0.740

The short-run and long-run demand elasticities can be determined from Table 4.4 respectively. The long-run parameters are:

$$\varepsilon_p^{LR} = \sum b_i / (1 - \sum a_i) = -0.727,$$
$$\varepsilon_y^{LR} = \Sigma c_i / (1 - \Sigma a_i) = 0.830,$$
$$\varepsilon_m^{LR} = \Sigma d_i / (1 - \Sigma a_i) = 0.849.$$

while the short-run price, income and structural shift elasticities are given by the estimated coefficients on the zero-lag terms:

$$\varepsilon_p^{SR} = -0.317, \qquad \varepsilon_y^{SR} = 0.810, \qquad \varepsilon_m^{SR} = 0.480.$$

4.4.4) Models Comparison

In order to discriminate among the performances of the three chosen models we looked at their ex post forecasting abilities over the periods of 1991-1994. Table 4.5 reports five commonly used measures of forecast error; (1) root mean squared error (RMSE); (2) root mean squared percentage error (RMSPE); (3) mean absolute error (MAE); (4) mean absolute percent error (MAPE); (5) Theil's inequality coefficient (U)

Table 5.5: Ex Post Forecast Errors for Chosen Models, 1991-1994

Model	RMSE	RMSPE	MAE	MAPE	U
Engle-Granger's ECM	0.0986	0.8642	0.0750	0.6627	0.0044
Hendry's ECM	0.1180	1.0342	0.0931	0.8180	0.0052
Restricted ADL model	0.1101	0.9667	0.0958	0.8430	0.0049

From Table 4.5, it is clear that over this brief period the Engle-Granger's ECM performs best in producing the smallest forecast errors as measured by the five forecast error indicators, while the other two models performed more or less the same. On this basis we conclude that Engle-Granger's ECM fits best to the Chinese coal consumption data. Overall, however, all three models perform quite satisfactorily in these tests.

4.5 Forecasting the Coal Demand in China

Having established Engle-Granger's ECM as being the most preferred approach, we can apply it to forecast the changes in future coal consumption. Accordingly, using the data to 1994, I obtain the following result by using the Johansen (1991)'s maximum likelihood approach:

$$q_t = 5.146 - 0.588 p_t + 0.821 y_t + 0.842 m_t + e_t. \tag{4.5.1}$$

$$(-6.39) \quad (35.70) \quad (25.52)$$

The second step of Engle-Granger approach can then be followed, the result of which is reported in the following equation:

$$\Delta q_t = 0.675 \Delta y_t - 0.168 \Delta p_t + 0.552 \Delta m_t - 0.693\{q_{t-1} - 5.146$$

$$(6.81) \quad (-1.92) \quad (6.82) \quad (-7.3)$$

$$-0.821 y_{t-1} + 0.588 p_{t-1} - 0.842 m_{t-1}\} + e_t. \tag{4.5.2}$$

Sample years = 1954-1994, $\overline{R}^2$ = 0.884, SSR = 0.0967, DW = 1.86, LM(4) = 0.003 [$\chi^2(4)$ = 9.488], LARCH(4) = 4.229 [$\chi^2(4)$ = 9.488], CF (break point = 1980) = 0.540 [$F_{0.05}(15,23)$ = 2.13].

Before using the above equations to obtain a forecast, it is necessary to check the stability of the model as represented by equation (4.5.2). The presence of model instability will make it difficult to interpret regression results and to forecast accurately. This is particularly important for China since the country has engaged in economic reforms after 1979 that may have significantly altered consumption behaviour. Therefore, I conduct CUSUM of squares test and plot the recursive estimates of each coefficient in the equation. The results are reported in Figure 4.1 and 4.2 indicating that the chosen model is largely stable over the examination periods.

Figure 4.1: The CUSUM of squares test for equation (4.14)

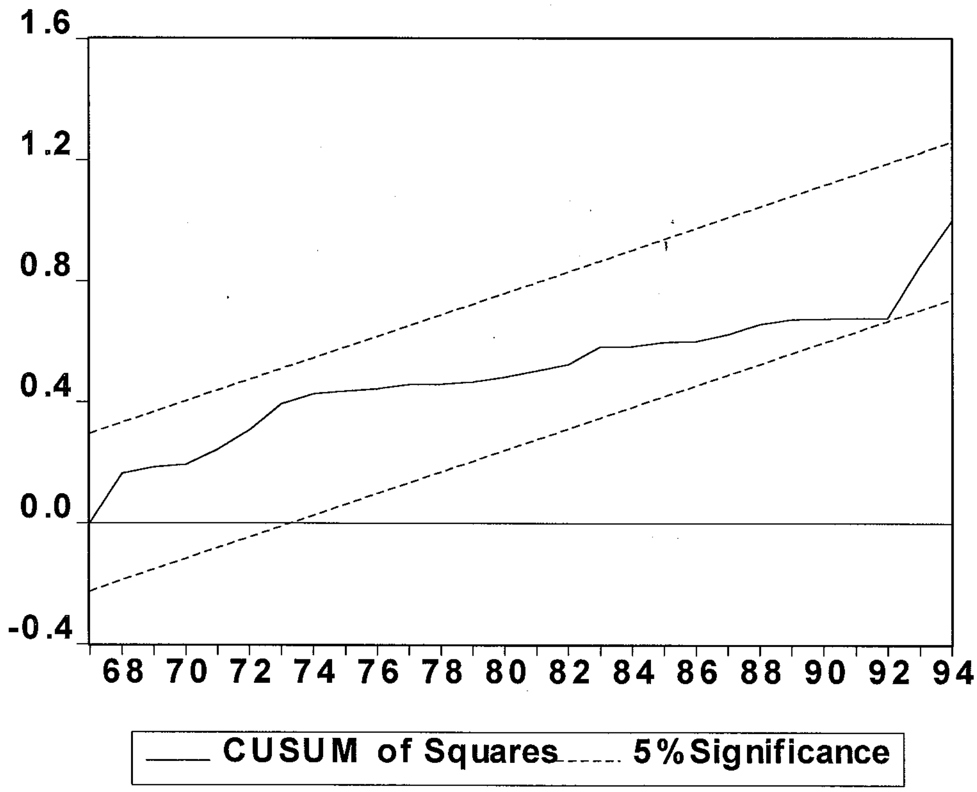
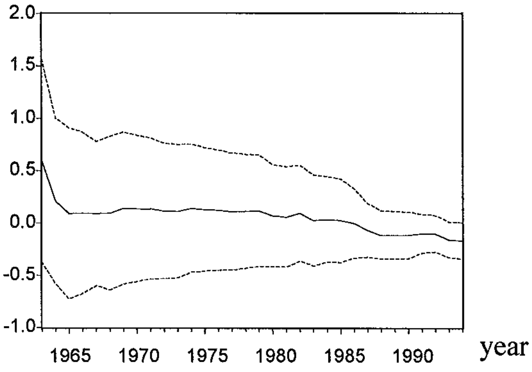
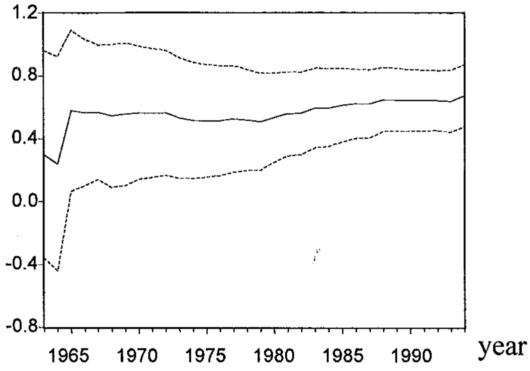


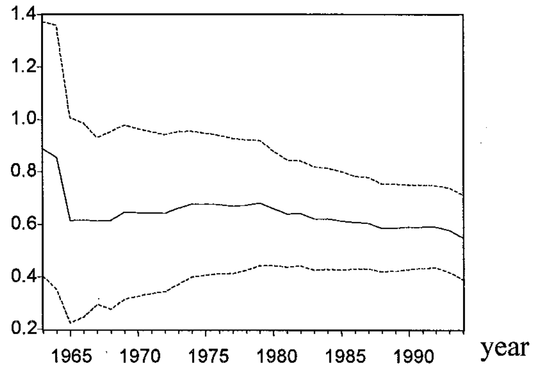
Figure 4.2: Recursive Estimates of Coefficients in Equation (4.5.2).



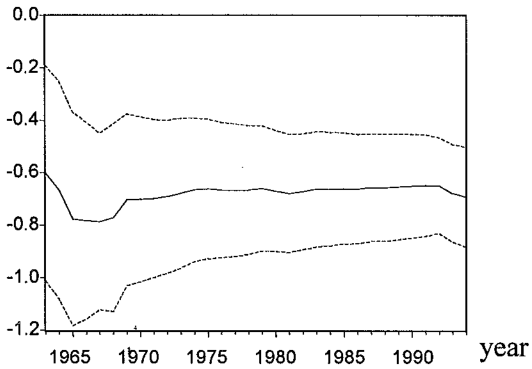
Recursive estimates of Δy_t's coefficient



Recursive estimates of Δp_t's coefficient



Recursive estimates of Δm_t's ceofficient



Recursive estimates of disequilibrium error

The final part of this section is to forecast the coal demand of the country. In doing that, I need to make some reasonable assumptions about how the exogenous variables will change in the forecast period. In the first scenario I assume the economy will grow by 10 percent and the real price of coal rise by 2 percent annually during the forecast period, while the structure of the economy remains unchanged. The economic growth rate is fixed at 10 per cent because the economy grew approximately at this rate over the years 1990 to 1994. As shown in Figure 4.3 (a), the demand will reach 1.76 billion tons by the year 2000. Since the government has already planned the production target of 1.40 billion tons for year 2000,[6] the demand will exceed the official target by 25.7 per cent. In order to narrow this gap, one possibility is to raise the price of coal. As shown by Figure 4.3 (b), if the real price of coal rises by 8 per cent annually, the demand will reach 1.49 billion ton, significantly closer to the official output target than under scenario 1. However, the impact of such a large increase of coal prices on inflation will be considerable. For a country which currently experiences chronic inflation, this is unlikely to be an acceptable solution. Probably as a consequence of the energy constraint, the central government has decided recently to scale down the economic growth rate during the 9th five-year plan (1996-2000) to eight per cent per year. Based on this new figure and a 4 per cent annual increase in the real coal price, coal demand will reach approximately 1.53 billion tons in 2000, as reported in Figure 4.3 (c). Further, if the share of heavy industry's output in national income drops by 1 percentage point over the forecast period, the coal demand will fall to a more manageable level of 14.8 billion tons as presented in Figure 4.3 (d), exceeding the official output target by 5 per cent at the end of century.

[6] Source: The People's Daily, "The Central Communist Party's Proposal for the Forumlation of the Coming Ten Years' Social and Economic Development Strategy and the Eighth Five Year Plan," 29th January, 1991.

Figure 4.3 (a): Forecast of Coal Demand in China: Scenario 1

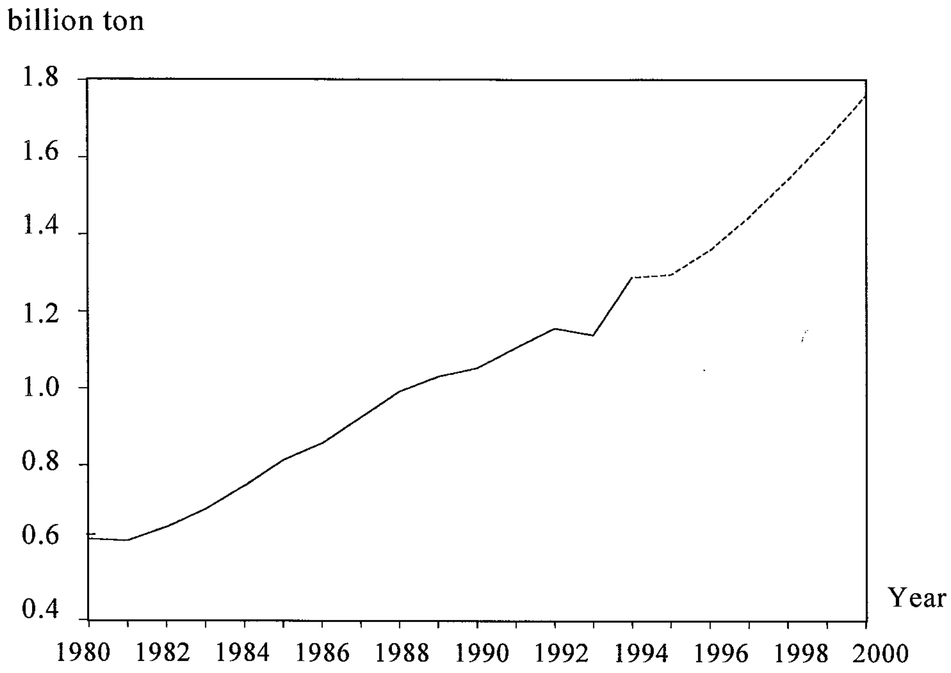


Figure 4.3 (b) Forecast of Coal Demand in China: Scenario

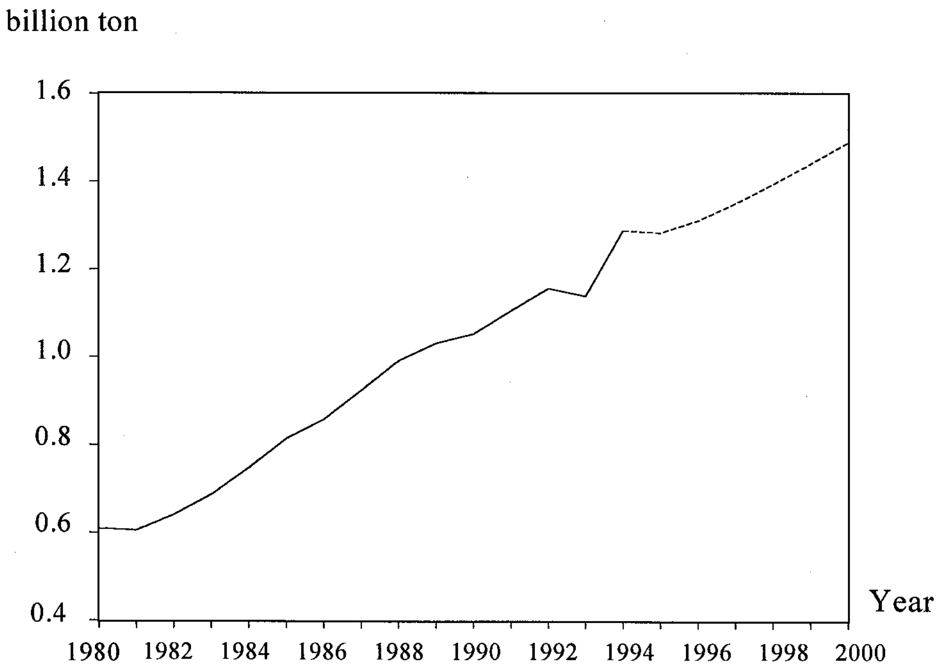


Figure 4.3 (c) Forecast of Coal Demand in China: Scenario 3

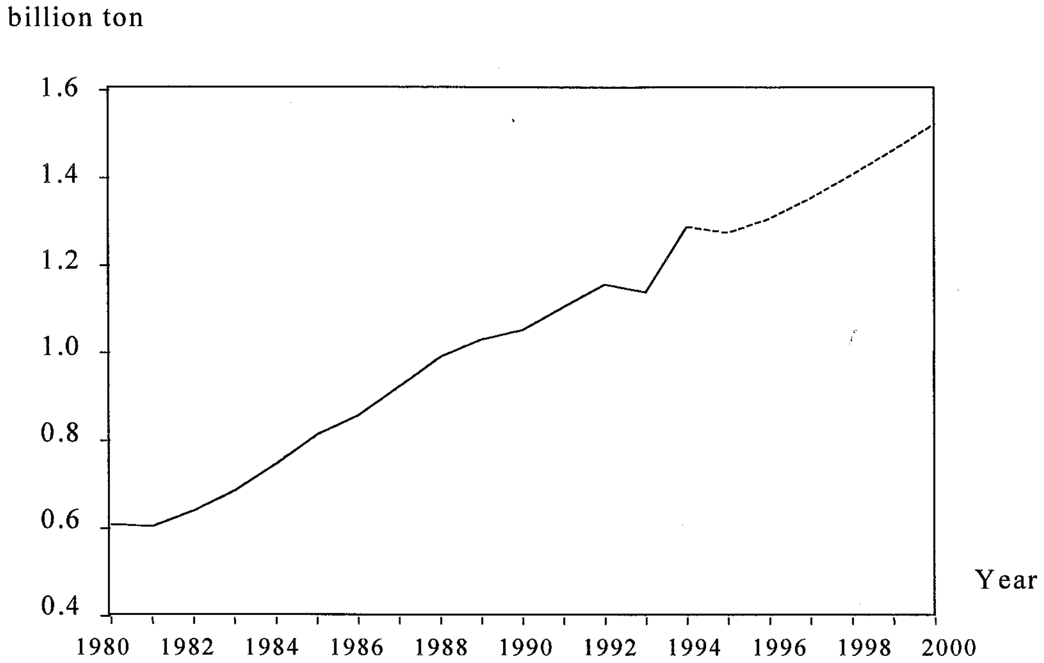
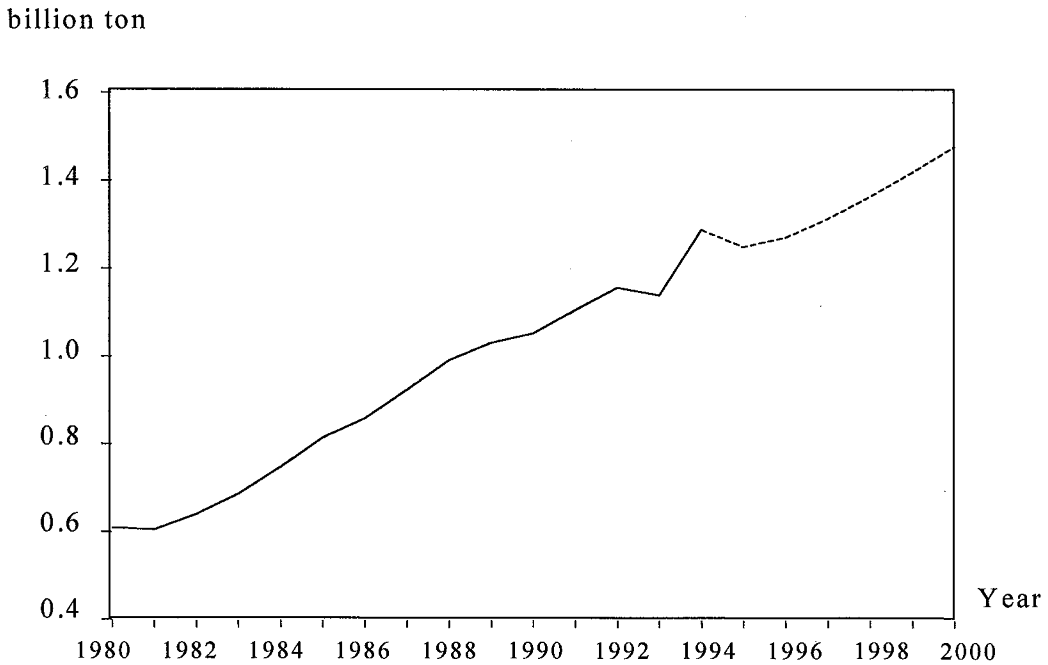


Figure 4.3 (d) Forecast of Coal Demand in China: Scenario 4



4.6 Conclusion

In this chapter, I have applied Engle-Granger's type ECM, Hendry's type ECM and general-to-specific approach to analyse the consumption behaviour of the coal industry. It is found that, in all these cases, not only income and price are important in determining demand but also the relative size of heavy industry. This probably reflects the importance of this sector in the consumption of coal. By comparing the forecast error, it is possible to conclude that the Engle-Granger's type ECM performs most satisfactorily. This model is then used to capture the demand behaviour of the industry. In the stability tests we have conducted, no evidence is found of a structural change in energy demand following the economic reform in 1979. When the estimated model is used to forecast coal demand, it is found that the energy constraint will require the economy to grow at a rate lower than ten per cent annually. Further, the optimistic scenario of our estimates indicates that as much as a 5 per cent of shortfall in coal consumption will arise at the end of this century. This highlights the need of an effective management policy in handling the country's largest energy sector as China moves toward the new century.

Chapter 5: Factor Demand

5.1 Introduction

In reviewing the energy balance situation in Chapter Two, I found that China still needs to confront a number of problems over the future although the imbalance has largely been kept to a manageable level over the last few years. In order to quantify the imbalance, I have carried out two forecast exercises in Chapters 3 and 4. My forecasts of energy consumption by econometric methods show that the predicted energy demand will be more than its supply in 2000 and 2010. This finding highlights the need for an effective management policy in handling the country's largest energy sector. The relevant polices have been discussed in Chapter Two. However, the analyses are mainly qualitative and the findings may be different from the ones obtained in quantitative studies. In the following chapters, I will mainly emphasise on evaluating China's energy pricing policy which is controversial and has become a hot issue in China.

Energy prices, like most commodity prices, have been predominately determined by government decisions rather than market forces. In general, they are lower than their production costs. This occurs because the Chinese system has generally excluded capital costs in establishing prices. In addition, the authority attempts to provide low energy cost for industrial use so as to stimulate the country's potential output and productivity. However, such a low pricing policy induces low returns on investment in energy and so reduces the financial ability to develop energy industries[1]. This became a particularly serious problem after the reform. China has been experiencing large budget deficits resulting from, among other reasons, increased pressure for greater investment in infrastructural construction. Moreover, many economists believe that this kind of pricing policy has led to a pervasive wastage of energy as the price does not reflect the opportunity cost[2]. With a view to generating budget revenues and alleviating the adverse impacts of the low energy price policy on energy utilisation, various Chinese economists and policy-makers have suggested the government should reform the energy price system by gradually raising energy prices up to market levels [3].

It is, therefore, important to investigate the complementarity/substitutability between energy and capital so that we can better understand the effects of energy price adjustments. In turn, this enables an evaluation of the effect of energy price changes on output and energy use. If, for example, energy and capital are found to be complements, other things being constant, higher energy prices will reduce capital investment and so less capital will be employed for production. This would

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[1] See Clarke and Winters (1995).

[2] Besides, under the rigid price system, some industrial raw materials and farm products were sold at such artificial low prices that many state-owned enterprises producing basic industrial goods were unable to cover their production costs. The deficit had to be made up by state subsidies, which was a big drain on the state budget. Although this rigid price control system ensured the satisfaction of the basic needs of the people for subsistence and stabilised prices, it discouraged the producers from boosting output and improving the quality of their products for lack of a profit incentive. As a result, the economy stagnated and those goods which were in short supply had to be rationed (Wang, 1992).

result in a decrease in labour productivity growth and reduce future output. Therefore, a price increase policy may be counter productive. Alternatively, if a substitution relationship exists between energy and capital, higher energy prices will encourage capital investment and thus increase potential GNP. Therefore, a high pricing regime is predicted to have the desirable effect of conserving the scarce energy resources and relieve the energy bottlenecks to growth. However, it should be noted that the above mentioned effects of the energy prices on output occur only in the short run. Over the long run, if energy prices keep increasing and cause capital inputs to rise continuously, the effect on total output can not last forever even if energy and capital are substitute. This is because if other factor inputs remained fixed, the return of capitals will diminish and output will deteriorate eventually.Therefore, the effects of energy price changes on output hinge not only on the substitutability /complementary between energy and capital but also on the time horizon.

In section 2, I will review the relationship between capital and energy from previous studies. Since it is needed to derive input demand functions and relevant elasticities for examining the relationships among various factors, section 3 will explain how to derive the input demands and discuss which approach is particularly appropriate for China's situation[4]. Section 4 will conclude the findings in this chapter.

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[3] For discussion of price reform, please see Wang (1992), Clarke and Winters (1995) and Nakijima (1992).

[4] The derivation of relevant elasticities will be discussed in Chapter Six.

5.2 Capital-Energy Controversy

In reviewing the literature, the available econometric evidence of Capital–Energy (K-E) relationship is contradictory, in the sense that the support of both K-E substitutability and K-E complementarity can be found. Controversies over K-E possibilities stem from the following five considerations.

5.2.1) Data Set

Griffin and Gregory (1976) and Baltagi and Griffin (1984) argue that different data sets may reveal different results of the K-E relationship. Time series (single country) data reflect short-term relationships only, because they do not necessarily accommodate the assumption of instantaneous adjustment of some inputs (e.g. capital) in response to changes in their input prices (w_k), especially given a cost/profit function does not possess a dynamic mechanism. In contrast, cross section data set have wider variation in the relative input prices, and so can capture the long run effects. Moreover, pooled cross-section data also give a higher range of energy price variability over time and individual units; the estimation of the cost/profit functions, therefore, can also capture long run behaviour. As mentioned in Apostolakis(1989)[5], time-series data are likely to classify K-E as complements,

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[5] Apostolakis(1989) explains in a different way why cross-sections typically reflects long-run adjustments whereas annual time-series tends to reflect short-run reactions. This is because disequilibrium among firms tends to be synchronized in response to common market forces and the business cycle. Many disequilibrium effects wash out so that the higher cross section slope estimates can be interpreted as long-run

whereas pooled cross-section studies normally conclude that the two inputs are substitutes.

5.2.2) Fixty of Certain Inputs

Mcfadden (1978) and Diewert and Wales (1987) develop the short run variable cost functions (expenditure on variable inputs, rather than total costs) which are dependent on variable input prices, the level of output and quantity of fixed factors (instead of the prices of fixed factors). Similarly, the short run profit functions are defined as total revenue minus total variable costs (not total costs). These short run functions are expressed in terms of the quantity of fixed factors and the prices of various inputs and outputs. These short run models are modified from the traditional long run models in which all input factors, including fixed inputs in short run, are classified as variable factors and thus all the prices are treated as explanatory variables. According to Berndt, Morrison and Watkins (1981), these two types of functional forms may get opposite results of K-E relationship. This is because in the short run, for a given capital stock, energy input per unit of capital is constant, i.e. capital and energy must be used in certain fixed proportions, so K-E may be complementary in the short run. However, the capital-energy ratio is flexible in the long run, and thus their relationship may change.

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coefficients. Thus, dynamic specification errors that bias time series estimates will

5.2.3) Types of Capital Input Employed

Field and Grebenstein (1980) argue that different types of capital employed in the study may also lead to contradictory results of the K-E relationships. Disaggregating capital into reproducible physical (structures, machinery and equipment) and working capital (cash, government securities, inventories) in their study, they find the reproducible physical capital and energy are complements, whereas working capital and energy are substitutes.

5.2.4) Types of Labour Input Employed

Berndt and White (1979) disaggregate labour into non-productive (unskilled) and productive (skilled) workers. They find that under this approach, capital and energy are highly complementary. On the other hand, capital and unskilled labour are substitutes, whereas capital and skilled labour are complements. Therefore, an increase in energy price will increase the demand for unskilled labour and reduce the demand for skilled labour. This implies that rising energy prices will have a positive redistribution effects.

5.2.5) Gross and Net effect

Berndt and Wood (1979 and 1981) mention that excluding the scale effect when measuring the effects on factor prices changes may produce different results of the total effects on K-E relationships. Kintis and Panas, (1989) find that the price

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be less observable in cross sections.

elasticities derived from profit functions measure the total effect, whereas the price elasticities derived from cost functions capture substitution effects only and exclude the scale effects. Therefore, the two types of measurements may give two different results.

In addition to endogenous pricing under the imperfectly competitive market, there are studies which introduce the effects of technical progress on factor demands, rational expectations, dynamic specifications (i.e. derive analytically the optimal transition path from SR to LR: cointegration, ECM (Friesen, 1992), time varying parameter approaches, various functional forms, specification of multiple outputs and relaxing the assumption of constant return to scale. (i.e. variable RTS (Kim, 1992)).

There were almost no relevant studies that look into the K-E relationship in the Chinese Manufacturing Industry. Moreover, a few studies employ only aggregate data; they study either certain manufacturing industries or the total manufacturing industry. Hence, it seems that there is really a need for a more disaggregated approach, if only to verify the aggregate results. My study is based on a pooled firm level data.

My own view is that K-E relationship in China can only be understood in the context of rationing. Rationing is always present due to such factors as import licensing, foreign exchange control, exogenous factor supply shocks (energy crisis, bad harvest, etc.). As China has been transiting from a centrally planned to a market economy, it is not unusual for Chinese enterprises to face shortfall of some inputs. Thus, quantity controls and rationing of inputs allocates the limited available inputs to individual firms and may regulate production levels beyond the socially optimum levels. Given this background, the above traditional studies which ignore the effect of rationing appear to be far from being fruitful. My study, therefore, tries to fill the gap by taking quantity controls and rationing of inputs into account when deriving input demand functions and their relevant input price elasticities.

To achieve this, I will follow the concept of virtual pricing from Neary and Roberts (1980) and Squires (1994).[6] It is clear from the subsequent formulae that the price elasticities under no rationing may be opposite in sign to that with rationing. This may serve as an alternative explanation of the K-E controversy which is quite different from the previous studies.

5.3 Derivation of Factor Demand Function

To determine the capital - energy (K-E) relationship, the first step is to derive the input demand functions. In this section, I will start by explaining how the input demand functions can be derived from the primal and dual approach and then discuss the usefulness and the drawbacks of the two approaches. After that, I will explain why a translog profit function, rather than a translog cost function, is employed in my study to derive the price elasticities of the demand.

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[6] The two approaches will be discussed in Section 6.2 and the elasticities under virtual pricing approach will be derived in Section 6.3.

5.3.1) The Primal and Dual Approach for Deriving Input Demand Function Under Profit Maximisation and Cost Minimisation.

To derive the input demand function, let us firstly consider a competitive firm that produces output q using input vector $x = (x_1,\ldots\ldots,x_n)$, where output price P $\in R^n_{++}$ and the input price $W = (W_1,\ldots\ldots,W_n)$ are given to the firm. For the production plans to be feasible, it is assumed that the firm is subject to a production constraint

$$q \leq f(x) \tag{5.1}$$

Here, f: $R^n_{+} \rightarrow R$ is known as the firm's production function. f(x) is the maximum attainable output from the input vector, x and q is a scalar denoting the quantities that the firm can produce. The objective of rationed firm is profit maximisation or cost minimisation.

5.3.1.A) Profit Maximisation:

The maximisation profit function problem is defined as

$$\underset{x \in R^n_{++}}{Max} \quad \pi'(P,W) = P \cdot q - \sum_{i=1}^{n} W_i x_i \qquad \text{subject to } q \leq f(x) \tag{5.2}$$

The Lagrangian is written as

$$L(q,x,\lambda;P,W) = P \cdot q - \sum_{i=1}^{n} W_i x_i + \lambda(f(x) - q) \tag{5.3}$$

5.3.1.A.a) The Primal Approach

Here, the input demand functions can be derived by solving the Lagragean function - which specifies either a profit maximisation or a cost minimisation problem subject to the production constraint. The procedures are just to find the partial derivatives of the Lagragean function with respect to all the endogenous variables and solve the Kuhn-Tucker condition.

Based on (5.3), the Kuhn-Tucker conditions therefore are: $\exists\ \lambda^M$ such that

$$\text{(I)}\ \frac{\partial L}{\partial q} = P - \lambda^M = 0\ ;\ \frac{\partial L}{\partial x_i} = -W_i + \lambda^M f_i(x^M) = 0,\ i = 1 \ldots n$$

$$\text{where } f_i(x^M) = \frac{\partial f}{\partial x_i}$$

$$\text{(II)}\ \lambda^M > 0$$

$$\text{(III)}\ \left(q^M, x^M\right) \in R^{n+1}_{++} \text{ and } f(x^M) - q^M = 0$$

From (I), it is clear that λ^M>0 and so (II) is redundant. Substituting λ^M=P into (I) gives

$$\text{(a)}\ P \cdot f_i(x^M) = W_i\ \ ;i\text{=1,....,n and } x^M \in R^n_{++}$$

$$\text{(b)}\ q^M = f(x^M)\ \ (\text{with } \lambda^M = P) \qquad (5.4)$$

Solving (5.4a) and (5.4b) simultaneously, we can obtain input demand and output supply functions: x^M(P,W) and q^M(P,W). This means that all the profit-maximising firms (with exogenous pricing) produce the quantities that must fulfil the conditions (5.4a) & (5.4b).[7]

However, it may be difficult to obtain the derivations $f_i(x^M)$ for some complicated production functions and so the solutions $q^M(P,W)$ & $x^M(P,W)$ are not easy to derive. Alternatively, we may use the dual approach.

5.3.1.A.b) The Dual Approach

This approach involves deriving output supply and input demand equations from an indirect profit function. An indirect profit function is defined as the maximum profit that can be derived from a given set of input and output prices. It may be obtained by substituting the profit-maximising input demand and output supply equations derived in the primal approach (i.e., $x^M(P,W)$ and $q^M(P,W)$) into the direct profit function (5.2) so that

$$\begin{aligned}\pi'^M &= P\cdot q^M(P,W) - \sum_{i=1}^{n} W_i \cdot x_i^M(P,W) \\ &= \pi'^M(P,W)\end{aligned} \qquad (5.5)$$

[7] To maximise profit, condition (b) tells us that the firm produces 'on the production function' whereas condition (a) tells us that the value of marginal product of input i, $P\cdot f_i(x^M)$ equal the price of input i (W_i) for all i = 1,.....,n at the chosen production plan. If this were not so and $P\cdot f_i(x^M) > W_i$ for some i = 1,.....,n, a small increase in the use of input i (and hence in output to satisfy (b)) would lead to a rate of increase in additional revenue of and a rate of increase in costs of Wi; since $P\cdot f_i(x^M) > W_i$, and profits would be increased. Similarly a small reduction in x^M when $P\cdot f_i(x^M) <$ W_i, leads to increased profits, we should have $P\cdot f_i(x^M) = W_i$ for all i = 1,.....,n for a profit maximum. Madden(1996) gives detailed discussion on this issue.

where the notation π'^{M} is used to indicate maximum profit while $\pi'^{M}(P,W)$ represents the relationship between π'^{M} and prices. Actually, there is no need to derive such an indirect profit function, because a principal advantage of this approach is the avoidance of having to use the primal approach. In practice, we need only to specify an indirect profit function which has a number of special properties[8]. From this indirect profit function, we can use Hotelling's Lemma to derive the output supply and input demand equations, $q^{M}(P,W)$ and $x'^{M}(P,W)$ and then estimate the equations (5.6a) and (5.6b) using sample data. According to the Hotelling's Lemma, the first partial derivatives of the indirect profit function with respect to each of the input prices defines the negative of the input demand functions (5.6a) and the indirect profit function with respect to output price provides the output supply equation (5.6b). That is,

[8] An indirect profit function that is consistent with the assumed optimising behaviour should have the following properties :

1) $\pi'^{M}(P,W)\geq 0$, for $(P,W) \geq 0$ implying that negative profit is not occurred if the firm can produce nothing and achieve a zero profit.

2) $\pi'^{M}(P^1,W)\geq \pi'^{M}(P^2,W)$, for $P^1\geq P^2$ and $\pi'^{M}(P,W^1) \geq \pi'^{M}(P,W^2)$, for $W^2\geq W^1$. These mean that the profit function is monotonically increasing .

3) $\pi'^{M}(P,W)$ is homogenous of degree one in all prices implies that double all prices results in double profit. This follows the definition of profit.

4) $\dfrac{\partial\pi'^{M}(P,W)}{\partial P}$ and $\dfrac{\partial\pi'^{M}(P,W)}{\partial W_i}$ are homogenous of degree zero in all prices. This implies that a proportional increase in all prices does not alter the input mix nor encourage the firm to produce more output meaning that the producer does not suffer from money illusion.

5) $\pi'^{M}(P,W)$ is convex in all prices if the production function, $q = f(x)$, is strictly concave. It is necessary for the indirect function have a maximum. If the production function does not eventually exhibit decreasing returns to scale, the producer could indefinitely increase the scale of operations and hence to have no limit to profit.

$$\frac{\partial \pi'^{M}}{\partial W_i} = -x_i^{M}(P,W) < 0; \tag{5.6a}$$

$$\text{and, } \frac{\partial \pi'^{M}}{\partial P} = q^{M}(P,W) > 0, \qquad \forall i = 1,\ldots\ldots,n \tag{5.6b}$$

where the profit function $\pi'^{M}(P,W)$ is assumed to be twice continuously differentiable and its Hessian matrix is negative semi-definite.

5.3.1.B) Cost Minimisation

Other than maximising profit, there is another issue in the theory of the firm which is of economic interest but which is separate from (although related to) the behaviour of profit maximising firms. This is the analysis of the so-called cost-minimisation problem for a firm. In this problem, a firm may want to choose the inputs that lead to the minimum cost of production of a given output level q , given a set of input prices W.

5.3.1.B.a) The Primal Approach

The typical cost minimisation problem becomes

$$\underset{x \in R^{n}_{++}}{\text{Min}}\ C^{H}(q,W) = \sum_{i=1}^{n} W_i x_i \quad \text{subject to } q \le f(x) \tag{5.7}$$

The Lagrangean function for equation (5.7) therefore is

$$L(x,\lambda;P,q) = -\sum_{i=1}^{n} W_i x_i + \lambda(f(x) - q) \tag{5.8}$$

and Kuhn-Tucker are : $\exists\ \lambda^H$ such that

(I) $-P_i + \lambda^H f_i(x^H) = 0 \qquad i = 1.........n$

(II) $\lambda^H > 0$ and

(III) $x^H \in R^n_{++}$ and $f(x^H) = q$ (5.9)

From (I), $\lambda^H = P_i / f_i(x^H) > 0$ and (II) is redundant,

Eliminating λ^h from (I) we get, equivalently to (I)-(III)

(a) $\dfrac{f_i(x^H)}{f_j(x^H)} = \dfrac{W_i}{W_j}$ for all i, j = 1....n

(b) $f(x^H) = q.$ (5.10)

Solving (5.10a) and (5.10b) simultaneously for x_i, the conditional input demand functions can be obtained :

$$x_i^H = x_i^H(q, W) \qquad \text{for all} \quad i = 1........n \tag{5.11}$$

where x_i^H denotes the cost-minimising level of the i-th input and x_i^H (q,W) is known as conditional input demand function. x_i^H (q,W) represents the functional relationship that exists between x_i^H and the input prices and output. The main difference between these conditional input demand functions and the demand functions under profit maximisation (refer to equation (5.6a) & (5.11)) and (5.6a) is that the output quantity (q), instead of output price (P), appears as an argument in the demand function.

The optimal value function, known as the firm's indirect cost function, is defined as the minimum cost of producing a particular output with given input prices. It may be obtained by substituting the cost-minimising input demand equations derived in the primal approach (i.e. equation(5.11)) into the direct cost function i.e.

$$C^H = \sum_{i=1}^{n} W_i x_i^H(q, W_i) \tag{5.12}$$

$$= C^H(q, W_i) \tag{5.13}$$

where the notation C^H is used to indicate minimum cost while $C^H(q,W_i)$ represents the relationship between C^H and the exogenous variables W_i and q.

5.3.1.B.b) The Dual Approach

Similar to the case of profit-maximisation, we are unlikely to be able to derive an indirect cost function in practice. Instead, we estimate the cost function[9]

[9] Also, the cost function under dual approach has to fulfil the following properties (the explanations are similar to the profit case above):

and then derive $x_i^H(q,W)$ by using Shepherd's lemma which is also derived from the Envelope Theorem, which states that the first partial derivative of the indirect cost function with respect to each of the input prices defines the conditional input demand functions (i.e. conditional upon the output level, q). That is,

$$\frac{\partial C^H}{\partial W_i} = x_i^H(q, W_i) \qquad \forall i = 1......n \tag{5.14}$$

Similar to the profit function, the cost function $C^H(q,W_i)$ is also assumed to be twice continuously differentiable.

According to Chambers(1988), if $x_i^M(P,W)$ is the unique profit-maximising demand, it must equal the cost minimising derived demand. That is

$$x_i^M(P,W) = x_i^H(q(P,W),W)\ ,\ \forall \quad i = 1........n \tag{5.15}$$

5.3.2) The Usefulness Of The Dual Approach:

In summary, the dual approach is to obtain the input demands and output supply by differentiating the profit function or to obtain the conditional demand

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1) $C^H(q,W) \geq 0$, for $W \geq 0$ and $q > 0$.
2) $C^H(q,W^1) \geq C^H(q,W^2)$, for $W^1 \geq W$.
3) $C^H(q,W)$ is homogenous of degree one in all prices.
4) $\frac{\partial C^H(q,W)}{\partial W_i}$ is homogenous of degree zero in all prices.
5) $C^H(q,W)$ is weakly concave in input prices if the production function, $q = f(x)$, is strictly quasi - concave. For example, the traditional 3 - stage S - shaped production function is strictly quasi - concave.

functions by differentiating the cost function, and then estimating the relevant parameters by econometric methods, with no other algebraic manipulations required. In other words, there is no need to construct a Lagrangean function and the associated first order condition as given by (5.4) or (5.10). The dual approach provides us with an easier method of deriving input demand equations (as discussed above).

If I employ the primal approach, I need to directly estimate the production function and treat the quantities of factor inputs (x_i) as exogenous and quantity of output (q) as endogenous[10]. As mentioned in Berndt (1991, p.460), at a highly aggregate level, quantities of inputs may be exogenous but for a more disaggregate level, prices are more likely to be exogenous than quantities because individual firms choose the quantities of factor inputs (x_i) subject to their prices. Since I will employ the firm level (disaggregate) data set, the input quantities are unlikely to be exogenous to the optimisation decision. Therefore, direct econometric estimation of a production function may suffer from simultaneous equation bias, and so the primal approach is not appropriate from a statistical perspective.[11]

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[10] For more details, please refer to Berndt (1991) and Kintis and Panas (1989).

[11] Zellner, Kmenta and Dreze (1966) show that direct estimation of a production function is acceptable if one assumes the producer is attempting to maximise expected rather than actual profit. Their arguments are often used to justify the direct econometric estimation of production functions.

5.3.3) Why the Profit Function Has Certain Advantages Over Cost Function

The advantage of dual approach mentioned above cannot be applied to the case of cost function. A cost minimising firm attempts to select the input quantities (x) with a particular output (q) and given input prices (W). In other words, the solutions x(q,W) are functions of q and W. As q is unlikely to be exogenous, single estimation of the cost equation may suffer from simultaneous equation bias.

Although the Chinese economy is not fully marketised, the assumption of exogenous prices is also valid in my study because a state-owned enterprise under the economy administered by central authorities can be viewed as a price taker[12]. The factor prices in such economy sometimes are likely to be more exogenous than that under a non-competitive market in the Western economy[13]. Therefore, the estimation of an indirect profit function which has the exogenous prices on the right hand side may be more appropriate from a statistical perspective.

Besides, the effect of the change in factor price on the cost minimising input demands, $x_i^H(q(P,W),W)$, only reflect net substitution effect, whereas the effect on

[12] A state-owned enterprise sells goods and services according to the prices determined by the government.

[13] See Brada and Kutan (1994).

profit maximising input demands, $x_i^M(P,W)$, includes both net substitution effect and scale effect. That is[14]

$$\frac{\partial x_i^M(P,W)}{\partial W_j} = \frac{\partial x_i^H(q(P,W),W)}{\partial W_j} - \frac{\partial x_i^H(q(P,W),W)}{\partial q} \cdot \frac{\partial q(P,W)}{\partial W_j} \qquad (5.16)$$

where $\frac{\partial x_i^H(q(P,W),W)}{\partial W_j}$ is the partial derivative of cost minimising (i.e. Hicksian) demand for input x_i with respect to W_j. This expression denotes the net

[14] See Sakai (1973) or Chambers (1988) for proof. Moreover, note that the decomposition of the total effect into substitution and scale effect is quite analogous to the substitution and income effect in the Slutsky decomposition familiar from consumer theory. However, they are not exactly the same. Firstly, consumption theory considers two commodities (e.g. x,y) that can be considered as being similar but for the firm behaviour, we have two different kinds of commodities to consider - inputs and outputs. Therefore, their mutual relations and their cross relations take a little more disentangling.

Secondly, to the case of own price effect, as proved by Sakai (1973), the net substitution and scale effects always move in the same direction i.e. the own price elasticity of derived demand under profit maximisation (total effect) must be greater than that under cost minimisation (net substitution effect). This contrasts markedly with the total own price effect in consumption theory since the latter, the net substitution and income effect may go in the opposite direction.

Thirdly, taking partial derivative of (5.6a) and according to Young's Theorem, a second partial derivative should be invariant to the order of the differentiation,

$$\frac{\partial x_i^M(P,W)}{\partial W_j} = -\frac{\partial^2 \pi'(P,W)}{\partial W_j \partial W_i} = -\frac{\partial^2 \pi'(P,W)}{\partial W_i \partial W_j} = \frac{\partial x_j^M(P,W)}{\partial W_i} \qquad (5.17)$$

From that, the total effect is symmetrical between two inputs, i.e. if i is said a gross substitute for the input j then j must also be a gross substitute of i. Therefore, the scale effect, as the difference of the total and substitution effect, is symmetrical too. This contracts markedly with the income effect in consumer theory since the latter may not be symmetrical.

substitution effect which measures the effect of the change in input price ratio on technical substitution among the inputs along the original frontier.

$\frac{\partial x_i^H(q(P,W),W)}{\partial q} \cdot \frac{\partial q}{\partial W_j}$ is known as the scale effect which captures the induced changes in all outputs along the new expansion path associated with input prices, contributing the additional variation in input i. $\frac{\partial x_i^M(P,W)}{\partial W_j}$ is the partial derivative of profit maximising (Marshallian) demand for input x_i with respect to W_j. This expression denotes the (total or gross) effect measuring the total changes in profit maximising demand resulting in altering W_j.

Expression (5.16) may relate to one of the reasons why there are K-E controversy in the former studies. To explain this, let us firstly consider the cost minimisation approach; inputs are defined as net substitutes if the cross price partial derivatives of the conditional demand functions are positive[15], i.e., the net substitution effect (for cost minimising demand) is,

$$\frac{\partial x_i^H(q(P,W),W)}{\partial W_j} = \frac{\partial x_j^H(q(P,W),W)}{\partial W_i} \geq 0 \tag{5.18}$$

[15] That is, the first item of (5.16)

On the other hand, as revealed in (5.16), if the scale effect, $\frac{\partial x_i^H(q(P,W),W)}{\partial q} \cdot \frac{\partial q(P,W)}{\partial W_j} \leq 0$ [16] and its magnitude outweight the net substitution effect, the cross price effect under profit maximisation (for profit maximising demand) may show that the two inputs are gross complements,

i.e. $\frac{\partial x_i^M(P,W)}{\partial W_j} \leq 0$

Therefore, a pair of inputs can be complements for "cost minimising demand", whereas the corresponding "profit maximising" measure could be classified as substitutes. Hence, the result of K-E relationship from the profit function may be different from that of the cost function. This may be one of the reasons exploring why K-E controversy occurs in the literature. Moreover, by definition, an input is called normal (inferior) if $\frac{\partial x_i^H(q,(P,W),W)}{\partial q}$ is non-negative (non-positive). Whereas, the output is classified as regressive (non-regressive) of W_j if $\frac{\partial q(P,W)}{\partial W_j} \leq 0$ (or ≥ 0). Therefore, the sign of the scale effect depends on the signs of $\frac{\partial x_i^H(q,(P,W))}{\partial q}$ and $\frac{\partial q(P,W)}{\partial W_j}$ and so the K-E controversy may be arisen from inferior/normal factors and/or regressive/non-regressive output.

[16] That is, the second item of (5.16).

5.3.4) Choice of Functional Forms

The above discussion so far suggests that we should employ the dual method to specify and estimate the factor demand functions from some sort of profit functions. Unfortunately, there is no clear prior criteria for choosing a functional form. Indeed, a variety of functional forms such as Cobb-Douglas, Constant Elasticity of Substitution (CES), Zellner-Revankar, Quadratic and transcendental logarithmic (Translog) have been used to derive input demand functions. Although there are some theoretical studies (e.g. Caves and Christensen, 1980; Barnett and Lee, 1985; Lau, 1986; Diewert and Wales, 1987; and Chambers 1988), addressing the properties of various functional forms across sample space, it is still confusing to ascertain which is best suited for use in empirical application[17].

It is generally agreed that an appropriate functional form should be:

1. sufficiently flexible that it can accommodate various production structures; and

2. satisfy the properties mentioned above or permit the imposition of these properties through the application of appropriate constraints. [18]

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[17] Recently, some economists such as Gordon (1996) who uses the Bayesian methods and argues that there is in fact no need to choose the functional forms; the optimal strategy is just to use a mixture of functional forms to estimate the parameters of interest.

[18] Unfortunately, these two objectives are often in conflict. The imposition of constraints upon a flexible functional form to achieve appropriate theoretical properties can subsequently reduce the flexibility of many popular flexible functional forms (see Diewert and Wales, 1987).

In my study, I specify the profit function by the translog form because it is flexible[19]. That is, the translog model has no prior restrictions on elasticities. This model has the advantage over the less-flexible functional forms such as the Cobb-Douglas (CD), and the constant elasticity of substitution (CES) functions. The CD function requires its elasticity of substitution (ES) always and everywhere equal to one and the constant elasticity of substitution (CES) function assume its ES must be the same everywhere. There is a further important consideration, if I employ another popular functional form, quadratic form, I need the data of energy consumption. However, in the survey that I obtained, most of the enterprises in China recorded the prices, expenditures and profits only, instead of the quantity of energy inputs. This explains why translog function is more appropriate to derive input demands (by using the dual approach) for the data set of Chinese state enterprises.

The tranlog functional form has a number of drawbacks, however.

(I) Like other flexible functional forms, the translog model has no prior restrictions on elasticities, but this flexibility is achieved at the cost of giving up the global imposition of some theoretical requirements. Therefore, it limits the range of technologies that can be characterised. On the contrast, the CD and CES

[19] It is because translog can be viewed as a functional form by itself or a second order Taylor series expansion that will approximate any functional form at a single base point. (Diewert (1974)). Other flexible functional forms such as the Normalised Quadratic, the Generalised Leontief, and the Generalised Mcfadden can also be applied in dual analyses of production. For more on their properties, please refer to Diewert and Wales (1987).

globally impose theoretical requirements at the cost of giving up local flexibility.

(II) Burgess (1975) points out that the translog function is not self-dual[20], except at the actual point of approximation, whereas the CD and CES specification are both self-dual. That is, we can not derive the production function implied by the indirect translog cost or translog profit functions, although the production function does exist. This is due to the fact the mathematical derivation of its form is intractable. Fortunately, it is not a great problem, since the estimates of key measures such as substitution elasticities and the total elasticity of production can still be derived.

(III) Kuh (1976) argues that the translog production and cost functions do not necessarily describe the same technology, and the two approaches often yield quite different estimates of the elasticities of substitution. The inherent discrepancy between the theoretical and the empirical results is one of the weakness of translog functional form.

(IV) Since the translog function is a second-order approximation, the differentiation process transforms the system of value-share equations into a first-order approximations only. Hence the quality of the approximation will deteriorate overall. Moreover, it may suffer from statistical problems such as multicollinearity (Theil, 1980).

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[20] Indeed, most of the flexible functional forms appear to not be self-dual except the normalised quadratic, as noted in Squires (1994).

(V) Just like the other generalised quadratic forms, the translog form is very inflexible in that it represents separable technologies. It cannot model nonhomothetic weakly separable functions (Chambers 1988 and Blackorby, Primont and Russel ,1977).

5.4 Conclusion

In this chapter, I found the form of the relationship between energy and capital is controversial issue, which results in opposing energy pricing policies for narrowing the energy deficit. It is believed that these arguments are raised by different estimations or techniques employed in the studies, such as different data sets, functional forms and various dynamic specifications. Nevertheless, rationing, especially usual in China, may provide an alternative explanation for the arguments. Thus, I decided to incorporate rationing behaviour in this study.

To examine the relationships among various factors, it is needed to derive input demand functions and relevant elasticities[21] for use. Having reviewed the literature, I found the dual approach to derive the input demand function from the translog profit function has arguable greater net advantage compared to other alternatives, especially given data limitations.

[21] The derivation of relevant elasticities from the translog profit function will be discussed in Chapter Six.

Chapter 6: Derivation of Various Elasticities With/Without Rationing

Following the discussion in Chapter Five, I now derive the input demand functions and their relevant price elasticities from the translog profit function by using the dual approach. In Section 6.1, I will use the traditional approach to derive the input demand functions and elasticities of unregulated inputs. In section two I will compare the two possible approaches, the auxiliary constraint and virtual price approach, for modelling the firm/consumer behaviour under rationing. After that, in section 6.3, I will explain how this rationing is incorporated into the derivation of input demand functions.

6.1 Derivation of Various Elasticities without Rationing

This section mainly follows the theoretical framework developed by Lau (1976), Diewert (1973) and Sidhu and Baanante (1981). Firstly, let us consider the relevant function, π :

$$\pi = \pi(w, F) \tag{6.1.1}$$

Where π is the normalised restricted profit function (i.e. π' / P) which is defined as total revenue minus total costs of variable inputs normalised by prices of output (P). w is a vector of variable inputs prices, normalised by P (i.e., w = W_1/P, W_2/P,........W_n/P) and F is a vector of fixed inputs.

The normalised restricted translog profit function for a given output is defined as

$$\ln \pi = \alpha_0 + \theta_t T + \frac{1}{2}\theta_{TT} T^2 + \sum_{i=1}^{n} \alpha_i \ln w_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{h=1}^{n} \theta_{ih} \ln w_i \ln w_h + \sum_{i=1}^{n} \theta_{iT} T \ln w_i$$
$$+ \sum_{k=1}^{m} \rho_k \ln F_k + \frac{1}{2}\sum_{k=1}^{m}\sum_{j=1}^{m} \rho_{kj} \ln F_k \ln F_j + \sum_{i=1}^{n}\sum_{k=1}^{m} \delta_{ik} \ln w_i \ln F_k + \sum_{k=1}^{M} \varphi_{kT} T \ln F_k$$

(6.1.2)

Note that the time trend variable T and its square (T^2) are included in the translog function. [1] They are used to allow the possibility of technical change.[2] The partial derivative of profit function with respect to T $(\partial \ln \pi / \partial T)$ will then measure the rate of movement of the profit function over time. For technological progress to occur, the sign of $(\partial \ln \pi / \partial T)$ value should be positive indicating the profit function is shifting up over time (and the cost function is falling and production function is rising over time.)

If the coefficients of the terms $T \ln w_i$ (i.e.θ_{iT}) and of $T \ln F_k$ (i.e. φ_{kT}) are zero, the inclusion of the time variables will account for the Hicks-neutral technological change. This means that when the isoquants and production possibility curves (PPCs) shift up and down, their slopes (marginal rate of technical substitution and marginal rate of transformation) remain unchanged (i.e. parallel shifts). On the other hand, non-neutral technical change can be also accounted for by

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1 The T^2 term is included to provide consistency with the second order approximation notion of the translog form.

including those terms which involve the interactions of the other regressors and time. This occurs when θ_{iT} and φ_{kT}, result in non-parallel shifts in the isoquants and PPCs. Note that the non-neutral technical change is also called biased technological change, because the movement in the production/cost/profit functions are biased in favour of certain input(s) and/or output(s) at the expense of the other inputs.

By using Young's Theorem, we have $\theta_{ij} = \theta_{ji}$ and $\rho_{kj} = \rho_{jk}$ so that symmetry restrictions are ensured. Since the normalised restricted translog profit function is restricted to be linearly homogeneous in variable inputs prices (w_i) and in fixed input (F_k), this requires the following restrictions to be imposed on the parameter estimates (Diewert, 1982):

$$\left.\begin{aligned} &\sum_{i=1}^{n}\alpha_i = 1, \sum_{i=1}^{n}\theta_{ih} = 0 \quad \text{for all } h = 1,\ldots\ldots,n \\ &\sum_{i=1}^{n}\theta_{iT} = 0, \sum_{i=1}^{n}\delta_{ij} = 0 \quad \text{for all } j = 1,\ldots\ldots,n \\ &\sum_{k=1}^{m}\rho_k = 1, \sum_{k=1}^{m}\rho_{kj} = 0 \quad \text{for all } j = 1,\ldots\ldots,n \\ &\sum_{k=1}^{m}\varphi_{kT} = 0, \sum_{j=1}^{m}\delta_{ij} = 0 \quad \text{for all } i = 1,\ldots\ldots,n \end{aligned}\right\} \qquad (6.1.3)$$

In addition to monotonicity, the estimated parameters are required to be correctly signed. This means that the estimated shares for fixed inputs must be positive, while for the variable input case (i.e. input prices) must be negative. Besides, the convexity condition of the profit function implies that the Hessian matrix must be positive definite. If these regular conditions are satisfied, there is

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2 Under constant returns to scale the effects of technical progress are manifested either in increased output or in reduced factor demands and costs.

sufficient information describing completely the well-behaved production function which are completely specified[3].

Before going to derive the input demand equations and the relevant price elasticities, let us use the Hotelling's Lemma allow me to derive the profit share and elasticity functions :

$$\frac{\partial \pi}{\partial w_i} = -x_i \tag{6.1.4}$$

and so,

$$\frac{\partial \pi}{\partial w_i} \cdot \left(\frac{w_i}{\pi}\right) = \frac{\partial \ln \pi}{\partial \ln w_i} = \frac{-w_i x_i}{\pi} = S_i \leq 0 \tag{6.1.5}$$

Where the x_is are the optimised quantities of the variable inputs and S_i is defined as profit share. Applying this lemma to Equation (6.1.2), we can obtain the profit share functions :

$$S_i = \frac{\partial \ln \pi}{\partial \ln w_i} = \alpha_i + \sum_{h=1}^{n} \theta_{ih} \ln w_h + \sum_{k=1}^{m} \delta_{ik} \ln F_k + \theta_{iT} T \tag{6.1.6}$$

Where $S_i = -w_i \, x_i / \pi$

[3] Although it is difficult to obtain sufficient conditions on the parameters of the translog profit function, which will ensure that it is globally consistent with the properties mentioned above, this may not be a very serious defect in empirical applications. (Diewert, 1974).

From (6.1.5) the input demand equations for the ith variable input can be written as

$$x_i = \frac{\pi}{w_i}\left(-\frac{\partial \ln \pi}{\partial \ln w_i}\right), \tag{6.1.7}$$

and

$$\ln x_i = \ln \pi - \ln w_i + \ln\left(-\frac{\partial \ln \pi}{\partial \ln w_i}\right). \tag{6.1.8}$$

Based on (6.1.8), we can derive various elasticities:

6.1.1) The own-price elasticity of demand for x_i (ξ_{ii}):

To obtain ξ_{ii}, differentiating (6.1.8) with respect to lnwi, , that is,

$$\xi_{ii} = \frac{\partial \ln x_i}{\partial \ln w_i} = \frac{\partial \ln \pi}{\partial \ln w_i} - 1 + \frac{\partial \ln}{\partial \ln w_i}\left(-\frac{\partial \ln \pi}{\partial \ln w_i}\right). \tag{6.1.9a}$$

Substituting (6.1.5) into (6.1.9a), ξ_{ii} becomes:

$$\xi_{ii} = \frac{\partial \ln \pi}{\partial \ln w_i} - 1 + \frac{\partial \ln(-S_i)}{\partial \ln w_i}.4 \tag{6.1.9b}$$

Since $\frac{\partial \ln(-S_i)}{\partial \ln w_i} = \frac{\partial(-S_i)/(-S_i)}{\partial \ln w_i} = \frac{\partial(-S_i)/\partial \ln w_i}{(-S_i)}$, (6.1.9b) becomes,

$$\xi_{ii} = S_i - 1 + \frac{\partial(-S_i) / \partial \ln w_i}{(-S_i)} \qquad (6.1.9c)$$

Where $\partial S_i / \partial \ln w_i$ can be obtained by differentiating (6.1.6) with respect to $\ln w_i$,

and so, $\xi_{ii} = S_i - 1 + \frac{\theta_{ii}}{S_i}$, [5] (6.1.10)

6.1.2) The cross-price elasticity of demand for input i with respect to the price of the hth input (ξ_{ih}):

Similarly, by differentiating (6.1.8) with respect to $\ln w_h$, we can get ξ_{ih} as follows:

$$\xi_{ih} = \frac{\partial \ln x_i}{\partial \ln w_h} = \frac{\partial \ln \pi}{\partial \ln w_h} + \frac{\partial \ln}{\partial \ln w_h}\left(-\frac{\partial \ln \pi}{\partial \ln w_i}\right) \qquad (6.1.11a)$$

$$= \frac{\partial \ln \pi}{\partial \ln w_h} + \frac{\partial \ln(-S_i)}{\partial \ln w_h} \qquad (6.1.11b)$$

$$= S_h + \frac{\partial(-S_i) / \partial \ln w_h}{(-S_i)} \qquad (6.1.11c)$$

$$\text{As } \frac{\partial \ln w_i}{\partial \ln w_h} = \theta_{ih},$$

$$\xi_{ih} = S_h + \frac{\theta_{ih}}{S_i}, \quad i = 1,\dots n, h = 1,\dots n, \qquad (6.1.12)$$

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[4] Since $S_i (= \frac{-w_i x_i}{\pi})$ is negative, $(-S_i)$ is positive. Therefore, taking logarithm of $(-S_i)$ becomes valid.

[5] This result is similar to equation (6) in Sidhu and Baanante (1981)

Where $S_h = \frac{-w_h x_h}{\pi}$ and $\frac{\partial S_i}{\partial \ln w_h} = \theta_{ih}$, $i \neq h$,

6.1.3) The elasticity of demand for input i with respect to output price, $P\left(\xi_{iq}\right)$:

Also, ξ_{iq}, can be obtained from differentiating (6.1.8) with respect to lnP:

$$\xi_{iq} = \frac{\partial \ln x_i}{\partial \ln P} = \frac{\partial \ln \pi}{\partial \ln P} - \frac{\partial \ln w_i}{\partial \ln P} + \frac{\partial \ln}{\partial \ln P}\left(-\frac{\partial \ln \pi}{\partial w_i}\right), \quad (6.1.13a)$$

$$= \sum_{i=1}^{n} \frac{\partial \ln \pi}{\partial \ln w_i} \cdot \frac{\partial \ln w_i}{\partial \ln P} - (-1) + \frac{\partial \ln(-S_i)}{\partial \ln P} \quad (6.1.13b)^6$$

$$= \sum_{i=1}^{n} -S_i + 1 + \sum_{h=1}^{n} \frac{\partial \ln(-S_i)}{\partial \ln w_h} \cdot \frac{\partial \ln w_h}{\partial \ln P} \quad (6.1.13c)$$

$$= \sum_{i=1}^{n} -S_i + 1 + \sum_{h=1}^{n} \frac{\theta_{ih}}{S_i}(-1), \quad (6.1.14)$$

Where i =1, . . . , n,

$$\xi_{iq} = \sum_{i=1}^{n} -S_i + 1 - \sum_{h=1}^{n} \frac{\theta_{ih}}{S_i}, ^{7} \quad (6.1.15)$$

6.1.4) The elasticity of demand for input i with respect to the kth fixed factor $F_k\left(\varepsilon_{ik}\right)$

Similarly, differentiating (6.1.8) with respect to $\ln F_k$, I obtain

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6 Since $w_i = \frac{W_i}{P}, \frac{\partial \ln w_i}{\partial \ln P} = -1$

$$\varepsilon_{ik} = \frac{\partial \ln X_i}{\partial \ln F_k} = \frac{\partial \ln \pi}{\partial \ln F_k} - \frac{\partial \ln w_i}{\partial \ln F_k} + \frac{\partial \ln}{\partial \ln F_k}\left(-\frac{\partial \ln \pi}{\partial \ln w_i}\right). \quad (6.1.16a)$$

Since $\frac{\partial \ln w_i}{\partial \ln F_k} = 0$, substituting the differentiation of (6.1.2) with respect to $\ln F_k$, (6.1.16) becomes

$$\varepsilon_{ik} = \rho_k + \sum_{j=1}^{m} \rho_{kj} \ln F_j + \sum_{i=1}^{n} \delta_{ik} \ln w_i + \varphi_{kT} T + \frac{\partial \ln(-S_i)}{\partial \ln F_k} \quad (6.1.16b)$$

$$= \rho_k + \sum_{j=1}^{m} \rho_{kj} \ln F_j + \sum_{i=1}^{n} \delta_{ik} \ln w_i + \varphi_{kT} + \frac{\partial(-S_i)/\partial \ln F_k}{(-S_i)} \quad (6.1.16c)$$

As $\frac{\partial S_i}{\partial \ln F_k} = \delta_{ik}$, (6.1.16C) can be modified as follows,

$$\varepsilon_{ik} = \rho_k + \sum_{j=1}^{m} \rho_{kj} \ln F_j + \sum_{i=1}^{n} \delta_{ik} \underset{W}{\ln w_i} + \varphi_{kt} T + \frac{\delta_{ik}}{S_i}, \quad (6.1.17)^8$$

6.1.5) The output (supply) elasticity with respect to input prices (ξ_{qi})

Firstly, consider the nominal profit function of the following form:

$$\pi' = P \cdot q - \sum_{i=1}^{n} W_i x_i \quad (6.1.18)$$

Normalising (6.1.18) by P gives us the normalised profit function:

[7] This result is similar to equation (11) in Sidhu and Baanante (1981)
[8] This result is similar to equation (13) in Sidhu and Baanante (1981)

$$\pi = q - \sum_{i=1}^{n} w_i x_i \tag{6.1.19}$$

After rearranging, it will give us:

$$q = \pi + \sum_{i=1}^{n} w_i x_i \tag{6.1.20}$$

With the help of (6.1.7), (6.1.20) becomes

$$q = \pi + \sum_{i=1}^{n} w_i \frac{\pi}{w_i}\left(-\frac{\partial \ln \pi}{\partial \ln w_i}\right)$$

$$= \pi\left(1 - \sum_{i=1}^{n} \frac{\partial \ln \pi}{\partial \ln w_i}\right) \tag{6.1.21}$$

Taking log of (6.1.21) will result in:

$$\ln q = \ln \pi + \ln\left(1 - \sum_{i=1}^{n} \frac{\partial \ln \pi}{\partial \ln w_i}\right) \tag{6.1.22}$$

Since the elasticity of output (supply) with respect to price of the ith input is given by $\xi_{qi} = \frac{\partial \ln q}{\partial \ln w_i}$, I can differentiate (6.1.22) with respect to w_i to obtain ξ_{qi}, given as below:

$$\xi_{qi} = \frac{\partial \ln \pi}{\partial \ln w_i} + \frac{\partial \ln}{\partial \ln w_i}(1 - \sum_{h=1}^{n} \frac{\partial \ln \pi}{\partial \ln w_h}) \tag{6.1.23}$$

Referring to (6.1.5), (6.1.23) becomes

$$\xi_{qi} = S_i + \frac{\partial \ln}{\partial \ln w_i}(1 - \sum_{h=1}^{n} S_h). \tag{6.1.24}$$

From the result of (6.1.6), further modification can be made to (6.1.24)[7]

$$\xi_{qi} = S_i - \frac{\sum_{h=1}^{n} \theta_{hi}}{1 - \sum_{h=1}^{n} S_h}, \text{ where } i = 1, \ldots, n. \tag{6.1.25}$$

6.1.6) The output supply price elasticity (ξ_{qq})

Similarly, differentiating (6.1.22) with respect to ln P

$$\xi_{qq} = \frac{\partial \ln q}{\partial \ln P} = \frac{\partial \ln \pi}{\partial \ln P} + \frac{\partial \ln}{\partial \ln P}(1 - \sum_{i=1}^{n} \frac{\partial \ln \pi}{\partial \ln w_i}). \tag{6.1.26}$$

Using (6.1.5), (6.1.26) is equivalent to

$$\xi_{qq} = \frac{\partial \ln \pi}{\partial \ln P} + \frac{\partial \ln(1 - \sum_{i=1}^{n} S_i)}{\partial \ln P} \tag{6.1.27}$$

$$= \frac{\partial \ln \pi}{\partial \ln P} + \frac{\partial \ln(1 - \sum_{h=1}^{n} S_h)}{\partial \ln P} \tag{6.1.28}$$

Where i, h = 1……n. By using the Chain rule, we establish

$$\xi_{qq} = \sum_{i=1}^{n} \frac{\partial \ln \pi}{\partial \ln w_i} \cdot \frac{\partial \ln w_i}{\partial \ln P} + \sum_{i=1}^{n} \frac{\partial \ln(1-\sum_{h=1}^{n} S_h)}{\partial \ln w_i} \cdot \frac{\partial \ln w_i}{\partial \ln P} \qquad (6.1.29a)$$

$$= \sum_{i=1}^{n} S_i(-1) - \frac{\sum_{i=1}^{n}\sum_{h=1}^{n} \theta_{hi}(-1)}{1-\sum_{h=1}^{n} S_h} \qquad (6.1.29b)$$

$$= \sum_{i=1}^{n} -S_i + \frac{\sum_{i=1}^{n}\sum_{h=1}^{n} \theta_{ih}}{1-\sum_{h=1}^{n} S_h} \qquad (6.1.30)^{9}$$

Where $\theta_{ih} = \theta_{hi}$.

6.1.7) The elasticity for a change in the quantity of output with a change in fixed factor (ε_{qk})

Differentiating (6.1.22) with respect to F_k, ε_{qk} is obtained as follows:

[9] Similar result as equation (21) in Sidhu and Baanate (1981)

$$\varepsilon_{qk}=\frac{\partial \ln q}{\partial \ln F_k}=\frac{\partial \ln \pi}{\partial \ln F_k}+\frac{1}{1-\sum_{i=1}^{n} S_i}\left(-\sum_{i=1}^{n}\frac{\partial S_i}{\partial \ln F_k}\right) \tag{6.1.31}$$

$$=\rho_k+\sum_{j=1}^{m}\rho_{kj}\ln F_j+\sum_{i=1}^{n}\delta_{ik}\ln w_i+\varphi_{kT}T-\frac{\sum_{i=1}^{n}\delta_{ik}}{1-\sum_{i=1}^{n} S_i} \tag{6.1.32}$$

Where i=1,…..,n.

6.2 Firm Behaviour under Rationing

Before deriving the elasticities under rationing, I will discuss how the auxiliary constraint and the virtual pricing approach can be used to derive the input demands under rationing.

6.2.1) Auxiliary Constraint

Tobin and Houthakker (1950-51) presented the first paper to investigate how the consumer behavioural functions under rationing are related to the corresponding functions in unrestricted market by using Samuelson's concept of auxiliary constraints (1947). This concept can also be used in the profit maximising behaviour of a firm by introducing one more constraint in the profit function. To illustrate this approach, let us partition the input vector x, $(x_1, x_2, \ldots, x_n)$ into rationed inputs x_1^- [10] and freely chosen inputs x_h, where $x_h=(x_2, \ldots, x_n)$. The variable input prices for rationed x_1^- and unrationed x_h are W_1 and W_h, respectively. When an economy faces rationing, the profit maximising problem of the economy, which is modified from (5.2), can be defined as:

$$\max_{x \in R^n_{++}} \pi'(P, W, F) = P.q - \sum_{i=1}^{n} W_i x_i \quad \text{Subject to } q \le f(x) \text{ and } x_1 \le x_1^- \qquad (6.2.1)$$

When (6.2.1) is normalised by P, I obtain

$$\max_{x \in R^n_{++}} \pi(w, F) = q - \sum w_i x_i \quad \text{subject to } q \le f(x) \text{ and } x_1 \le x_1^- \qquad (6.2.2)$$

The Lagrangean function is written as

$$L(q, x, \lambda; w, F) = P.q - \sum_{i=1}^{n} w_i x_i + \lambda_1 (f(x) - q) + \lambda_2 (x_1^- - x_1) \qquad (6.2.3)$$

Solving the Kuhn-Tucker conditions, we obtain the following solutions:

$x_1^M(w, x_1^-, F), x_h^M(w, x_1^-, F), q^M(w, x_1^-, F)$ and $\pi^M(w, x_1^-, F)$, respectively.

If the free market equilibrium is at $x_1^M(w, x_1^-, F), x_h^M(w, x_1^-, F)$ and the constraint is at $x_1^- = x_1^M(w, x_1^-, F)$, the constraint would be auxiliary or non-biting at the prevailing prices, i.e.,

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10 Because there is only one input that needs to be rationed in my data, only the first input is assigned as rationed good.

$$\pi^{-}(w, x_1^{-}, F) = \underset{q, x_h \in R_{++}^{n+1}}{\text{Max}} [q - w_1 x_1^{-} - \sum_{h=2}^{n} w_h x_h]; \quad x_1^{-}, x_h \in R_{++}^{n} \tag{6.2.4}$$

and $$\pi^{M}(w, F) = \pi^{-}(w, x_1^{-}, F) \tag{6.2.5}$$

The use of the auxiliary constraint begs several questions. First, this optimum under auxiliary constraint cannot deviate from the free market optimum. Second, this auxiliary constraint is subject to the limitation that the price of the rationed input $\bar{x}_1$ (i.e. w_1) has to remain constant. In contrast, the virtual pricing approach can make such comparisons between the case of rationing and non-rationing in the more general condition.[11]

6.2.2) Virtual Pricing Approach

Using Neary and Roberts' (1980) concept,[12] I define virtual prices, w_1^{-}, as those prices which would induce an unconstrained firm to demand for the ration level of x_1^{-}. By adopting such a definition, the virtual prices w_1^{-} can be defined as implicit function of w_h and, x_1^{-}, i.e., $w_1^{-} = f(w_h, x_1^{-}, F)$. Thus, even if a constraint on the profit function is not imposed, $x_1 = x_1^{-}$ also can be achieved by altering the rationed input price vector w_1 at the virtual price w_1^{-}. In this situation, the

[11] For detailed discussion on this issue, please refer to Coddington, Johannson and Lofgren (1984).

constrained (with rationing) and the unconstrained profit function can be linked together[13], i.e.,

$$\pi^{-}(w, x_{l}^{-}, F) = \pi(w_{l}^{-}, w_{h,}, F) \qquad \text{if } w_{l} = w_{l}^{-} \qquad (6.2.6)^{14}$$

$$\pi^{-}(w, x_{l}^{-}, F) = \pi(w_{l}^{-}, w_{h}, F) + (w_{l}^{-} - w_{l})\, x_{l}^{-} \qquad \text{if } w_{l} \neq w_{l}^{-} \qquad (6.2.7)$$

Profits under the rationing regime cannot be higher than unrationed profits when $w_l \neq w_l^-$ and the second term on the right is monetary measure of an 'efficiency cost' of rationing input use. Furthermore, at the point where the virtual and actual price coincide, the ration level equals the unconstrained x_l, i.e. when $w_l = w_l^-$, $x_l = x_l^-$.[15]

[12] Although this concept was used originally for commodity demand, it is also valid for the input demand of firms.

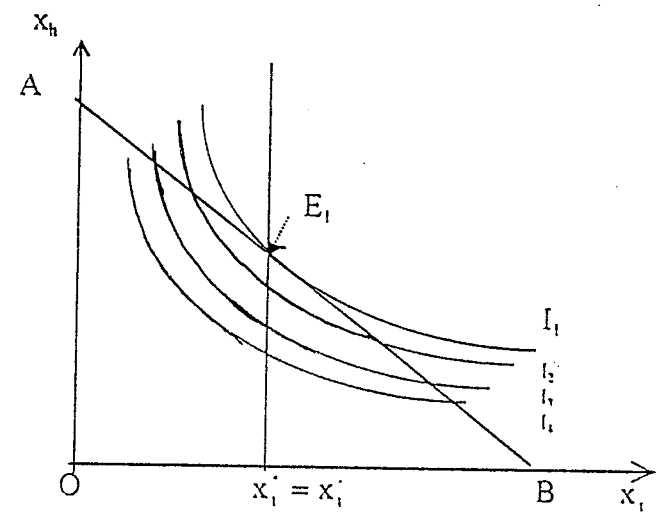
[13] For derivations, please see Squires (1994), p.239

[14] It is important to note that rationed inputs are different from fixed inputs. The case of fixed inputs involves a time horizon. In the short run, some factors restricted to be fixed are denoted as F. Hence, the input demand functions, output supply function and the profit function are the same as mentioned above except w_l^- is no longer the dependent variable and F is introduced in the model as explanatory variables, i.e. $x_l^M(w_h, F), x_h^M(w_h, F), q^M(w_h, F)$ and $\pi^M(w_h, F)$. Moreover, there are no optimal values of F_K because they are fixed in the short run. However, in the long run, F_K vary and become endogenous just like x and so the solution functions are no longer dependent on F but on their prices (w_F) instead i.e. $x_l^M(w_h, w_F), x_h^M(w_h, w_F), q^M(w_h, w_F)$ and $\pi^M(w_h, w_F)$. Of course, the optimal values of F(i.e. $F^M(w_h, w_F)$) can be found in the long run. Unlike the case of fixed inputs, the inputs rationed are affected by policy makers. This means that the rationed inputs can change from time to time under the control of the policy makers.

[15] For detailed discussion on this issue, please refer to Quiroga, Fernandez-Cornejo and Vasavada (1995).

Figure 6.1: The auxiliary constraint approach and the virtual price approach for utility maximisation.

6.1A: The auxiliary approach



6.1B: The virtual price approach

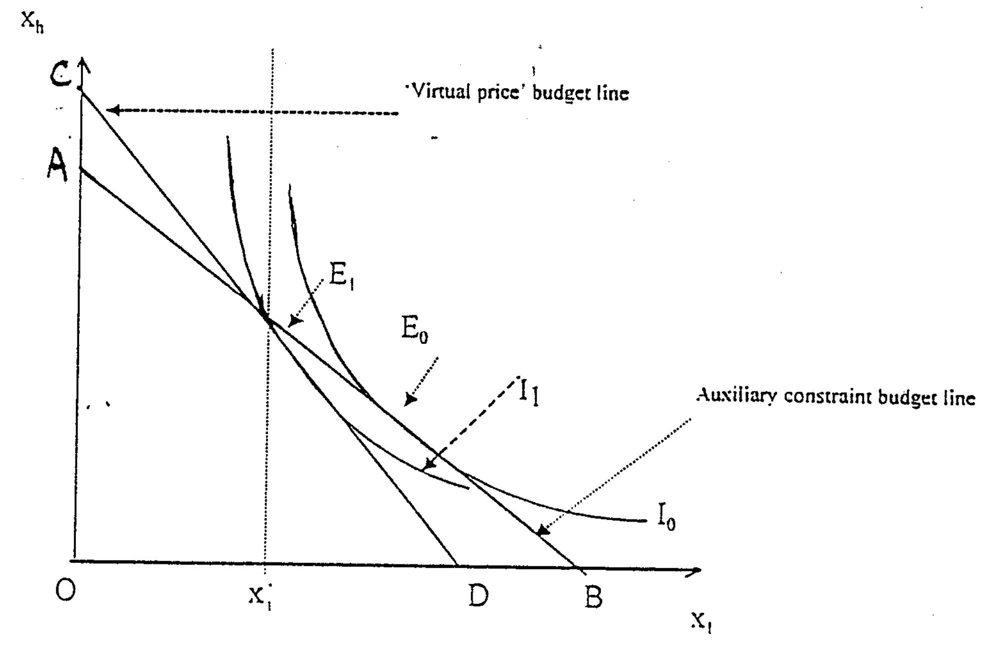
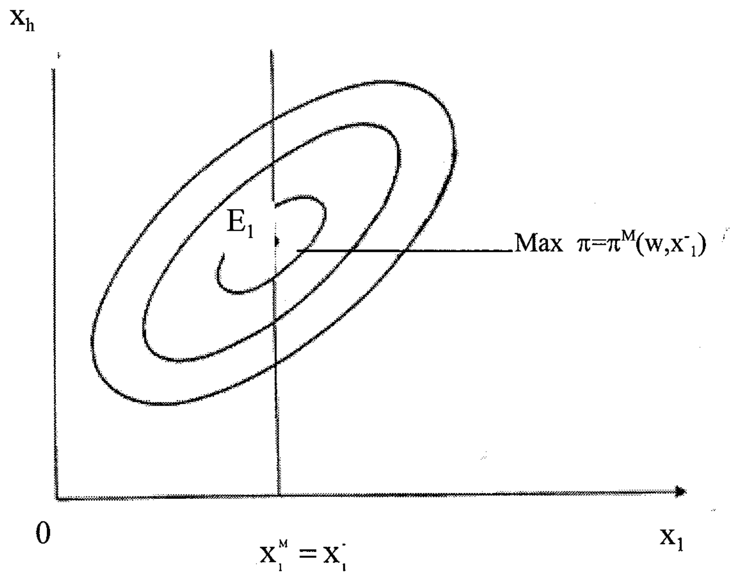
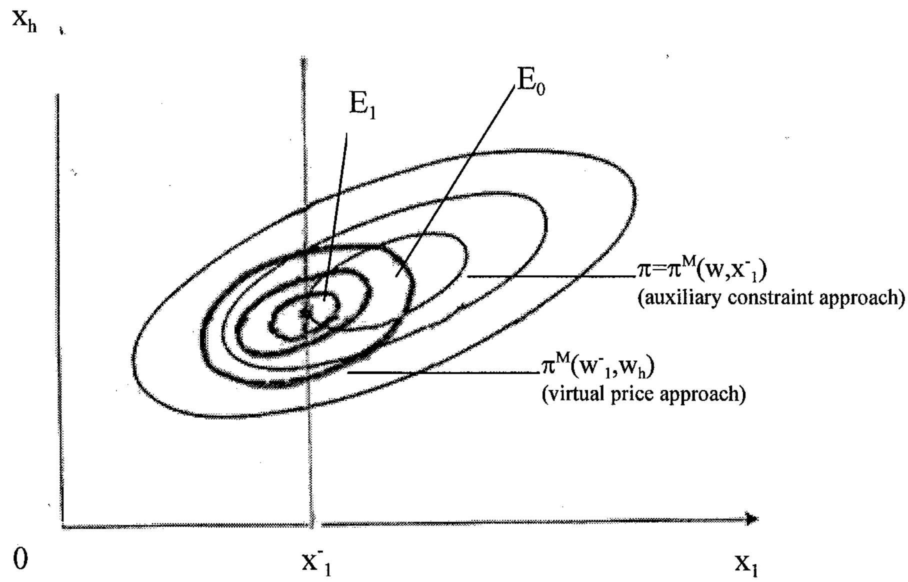


Figure 6.2: The auxiliary constraint approach and the virtual price approach for profit maximisation.

6.2A: The auxiliary constraint approach



6.2B: The virtual price approach



6.2.3) Difference Between Auxiliary Constraints and Virtual Pricing Approach

To depict the differences between auxiliary constraints and virtual pricing approach graphically; one may start with the consumer theory for simplification. The indifference map is shown in Figure 6.1A, where x_l^- denotes the quantity of rationed goods and x_h is the quantity of free market goods. The budget line is AB. The free market equilibrium (no rationing) E_1 is located at the tangency point at which the indifference curve I_1 cuts the budget line AB. If the ration x_l^-, equals the optimum quantity of x_l at E_1 (i.e. x_l^*),16 the constraint (or rationing) would be auxiliary or non-biting at the prevailing prices. However, as mentioned above, it is unreasonable to assume that optimum always coincides with the constraints. Moreover, the use of a sticky price is too restrictive an assumption. Indeed, if x_l^* is not equal to x_l^-, the story will be much more different. We can illustrate this phenomenon by using Figure 6.1B.

In Figure 6.1B, suppose the original free market equilibrium now becomes E_0, which may lie to the left or right of x_l^-. If it lies to the left of x_l^-, rationing does not alter the consumer's choice and the rationing is ineffective. However, if it lies to the right to x_l^-, rationing will distort the previous equilibrium and the 'purchasing possibility line' becomes $AE_1 x_l^-$. Then the new indifference curve I_1 does not cut the kinked budget line, $AE_1 x_l^-$, but passes through the new equilibrium point E_1.

16 x* is a short form of the profit maximising input demands, $x_i^M(w, F)$.

The slope of this indifference curve at E_1 measures the marginal valuation of x_1, which is greater than the price of x_1.[17]

Suppose that a new budget line CD is tangent to I_1 at E_1 at which the equilibrium quantity equals x_1^-, then the consumer is better off as if the price had risen to that indicated by CD and his income will be increased enough to buy more quantity of x_h, CA. This new price is referred to the concept of the virtual pricing[18].

Although the final position of the two approaches is the same, i.e. at E_1, which associated with the vector of goods equals quantity constraints x_1^-, the adjustment process and the starting point of the two approaches are different. The auxiliary constraint is unrealistically assumed to be naturally set at the optimum level and E_1 (in Figure 6.1A) is at the budget line AB. Whereas the virtual pricing equilibrium starts with E_0 via price adjustment (for the optimum is not equal to the constraint) and reached at the tangency point to the new budget line CD. Under this approach, even the auxiliary constraint x_1^- (in Figure 6.1B) corresponds to E_1 but this point is only at where the original budget line AB touches but is not tangential to the indifference curve I_1. In this sense, the consumer does not attain maximum utility with the budget line AB, whereas the consumer does attain maximum level with the new budget line CD under virtual-pricing-equilibrium.

17 This means that, under this situation, the consumer's utility is not at the maximum level.

18 This is also the idea of the marginal value of a coupon, which is essential to an understanding of the effects of rationing, and leads directly to the determinants of the Black market rate for coupons.

Similarly, these differences can also be applied to a firm's behaviour, but the above figures (6.1A and 6.2B) are not valid for this case because corresponding to the indifference curve in the case of firm is an isoquant which only refers to output level, rather than profit. However, a firm's objective in my study is neither maximising output nor minimising cost but maximising profit. Because of this, we employ the elliptical isoprofit curve for a firm[19]. The differences between the two approaches are presented in Figure 6.2A and 6.2B, respectively. In Figure 6.2A, the free market optimum is the peak at $x_l^M(w)$ which equals the auxiliary constraint $\bar{x}_l$. The highlighted isoprofit curves in Figure 6.2B are the isoprofit curves under virtual prices. Note that even the level of the profit and the point E_l under the two approaches are the same but the E_l is at the peak (maximum) of the 'virtual profit' hypersurface after price adjustment whereas E_l under auxiliary constraint is not at the peak of the 'auxiliary profit'(solid curves) hypersurface without any price adjustment under auxiliary constraint [20].

6.2.4) The Advantage of Virtual Pricing Approach

Neary and Roberts (1980) show that all the properties of the rationed demand and supply functions can be expressed in terms of the properties of the unrationed functions, provided the latter are evaluated at virtual prices. Besides, the derivatives of the rationed demand functions may be decomposed into income and

[19] However, this curve can also be interpreted as indifference curve based on the Utility function where the usual budget restriction has been substituted into the "argument set" by solving for the possible consumption of say, commodity x_l in terms of commodity x_h. In other words, the budget line is not needed. See Cuddington, Johansson and Lofgren (1984).

expansion effects which may in turn be related to the derivatives of the corresponding unconstrained demand functions. These imply that the behaviour of the firm under rationing can be fully predicted from the knowledge of its unconstrained demand functions. Thus, the virtual pricing approach has the advantage that it allows the parameters of the constrained profit function to be recovered from the unconstrained profit function; i.e. only the knowledge of the unconstrained profit function is needed. In other words, there is no need to specify and estimate a constrained function.[21] Instead, I only need to estimate the unconstrained function and the rationed inputs $\bar{x}_l$ and their derivatives can also be obtained. Furthermore, under the virtual pricing approach, I can use some stringent tests of hypotheses in conducting empirical demand analysis.

6.3 The Input Demand Functions and Elasticities under Rationing

Following the above discussion, it is possible to use the virtual pricing concept to derive the input demand functions and elasticities, by employing the

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[20] In the auxiliary constraint approach, the peak is at E_0 as in figure 6.1B, which is under the original price level.

[21] Lee and Pitt (1987) have analysed firm behaviour when the firm already faces rationing or does not use a particular input. However, this approach requires the knowledge of the firm's responses to changes in constraint levels and market conditions under the rationed regime and the relationship of the properties of the rationed and unrationed production technology. Moreover, it does not discuss the effects of the opposite case that input quantity constraints may be removed in a market economy (Squires 1994). Indeed, if the data generating process is consistent with unconstrained behaviour, estimating parameters under rationing will result in biased estimates. This is because a false restriction is imposed on the data when in fact the data are generated by an unconstrained model. (Quiroga, Fernandez-Cornejo and Vasavada, 1995).

translog model. To do that, I just separate w_1^- from the w vector and treat w_1^- as a function of prices of unrationed inputs, quantity of fixed factor and regulated inputs. Then recalling (6.1.6), I have

$$S_i = \frac{\partial \ln \pi}{\partial \ln w_i} = \alpha_i + \sum_{h=1}^{n} \theta_{ih} \ln w_h + \sum_{k=1}^{m} \delta_{ik} \ln F_k + \theta_{iT} T \tag{6.3.1}$$

$$\text{where } S_i = \frac{-w_i x_i}{\pi} \tag{6.3.2}$$

As mentioned before, the rationed input is indexed as 1 and the remaining variable inputs are indexed 2,.....,n. Under the quantity controls, $x_1 = x_1^-$ and so (6.1.5) becomes $S_1^- = \frac{-w_1^- x_1^-}{\pi}$.[22] Taking logarithm, it is modified as

$$\ln w_1 = \ln \pi + \ln(-S_1^-) - \ln x_1^- \tag{6.3.3}$$

As x_1^-, π and S_1^- depend on w_1 and F_k, we can establish the following equation:

$$\ln w_1^- = f(w_h, F, x_1^-) \qquad k = 1,......,m \tag{6.3.4}$$

On the other hand, for unregulated input (w_h), the following equation can be established:

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22 When doing estimation, S_1^- is treated as S_1 which is calculated from the observed variables, $w_1, x_1,$ and π. The "-" here is only for denoting that the economy is under rationing.

$$x_i(w,F,\bar{x_1}) = x_i(w,F) \text{ and } S_i^-(w_h,F,\bar{x_1}) = S_i(w,F)$$

Taking out the term $\ln w_1$ from (6.3.1) allows us to get:

$$S_i^-(w,F_k,\bar{x_1}) = \alpha_i + \theta_{i1}\ln w_1 + \sum_{h=2}^{n}\theta_h \ln w_h + \sum_{k=1}^{m}\delta_{ik}\ln F_k + \theta_{iT}T \qquad (6.3.5)$$

Similarly, the profit share equation for the regulated input $\bar{x_1}$ is :

$$S_1^- = \alpha_1 + \theta_{11}\ln w_1 + \sum_{i=2}^{n}\theta_{1i}\ln w_i + \sum_{k=1}^{m}\delta_{ik}\ln F_k + \theta_{iT}T \qquad (6.3.6)$$

Substituting (6.3.4) into (6.3.5) gives us the profit share function for the unregulated inputs (w_h) so that

$$S_i^- = \alpha_i + \theta_{i1}f(w_h,F,\bar{x_i}) + \sum_{h=2}^{n}\theta_{ih}\ln w_h + \sum_{k=1}^{m}\delta_{ik}\ln F_k + \theta_{iT}T \qquad (6.3.7)$$

Based on (6.3.7), I can derive various elasticities under rationing.

6.3.1) The own price elasticities for the unrationed good i (ξ_{ii}^-) (indexed 2,…,n)

For the economy without (or prior to) rationing, all factors are freely adjustable. As mentioned in Section 6.1, the own price elasticities of the partial equilibrium Marshallian demand (under profit maximisation) for all factors are derived from the share equation (6.3.1) of the translog profit function (6.1.2) and has the general formulae (6.1.9c), where the term $\frac{\partial S_i}{\partial \ln w_i}$ is obtained by differentiating (6.3.1) with respect to ln w_i (i.e.θ_i) and so the own price elasticities ξ_{ii} are the same as the ones given by (6.1.10), i.e. $\xi_{ii} = S_i - 1 + \frac{\theta_{ii}}{S_i}$, $i = 1......n$

In the case of rationing, although the own price elasticities with rationing of $\bar{x}_1$ for the unrationed goods i (indexed 2, ...n) are still based on the formula (6.1.9c), The term $\frac{\partial S_i^-}{\partial \ln w_i}$ is now obtained by differentiating the modified profit share function (6.3.7), instead of (6.3.1), with respect to ln w_i. The result is

$$\xi_{ii}^- = S_i^- - 1 + \frac{\partial S_i^- / \partial \ln w_i}{S_i^-}; \quad i = 2...n, \tag{6.3.8}$$

From (6.3.7),

$$\frac{\partial S_i^-}{\partial \ln w_i} = \theta_{i1} \frac{\partial f}{\partial \ln w_i} + \theta_{ii} \tag{6.3.9}$$

From (6.3.3 & 6.3.4) :

$$\frac{\partial f}{\partial \ln w_i} = \frac{\partial \ln w_1^-}{\partial \ln w_i} = \frac{\partial \ln \pi}{\partial \ln w_i} + \frac{\partial \ln(-S_1^-)}{\partial \ln w_i} \tag{6.3.10}$$

$$= S_i^- + \frac{\partial(-S_1^-) / \partial \ln w_i}{(-S_1^-)} \tag{6.3.11}$$

Differentiating (6.3.6) with respect to ln w_i, (6.3.11) becomes

$$\frac{\partial f}{\partial \ln w_i} = S_i^- + \frac{\theta_{11}\dfrac{\partial \ln w_1^-}{\partial \ln w_i} + \theta_{1i}}{S_1^-} \tag{6.3.12}$$

Since from (6.3.4) I have $\frac{\partial f}{\partial \ln w_i} = \frac{\partial \ln w_1^-}{\partial \ln w_i}$, I can apply this result to (6.3.12) to obtain:

$$\frac{\partial f}{\partial \ln w_i} = \bar{S}_i + \frac{\theta_{11}\dfrac{\partial f}{\partial \ln w_i} + \theta_{1i}}{\bar{S}_1}. \tag{6.3.13}$$

Rearranging (6.3.13), I get

$$\frac{\partial f}{\partial \ln w_i} = \frac{(\bar{S}_i\bar{S}_1 + \theta_{1i})}{(\bar{S}_i - \theta_{11})} = \frac{\bar{S}_i + (\theta_{1i} / \bar{S}_1)}{1 - (\theta_{11} / \bar{S}_1)}. \tag{6.3.14}$$

Substituting (6.3.14) into (6.3.9) and putting the new result of $\partial S/\partial \ln w_i$ into (6.3.8), the own price elasticities for unregulated goods with rationing of $x_1^- (\xi_{ii}^-)$ can be obtained as follows:

$$\xi_{ii}^- = S_i^- - 1 + \frac{\theta_{i1}\left[\dfrac{S_i^- + (\theta_{1i} / S_1^-)}{1 - (\theta_{11} / S_1^-)}\right] + \theta_{ii}}{S_i^-} \qquad i=2...n \tag{6.3.15}$$

Where $\theta_{i1} = \theta_{1i}$,

6.3.2) The cross-price elasticities for input i with respect to the price of the hth input (ξ_{ih}^{-}):

Similarly, as mentioned above, for the economy under rationing, the general formulae are basically the same as without rationing (i.e. 6.1.11c and 6.1.13c). However, the partial derivatives are obtained from (6.3.7) instead of (6.3.1). Thus, the Marshallian cross price elasticities ξ_{ih}^{-} can be derived as follows: First, I know from (6.1.11C) that

$$\xi_{ih}^{-} = S_h^{-} + \frac{\partial(S_i^{-})/\partial \ln w_h}{(S_i^{-})}, \quad i,h = 2,\ldots,n, \tag{6.3.16}$$

Where $$\frac{\partial S_i^{-}}{\partial \ln w_h} = \theta_{i1}\left[\frac{\partial f}{\partial \ln w_h}\right] + \theta_{ih}, \quad i,h = 2,..,n. \tag{6.3.17}$$

Similar to the steps of (6.3.10 - 6.3.14), I can also have

$$\frac{\partial f}{\partial \ln w_h} = \frac{[S_h^{-} + (\theta_{1h}/S_1^{-})]}{[1-(\theta_{11}/S_1^{-})]}, \tag{6.3.18}$$

and so $$\xi_{ih}^{-} = S_h^{-} + \frac{\dfrac{\theta_{i1}\left[S_h^{-} + (\theta_{1h}/S_1^{-})\right]}{1-(\theta_{11}/S_1^{-})} + \theta_{ih}}{S_i^{-}} \quad i,h = 2,\ldots\ldots,n \tag{6.3.19}$$

6.3.3) The elasticity of demand for unregulated input i with respect to changes in output price (ξ_{iq}^{-}) is :

Recalling (6.1.13c)

$$\xi_{iq}^{-} = \sum_{i=2}^{n} -S_i^{-} + 1 + \sum_{h=1}^{n} \frac{\partial \ln(-S_i^{-})}{\partial \ln w_h} \cdot \frac{\partial \ln w_h}{\partial P}. \tag{6.3.20}$$

$$= \sum_{i=2}^{n} -S_i^{-} + 1 + \frac{\partial(-S_i^{-})/\partial \ln w_1}{(-S_i^{-})} \cdot (-1) + \sum_{h=2}^{n} \frac{\partial(-S_i^{-})/\partial \ln w_h}{(-S_i^{-})} \cdot (-1). \tag{6.3.21}$$

Based on (6.3.17) and (6.3.18), I obtain

$$\frac{\partial S_i^{-}}{\partial \ln w_h} = \frac{\theta_{i1}\left[S_h^{-} + (\theta_{1h} / S_1^{-})\right]}{1 - (\theta_{11} / S_1^{-})} + \theta_{ih}. \tag{6.3.22}$$

Differentiating (6.3.5) with respect to ln w_1 , and substituting the result and (6.3.22) into (6.3.20), I can get

$$\xi_{iq}^{-} = -\sum_{i=1}^{n} S_i^{-} + 1 - \frac{\theta_{i1}}{S_i^{-}} - \sum_{h=2}^{n} \left\{ \frac{\dfrac{\theta_{i1}\left[S_h^{-} + \theta_{1h}/S_1^{-}\right]}{1 - (\theta_{11} / S_1^{-})} + \theta_{ih}}{S_i^{-}} \right\} \quad \text{Where } i,h = 2,\ldots\ldots,n. \tag{6.3.23}$$

6.3.4) The elasticity for a change in the quantity of unregulated inputs with respect to change in fixed factor (ε_{ik}^{-}):

Referring to (6.1.8), I get the $\ln x_i$ function under rationing for unrationed inputs,

$$\ln x_i = \ln \pi - \ln w_i + \ln(-S_i^{-}), \qquad i=2,\ldots,n \qquad (6.3.24)$$

Differentiating (6.3.24) with respect to $\ln F_k$ gives me the following elasticity

$$\varepsilon_{ik} = \frac{\partial \ln x_i}{\partial \ln F_k} = \frac{\partial \ln \pi}{\partial \ln F_k} + \frac{\partial \ln(-S_i^{-})}{\partial \ln F_k}, \quad i=2\ldots\ldots n \qquad (6.3.25)$$

$$= \frac{\partial \ln \pi}{\partial \ln F_k} + \frac{\partial(-S_i^{-})/\partial \ln F_k}{(-S_i^{-})}, \qquad i=2,\ldots,n \qquad (6.3.26)$$

where $\frac{\partial \ln \pi}{\partial \ln F_k}$ is the partial derivative of (6.1.2) with respect to F_k i.e.,

$$\frac{\partial \ln \pi}{\partial \ln F_k} = \alpha_1 \frac{\partial \ln w_1^{-}}{\partial \ln F_k} + \sum_{h=1}^{n} \theta_{1h} \ln w_h \frac{\partial \ln w_1^{-}}{\partial \ln F_k} + \theta_{1T} T \frac{\partial \ln w_1^{-}}{\partial \ln F_k} + \rho_k + \sum_{j=1}^{m} \rho_{kj} \ln F_j + \sum_{i=1}^{n} \delta_{ik} \ln w_i$$
$$+ \sum_{k=1}^{m} \delta_{1k} \ln F_k \frac{\partial \ln w_1}{\partial \ln F_k} + \varphi_{kT} T$$

(6.3.27)

$$= \frac{\partial \ln w_1^{-}}{\partial \ln F_k}\left(\alpha_1 + \sum_{h=1}^{n} \theta_{1h} \ln w_h + \theta_{1T} T + \sum_{k=1}^{m} \delta_{1k} \ln F_k\right) + \rho_k$$
$$+ \sum_{j=1}^{m} \rho_{kj} \ln F_j + \sum_{i=1}^{n} \delta_{ik} \ln w_i + \varphi_{kT} T \qquad (6.2.28)$$

$$= \frac{\partial \ln w_1^{-}}{\partial \ln F_k}(a) + b \qquad (6.3.29)$$

$$\text{where } a = \alpha_1 + \sum_{h=1}^{n} \theta_{1h} \ln w_h + \theta_{1T} T + \sum_{k=1}^{m} \delta_{1k} \ln F_k \tag{6.3.30}$$

and

$$b = \rho_k + \sum_{h=1}^{m} \rho_{kj} \ln F_j + \sum_{i=1}^{n} \delta_{ik} \ln w_i + \theta_{kT} T. \tag{6.3.31}$$

Differentiating (6.3.3) with respect to $F_{k,}$ I get

$$\frac{\partial \ln w_1^-}{\partial \ln F_k} = \frac{\partial \ln \pi}{\partial \ln F_k} + \frac{\partial \ln(-S_i^-)}{\partial \ln F_k} = \frac{\partial \ln \pi}{\partial \ln F_k} + \frac{\partial(-S_i^-)/\partial \ln F_k}{(-S_i^-)} \tag{6.3.32}$$

As from (6.3.6), I can establish

$$\frac{\partial S_1^-}{\partial \ln F_k} = \theta_{11} \frac{\partial \ln w_1^-}{\partial \ln F_k} + \delta_{ik} \tag{6.3.33}$$

Substituting (6.3.33) into (6.3.32), I have

$$\frac{\partial \ln w_1^-}{\partial \ln F_k} = \frac{\partial \ln \pi}{\partial \ln F_k} + \frac{\theta_{11} \dfrac{\partial \ln w_1}{\partial \ln F_k} + \delta_{ik}}{S_1^-} \tag{6.3.34}$$

Substituting (6.3.29) into (6.3.34), I get

$$\frac{\partial \ln w_1^-}{\partial \ln F_k} = \frac{\partial \ln w_1^-}{\partial \ln F_k} a + b + \frac{\theta_{11} \frac{\partial \ln w_1^-}{\partial \ln F_k} + \delta_{ik}}{S_1^-}$$

$$= \frac{\partial \ln w_1^-}{\partial \ln F_k}\left(a + \frac{\theta_{11}}{S_1^-}\right) + b + \frac{\delta_{ik}}{S_1^-}$$

$$= \frac{b + \frac{\delta_{ik}}{S_1^-}}{1 - a - \frac{\theta_{11}}{S_1^-}}$$

$$= \frac{\frac{bS_1^- + \delta_{ik}}{S_1^-}}{\frac{S_1^- - aS_1^- - \theta_{11}}{S_1^-}}$$

$$= \frac{bS_1^- + \delta_{ik}}{S_1^-(1-a) - \theta_{11}}. \tag{6.3.35}$$

Substituting (6.3.35) into (6.3.29), I obtain

$$\frac{\partial \ln \pi}{\partial \ln F_k} = \frac{bS_i^- + \delta_{ik}}{S_1^-(1-a) - \theta_{11}}(a) + b = \frac{abS_1^- + a\delta_{ik} + bS_1^- - abS_1^- - b\theta_{11}}{S_1^-(1-a) - \theta_{11}}$$
$$= \frac{a\delta_{ik} + bS_1^- - b\theta_{11}}{S_1^-(1-a) - \theta_{11}}. \tag{6.3.36}$$

On the other hand, differentiating (6.3.7) with respect to $\ln F_k$, I get:

$$\frac{\partial S_i^-}{\partial \ln F_k} = \theta_{i1} \frac{\partial f(w_h, F, x_1^-)}{\partial \ln F_k} + \delta_{ik}, \quad w_h = (w_2 \ldots w_n), \tag{6.3.37}$$

From (6.3.4), I know

$$\frac{\partial f(w_h, F, x_1^-)}{\partial \ln F_k} = \frac{\partial \ln w_1^-}{\partial \ln F_k} \quad . \tag{6.3.38}$$

Substituting (6.3.38) into (6.3.37) enables us to obtain:

$$\frac{\partial S_i^-}{\partial \ln F_k} = \theta_{i1}\frac{\partial \ln w_1^-}{\partial \ln F_k} + \delta_{ik}, \quad i=2,.....,n \tag{6.3.39}$$

Substituting (6.3.35) into (6.3.39), we get

$$\frac{\partial S_i^-}{\partial \ln F_k} = \frac{\theta_{i1}(bS_1^- + \delta_{ik})}{S_1^-(1-a)-\theta_{11}} + \delta_{ik}. \tag{6.3.40}$$

Substituting (6.3.36) and (6.3.40) into (6.3.26), we derive the following elasticities

$$\varepsilon_{ik}^- = \frac{a\delta_{ik} + bS_1^- - b\theta_{11}}{S_1^-(1-a)-\theta_{11}} + \frac{\dfrac{\theta_{i1}(bS_1^- + \delta_{ik})}{S_1^-(1-a)-\theta_{11}} + \delta_{ik}}{S_i^-},$$

$$= \frac{a\delta_{ik} + b(S_1^- - \theta_{11})}{S_1^-(1-a)-\theta_{11}} + \frac{\theta_{i1}(bS_1^- + \delta_{ik})}{S_i^-\left[S_1^-(1-a)-\theta_{11}\right]} + \frac{\delta_{ik}}{S_i^-}, \quad i=2,.....,n \tag{6.3.41}$$

Similarly, the output supply elasticities with respect to input price i (ξ_{qi}) and the output price (ξ_{qq}) can also be obtained from the base formula (6.1.23) and (6.1.29a). But the derivatives $\frac{\partial \ln}{\partial \ln w_h}(1-\sum_{i=1}^{n} S_h^-)$ and $\frac{\partial \ln}{\partial \ln P}(1-\sum_{i=1}^{n} S_i^-)$ do not refer to (6.3.1), but (6.3.7).

6.3.5) The output (supply) elasticity with respect to input price i (ξ_{qi}^{-})

Based on (6.1.23)

$$\xi_{qi}^{-} = S_i^{-} + \frac{\partial \ln}{\partial \ln w_i}(1-\sum_{h=1}^{n} S_h^{-}) \qquad i=2,.....,n \tag{6.3.42}$$

$$= S_i^{-} - \frac{\dfrac{\partial S_1^{-}}{\partial \ln w_i} + \sum_{h=2}^{n} \dfrac{\partial S_h^{-}}{\partial \ln w_i}}{1-\sum_{h=1}^{n} S_h^{-}} \tag{6.3.43}$$

From (6.3.17) and (6.3.18), I establish

$$\frac{\partial S_h^{-}}{\partial \ln w_i} = \theta_{h1}\left[\frac{S_i^{-} + (\theta_{1i}/S_1^{-})}{1-(\theta_{11}/S_1^{-})}\right] + \theta_{hi}. \tag{6.3.44}$$

Substituting (6.3.44) into (6.3.43) gives me

$$\xi_{qi}^{-} = S_i^{-} - \frac{\theta_{1i} + \sum_{h=2}^{n}\left\{\theta_{h1}\left[\dfrac{S_i^{-} + (\theta_{1i}/S_1^{-})}{1-(\theta_{11}/S_1^{-})}\right] + \theta_{hi}\right\}}{1-\sum_{h=1}^{n} S_h^{-}}. \tag{6.3.45}$$

6.3.6) The output (Supply) price elasticity (ξ_{qq}^{-})

Similarly, based on (6.1.26), the ξ_{qq}^{-} can be calculated

$$\xi_{qq}^{-} = \sum_{i=1}^{n} \frac{\partial \ln \pi}{\partial \ln w_i} \cdot \frac{\partial \ln w_i}{\partial \ln P} + \sum_{i=1}^{n} \frac{\partial \ln(1-\sum_{h=2}^{n} S_h^{-})}{\partial \ln w_i} \cdot \frac{\partial \ln w_i}{\partial \ln P}$$

$$= \sum_{i=1}^{n} -S_i^{-} + \sum_{i=1}^{n} \frac{\partial \ln(1-\sum_{h=2}^{n} S_h^{-})}{\partial \ln w_i}(-1)$$

$$= \sum_{i=1}^{n} \text{-}S_i^{-} - \frac{\sum_{i=1}^{n}\sum_{h=1}^{n} \frac{\partial S_h^{-}}{\partial \ln w_i}}{1-\sum_{h=1}^{n} S_h^{-}} \tag{6.3.46}$$

Substituting (6.3.44) into (6.3.46), I obtain,

$$\xi_{qq}^{-} = \sum_{i=1}^{n} -S_i^{-} - \frac{\frac{\partial S_1^{-}}{\partial \mathit{ln} w_1} + \sum_{h=2}^{n} \frac{\partial S_h^{-}}{\partial \mathit{ln} w_1} + \sum_{i=2}^{n} \frac{\partial S_1^{-}}{\partial \mathit{ln} w_i} + \sum_{i=2}^{n}\sum_{h=2}^{n} \left\{ \theta_{h1} \left[\frac{S_i^{-} + \mathit{(}\theta_{1i} / S_1^{-}\mathit{)}}{1-\mathit{(}\theta_{11} / S_1^{-}\mathit{)}} \right] + \theta_{hi} \right\}}{1-\sum_{h=1}^{n} S_h^{-}} \tag{6.3.47}$$

$$= \sum_{i=1}^{n} -S_i^{-} - \frac{\theta_{11} + \sum_{h=2}^{n} \theta_{h1} + \sum_{i=2}^{n} \theta_{1i} + \sum_{i=2}^{n}\sum_{h=2}^{n} \left\{ \theta_{h1} \left[\frac{S_i^{-} + (\theta_{1i} / S_1^{-})}{1-(\theta_{11} / S_1^{-})} \right] + \theta_{hi} \right\}}{1-\sum_{h=1}^{n} S_h^{-}}. \tag{6.3.48}$$

It is well known that the net substitution effect of changes in factor prices ("cost minimisation elasticities") can be expressed in terms of the difference between the total effect and the expansion effect.

$$\xi_{ih}^{H} = \xi_{ih} - \frac{\xi_{iq} \cdot \xi_{qh}}{\xi_{qq}} \tag{6.3.49}$$

Note that ξ_{ih}^{H} measures the net substitution effect (Hicksian elasticities), whereas $\xi_{ih}, \xi_{iq}, \xi_{qi}$ and ξ_{qq} are all Marshallian elasticities which have already been derived above equations (6.3.19), (6.3.23), (6.3.45) and (6.3.48).

6.3.7) The elasticity for a change in quantity of output with respect to a change in fixed factor $(\varepsilon_{q\bar{k}})$.

Again, $(\varepsilon_{q\bar{k}})$ can be obtained by differentiating (6.1.22) with respect to $\ln F_k$. The derivation is shown in (6.1.31) as follows:

$$\varepsilon_{q\bar{k}} = \frac{\partial \ln q}{\partial \ln F_k} = \frac{\partial \ln \pi}{\partial \ln F_k} + \frac{1}{1 - \sum_{i=1}^{n} S_i^{-}} \left(-\sum_{i=1}^{n} \frac{\partial S_i^{-}}{\partial \ln F_k}\right). \tag{6.3.50}$$

Substituting (6.3.36) and (6.3.40) into (6.3.50), I get

$$\varepsilon_{qk}^{-} = \frac{\partial \ln q}{\partial \ln F_k} = \frac{a\delta_{ik} + b(S_1^{-} - \theta_{11})}{S_1^{-}(1-a) - \theta_{11}} - \frac{1}{1 - \sum_{i=1}^{n} S_i^{-}} \left[\frac{\theta_{i1}(bS_1^{-} + \delta_{ik})}{S_1^{-}(1-a) - \theta_{11}} + \delta_{ik} \right] \quad (6.3.51)$$

6.3.8) The elasticities for a change in quantity of unregulated inputs i with respect to a change in regulated input x_1^{-}, $(\varepsilon_{ix_1^{-}}^{-})$:

Recall (6.3.24), I already have

$$\ln x_i = \ln \pi - \ln w_i + \ln(-S_i^{-}), \quad \text{where } -S_i^{-} = \frac{\partial \ln \pi}{\partial \ln w_i}, \quad i=2,\ldots\ldots,n.$$

I can differentiate (6.3.24) with respect to $\ln x_1^{-}$ and obtain

$$\varepsilon_{ix_1^{-}}^{-} = \frac{\partial \ln x_i}{\partial \ln x_1^{-}} = \frac{\partial \ln \pi}{\partial \ln x_1^{-}} + \frac{\partial \ln(-S_i^{-})}{\partial \ln x_1^{-}} \quad (6.3.52)$$

$$= \frac{\partial \ln \pi}{\partial \ln w_1^{-}} \left(\frac{\partial \ln w_1^{-}}{\partial \ln x_1^{-}}\right) + \frac{\partial \ln(-S_i^{-})}{\partial \ln w_1^{-}} \cdot \frac{\partial \ln w_1^{-}}{\partial \ln x_1^{-}} \quad (6.3.53)$$

From (6.1.5) and $\frac{\partial \ln(-S_i^{-})}{\partial \ln w_i} = \frac{\partial(-S_i^{-})/\partial \ln w_i}{(-S_i^{-})} = \frac{\theta_{ii}}{S_i^{-}}$ (6.3.54)

I can simplify (6.3.53) as

$$=S_1^-\left(\frac{\partial \ln w_1}{\partial \ln x_1^-}\right)+\frac{\theta_{i1}}{S_i^-}\cdot\frac{\partial \ln w_1^-}{\partial \ln x_1^-} \qquad (6.3.55)$$

$$=\frac{\partial \ln w_1^-}{\partial \ln x_1^-}(S_1^- +\frac{\theta_{i1}}{S_i^-}) \qquad (6.3.56)$$

To find $\frac{\partial \ln w_1^-}{\partial \ln x_1^-}$, I may differentiate (6.3.3) with respect to $\ln x_1^-$, which allows me to get

$$\frac{\partial \ln w_1^-}{\partial \ln x_1^-}=\frac{\partial \ln \pi}{\partial \ln x_1^-}+\frac{\partial \ln(-S_1^-)}{\partial \ln x_1^-}-1 \qquad (6.3.57)$$

$$=\frac{\partial \ln \pi}{\partial \ln w_1^-}\cdot\frac{\partial \ln w_1^-}{\partial \ln x_1^-}+\frac{\partial \ln(-S_1^-)}{\partial \ln w_1^-}\cdot\frac{\partial \ln w_1^-}{\partial \ln x_1^-}-1 \qquad (6.3.58)$$

Substituting $\frac{\partial \ln(-S_1^-)}{\partial \ln w_1^-}=\frac{\theta_{11}}{S_1^-}$ into (6.3.58)

$$\frac{\partial \ln w_1^-}{\partial \ln x_1^-}=\frac{\partial \ln \pi}{\partial \ln w_1^-}\cdot\frac{\partial \ln w_1^-}{\partial \ln x_1^-}+\frac{\theta_{11}}{S_1^-}\cdot\frac{\partial \ln w_1^-}{\partial \ln x_1^-}-1 \qquad (6.3.59)$$

Rearranging (6.3.59),

$$\frac{\partial \ln w_1^-}{\partial \ln x_1^-}=\frac{\partial \ln w_1^-}{\partial \ln x_1^-}(\frac{\partial \ln \pi}{\partial \ln w_1^-}+\frac{\theta_{11}}{S_1^-})-1 \qquad (6.3.60)$$

Referring to (6.1.5),

$$\frac{\partial \ln \pi}{\partial \ln w_1} = S_1^- . \tag{6.3.61}$$

Substituting (6.3.61) into (6.3.60), I obtain

$$\frac{\partial \ln w_1^-}{\partial \ln x_1^-} = \frac{\partial \ln w_1^-}{\partial \ln x_1^-}(S_1^- + \frac{\theta_{11}}{S_1^-}) - 1 . \tag{6.3.62}$$

So, $$\frac{\partial \ln w_1^-}{\partial \ln x_1^-} = \frac{-1}{1 - S_1^- - \frac{\theta_{11}}{S_1^-}} = \frac{1}{\frac{\theta_{11}}{S_1^-} + S_1^- - 1} . \tag{6.3.63}$$

Substituting (6.3.63) into (6.3.56), I get

$$\varepsilon_{ix_1^-}^- = \frac{S_1^- + \frac{\theta_{i1}}{S_i^-}}{\frac{\theta_{11}}{S_1^-} + S_1^- - 1} \tag{6.3.64}$$

6.1.9) The Marshalling elasticity for a change in the quantity of output with a change in regulated input, i.e. $\varepsilon_{qx_1^-}^-$:

Consider (6.1.22), I can obtain the following relationships

$$\ln q = \ln \pi + \ln(1 - \sum_{i=1}^{n} \frac{\partial \ln \pi}{\partial \ln w_i})$$

$$= \ln \pi + \ln(1 - \sum_{i=1}^{n} S_i^-) \qquad (6.3.65)$$

$$\varepsilon_{qx_1^-}^- = \frac{\partial \ln q}{\partial \ln x_1^-} = \frac{\partial \ln \pi}{\partial \ln w_1^-} \cdot \frac{\partial \ln w_1^-}{\partial \ln x_1^-} + \frac{1}{1 - \sum_{i=1}^{n} S_i^-} (-\sum_{i=1}^{n} \frac{\partial S_i^-}{\partial \ln x_1^-}) \qquad (6.3.66)$$

From (6.3.66), I can further develop

$$= S_1^- \cdot \frac{\partial \ln w_1^-}{\partial \ln x_1^-} + \frac{1}{1 - \sum_{i=1}^{n} S_i^-} (-\sum_{i=1}^{n} \frac{\partial S_i^-}{\partial \ln w_1^-} \cdot \frac{\partial \ln w_1^-}{\partial \ln x_1^-}) \qquad (6.3.67)$$

$$= \frac{\partial \ln w_1^-}{\partial \ln x_1^-} \left[S_1^- + \frac{1}{1 - \sum_{i=1}^{n} S_i^-} (-\sum_{i=1}^{n} \frac{\partial S_i^-}{\partial \ln w_1^-}) \right] \qquad (6.3.68)$$

Substituting (6.3.63) into (6.3.68), we finally have

$$\varepsilon_{qx_1^-}^- = \frac{1}{\frac{\theta_{11}}{S_1^-} + S_1^- - 1} \left[S_1^- - \frac{\sum_{i=1}^{n} \theta_{i1}}{1 - \sum_{i=1}^{n} S_i^-} \right] \qquad (6.3.69)$$

As mentioned in Squire (1994), the Marshallian demand for the rationed inputs is invariant to the changes in the price of output or unregulated or regulated inputs where the constraints is binding and this demand function is perfectly inelastic and fixed, that is, $\xi_{1q}^- = 0$, $\xi_{1h}^- = 0$ and $\xi_{11}^- = 0$.

To distinguish the price elasticities with rationing from those without rationing, the differences depend on various parameter and variables, i.e., there is no systematic relationship between these two types of elasticities. This conclusion is quite different from that obtained by Samuelson and Pollak (1969) who argue that the own price elasticities demand for commodity i with rationing is lower than those without rationing.

6.4 Conclusion

In the first section of this chapter, I employ the standard approach to derive the input demand functions and relevant elasticities from the tranlog profit equation. However, this approach neglects the influence of rationing on the input demand functions and price elasticities. Therefore, I developed a modification. To achieve this task, I followed the concepts of virtual pricing developed by Neary and Roberts (1980) and Squires(1994). This approach is better than the auxiliary constraint approach because it allows the parameters of the constrained profit function to be recovered from the unconstrained profit function. Thus, there is no need to know ex ante whether there are input quantity restrictions upon output supply , factor demand, and profitability for a profit maximising producer. I only need to estimate the traditional tranlog profit function and then substitute the estimated parameters into the formulae which are derived from the translog profit function that is incorporated in the virtual prices for the rationed input.

By comparing the derived formulae of the elasticities with and without rationing, I find that there is no systematic relationship between these two types of elasticities. This conclusion contrasts with the general assertion that the own price elasticities of demand for commodity i with no rationing are larger than those with rationing. As a further improvement, one can test which type of elasticity is more appropriate for use with the Chinese data.

Chapter 7: Empirical Findings

Having derived the elasticities with and without rationing in Chapter 6, this chapter will estimate them empirically and conduct energy policy analysis. In section 7.1, the firm data set is outlined. Section 7.2 explains how the translog profit equation is formulated and estimated with the firm data set. Then, the econometric technique used in this part is discussed in section 7.3. Section 7.4 presents the empirical findings. In this section, the estimated coefficients are substituted into the formulae derived in Chapter 6, in order to obtain the elasticities with rationing and without rationing. From the signs of the elasticities, the relationship between energy and other inputs will be examined, evaluating the effects of raising energy price policy on the economy. Section 7.5 evaluates various policy options based on the figures of energy forecasts obtained in Chapter 2 and 3 so as to acquire a more in-depth understanding of the effect of high price policy on managing energy sector.

7.1 The Data Set

The data set comes from the survey administered by the State Statistical Bureau. This is a joint project with the institute of Economics, Chinese Academy of Social Sciences (CASS), which is under a RSC grant co-ordinated by Prof. Y.Y Kueh, Dean of Social Science, Hong Kong Lingnan College. The detailed discussion on the data set can be found in Kueh et al. (1999).

This data set is based on a medium-scale questionnaire survey of 300 large and medium-size state-owned enterprises (SOEs) located in six major Chinese cities (Beijing, Shenyang, Shanghai, Wuhan, Congqing and Guangzhou). The 300 sample enterprises were chosen from the six major cities on a stratified random- sample basis. They are representative of China's largest industrial conglomerates, which in all, comprised some 2,006 so-called "large" and medium-scale" individual units (1989). The 300 enterprises constitute a sample size of 15 percent of the six cities combined. These cities were chosen not only for the regional variations which they represented, but also for the different stages they represent in terms of the implementation of economic reform.

The survey includes three sets of questionnaires:

7.1.1) The Enterprise Balance Sheet Questionnaire

These questionnaires generate detailed statistical information relating to output, sales, labour and material inputs, various factor prices (including profit retention), taxes, losses, sources of capital supply, patterns of fund disbursement and other financial aspects of the enterprises. Such information was used to examine the changing degree of enterprise autonomy and to test the relative hardness of enterprises' budget constraints under the impact of the reforms. The questionnaire contained 114 items and was submitted to the 300 sample enterprises, to be filled by the enterprise accountants. In response to each question, data were requested for every year from 1984 to 1988. In all, 205,200 observations were generated from the Balance Sheet.

7.1.2) The Enterprise Director Questionnaire

This form contains 46 questions. It was designed to identify and to assess the goals, attitudes, motivation and behaviour of the directors or managers of the sample enterprises. Questions relating to the administrative, environment and business conditions surrounding enterprises, as well as inter-enterprise co-operation, were also included. The questionnaire was submitted to enterprise directors for their personal attention: only one out of a total of 300 failed to respond. More than 13,754 observations were obtained from this survey.

7.1.3) The Enterprise Supervisory Bureau Questionnaire

The questions were administered to the heads of 64 industrial bureaux, located in the six major cities: Beijing 11, Shanghai 10, Wuhan 11, Chongqing 13, Guangzhou 8, and Shengyang 11. The Bureau survey provided basic information on two important aspects of enterprise behaviour: first, the nature and degree of state control, to which enterprise supervisory bureaux were subject; second, the means whereby those bureaux sought to control the enterprises under their jurisdiction. This questionnaire contained 11 questions and generated 704 observations.

Incorporating the data from the three questionnaires, my data set covers 279 variables, including SOEs' incentives for reform policies, financial accounts and information of prices, production and sales. It should, however, be noted that complete figures are not available for all the data points. Since there were some missing observations and miscoding in the survey, our finalised balanced data set consists of only 225 firms over 1985-88.

7.2. Estimation of Translog Model

To estimate energy demand and to investigate the substitutability and the complementarity among various inputs, the typical KLEM model developed by Berndt and Wood (1975) is followed. Based on this model, it is assumed there exists in the Chinese manufacturing industry, a twice differentiable production function relating the flow of gross output q to the services of four inputs: capital (K), labour (L), energy(E), and all other intermediate materials(M). Corresponding to such a production function there exists a profit function which reflects the underlying production technology mentioned in Chapter Five.

As in many other related studies, capital is treated as fixed factor in this model. On the other hand, to study the effect of labour input on output more accurately, two components should be identified for it. One of them is the number of labourer (named as 'labour') and the other one is the efforts of the labour input. In this study, labour is also treated as fixed factor together with capital. This can be justified as follows. Since economic reform began in 1978, the Chinese authorities have modified the management system of large and medium sized SOEs continuously by introducing a series of management reforms, including the contract management, the managerial responsibility system, the internal contract system and the share-holding system for improving the performance of firms. Undeniably, these reforms give the SOEs certain autonomy and working incentives, aimed at improving their performance. However, there are still some significant limits on managerial authority. The managers of SOEs still have to obtain approval for the appointment and the discharge of key enterprise employees from factories, i.e., they were not granted the right to fire and hire ordinary workers[1]. Therefore, labour is viewed as a fixed factor of the SOE's. On the other hand, the 'efforts of labour inputs' is obviously a variable factor. However, it cannot be measured, especially in China, due to data availability. Therefore, this component is not included in my model which may suffer from mispecification error.

Using the data set mentioned in 7.1.1, this estimation is based on cross-section study over four years.[2] Therefore, it is not possible to introduce time trend variables in the model and so technical progress is not captured in the estimation. This problem is not overly serious, however, because the study covers only four years. Therefore, it is not unreasonable to assume that technical change over the estimation period will be insignificant.

[1] The labour contract system under which workers are hired for three years to five years applies only to newly admitted workers. Indeed, almost 90% of workers in Chinese state sectors are fixed workers with permanent job tenures(Keun Lee,1990).

[2] The reasons for cross-sectional estimation will be discussed in 7.3

Following on the above discussion, the translog profit function (6.1.2) prior to quantity constraints for the model becomes:

$$
\begin{aligned}
\ln \pi = {} & \alpha_0 + \alpha_E \ln w_E + \alpha_M \ln w_M + \frac{1}{2}\theta_{EE}(\ln w_E)^2 + \frac{1}{2}\theta_{EM} \ln w_E \ln w_M \\
& + \frac{1}{2}\theta_{ME} \ln w_M \ln w_E + \frac{1}{2}\theta_{MM}(\ln w_M)^2 + \rho_L \ln L + \rho_K \ln K \\
& + \frac{1}{2}\rho_{LL}(\ln L)^2 + \frac{1}{2}\rho_{KK}(\ln K)^2 + \frac{1}{2}\rho_{LK} \ln L \ln K + \frac{1}{2}\rho_{KL} \ln K \ln L \\
& + \delta_{EL} \ln w_E \ln L + \delta_{ML} \ln w_M \ln L + \delta_{EK} \ln w_E \ln K + \delta_{MK} \ln w_M \ln K
\end{aligned}
$$

(7.2.1a)

where π is normalised profit defined as total revenue minus total costs of variable inputs, w_E and w_M are prices of energy and material inputs normalised by price of output. K and L are capital and labour which are treated as fixed factors. As mentioned in chapter six, π, w_E and w_M are normalised by output price, P.

To ensure that the 'implicit' production function under the translog profit model is well behaved, section (6.1.3) is followed, imposing 12 restrictions[3] on the coefficients of (7.2.1a) i.e.,

$\theta_{EM} = \theta_{ME}$, $\rho_{LK} = \rho_{KL}$, $\alpha_E + \alpha_M = 1$, $\theta_{EE} + \theta_{ME} = 0$, $\theta_{EM} + \theta_{MM} = 0$,

$\rho_K + \rho_L = 1$, $\rho_{LL} + \rho_{KK} = 0$, $\rho_{LK} + \rho_{KK} = 0$, $\delta_{EL} + \delta_{ML} = 0$, $\delta_{EK} + \delta_{MK} = 0$,

$\delta_{EL} + \delta_{EK} = 0$, $\delta_{ML} + \delta_{MK} = 0$.

[3] As the three restrictions: $\delta_{EL} + \delta_{ML} = 0$, $\delta_{EK} + \delta_{MK} = 0$, $\delta_{EL} + \delta_{EK} = 0$, it automatically imply $\delta_{ML} + \delta_{MK} = 0$. Therefore, there are only 11 linearly independent restrictions.

The restricted version of (7.2.1a) thus becomes:

$$
\begin{aligned}
\ln\pi &= \alpha_0 + \alpha_E \ln w_E + (1-\alpha_E)\ln w_M - \frac{1}{2}\theta_{EM}(\ln w_E)^2 + \theta_{EM}\ln w_E \ln w_M \\
&- \frac{1}{2}\theta_{EM}(\ln w_M)^2 + \rho_L \ln L + (1-\rho_L)\ln K - \frac{1}{2}\rho_{LK}(\ln L)^2 \\
&- \frac{1}{2}\rho_{KL}(\ln K)^2 + \rho_{LK}\ln L \ln K + \delta_{EL}\ln w_E \ln L - \delta_{EL}\ln w_M \ln L \\
&- \delta_{EL}\ln w_E \ln K + \delta_{EL}\ln w_M \ln K
\end{aligned}
\qquad (7.2.1b)
$$

After rearranging, (7.2.1b) becomes,

$$
\begin{aligned}
(\ln\pi - \ln w_M - \ln K) &= \alpha_0 + \alpha_E(\ln w_E - \ln w_M) + \theta_{EM}\left[\ln w_E \ln w_M - \frac{1}{2}(\ln w_E)^2 - \frac{1}{2}(\ln w_M)^2\right] \\
&+ \rho_L(\ln L - \ln K) + \rho_{LK}\left[\ln L \ln K - \frac{1}{2}(\ln L)^2 - \frac{1}{2}(\ln K)^2\right] \\
&+ \delta_{EL}(\ln w_E \ln L - \ln w_M \ln L - \ln w_E \ln K + \ln w_M \ln K)
\end{aligned}
\qquad (7.2.1c)
$$

In China, especially during the estimation period, 1985-88, material inputs are more likely than energy to face quantity controls and rationing. It is because China has been self-sufficient and even an exporter in energy (but not in materials) in that 1985-88[4]. As mentioned in Chapter One, the 'energy imbalance" problem only started from 1992 and the data set for this model covers 85-88, before the energy shortfall period. Hence, in this data set, the study ex-ante access quantity

[4] During the estimation period 85-88 of the data set, total energy production exceeds consumption and much more is exported than imported. For more information, refer to China Statistical Year Book, 1990.

constraints for material inputs, not for energy. However, the empirical findings can also be projected to conduct energy policy analysis on energy imbalance.[5]

Following the process mentioned in Chapter six, a system of profit share equations prior to quantity constraints derived from equation (7.2.1a) subject to the restrictions mentioned above are expressed as follows[6]:

$$S_E = \frac{-w_E E}{\pi} = \alpha_E - \theta_{EM} \ln w_E + \theta_{EM} \ln w_M + \delta_{EL} \ln L \qquad (7.2.2a)$$

$$S_M = \frac{-w_m M}{\pi} = (1-\alpha_E) + \theta_{EM} \ln w_E - \theta_{EM} \ln w_M - \delta_{EL} \ln L \qquad (7.2.2b)$$

To obtain the most efficient estimations, the normalised translog profit equation (7.2.1c) and the system of variable factor demand (7.2.2a) and (7.2.2b) is jointly estimated[7] for E and M, by the seemingly unrelated regression estimation (SURE) technique (Zellner, 1962).[8]

[5] This part will be discussed in 7.25.
[6] It is derived from equation (6.1.6)
[7] One may directly estimate the translog profit function (7.1c) but gains in efficiency can be realised by estimating the restricted profit share equations which transform to optimal, profit maximisation input demand equations. Similar arguments on the translog cost function can be found in p.470 in Berndt (1991)
[8] The joint estimation will give more efficient parameters than sole estimation of the share system. See Berndt (1991)

7.3 Estimation of pooled data

This data set contains the pooling observations on 225 firms over 1985-88. To estimate such a pooled data model, one may have to use the panel data method. To construct a panel data regression, let us consider

$$y_{it} = x'_{it}\beta + u_{it}, \qquad i=1,2,......,N \text{ and } t=1,2,......,T \tag{7.3.1}$$

where N is the number of cross-section units (provinces) and T is the number of time periods. β is K x 1, x_{it} is a vector of K explanatory variables. Modifying (7.3.1) by introducing a time invariant term α_i and an individual (firm) invariant effect λ_t into the equation, (7.3.1) becomes:

$$y_{it} = x'_{it}\beta + \alpha_i + \lambda_t + \varepsilon_{it}; \tag{7.3.2}$$

where α_i accounts for any individual (firm) specific effect that is not included in the regression, whereas λ_t accounts for the time specific effect that is not included in the regression. $\varepsilon_{it,}$ as the remaining disturbance varying with individuals and time, can be thought of as the usual stochastic disturbance in the regression. In other words,

$$u_{it} = \alpha_i + \lambda_t + \varepsilon_{it}; \qquad \varepsilon_{it} \sim \text{iid } (0, \sigma^2_\varepsilon) \tag{7.3.3}$$

There are two possible approaches to estimate (7.3.3). One of them is a 'random effects' model which occurs when each firm has its individual(firm) and time specific disturbances; α_i and λ_t are treated as random disturbances i.e. $\alpha_i \sim$ iid $(0, \sigma^2_\alpha)$ and $\lambda_t \sim$iid $(0, \sigma^2_\lambda)$, where α_i are independent of the ε_{it} and x_{it} are independent of α_i and ε_{it} for all i and t. These assumptions are sufficient for OLS to be asymptotically unbiased. OLS is not efficient, however, because the standard errors associated with the OLS will be understated (Johnston, 1997). Instead, the Feasible Generalised Least-Squares (GLS) procedure is introduced to obtain efficient estimation.

Alternatively, a 'fixed effects' model occurs when both the firm and time specific effects are invariant, i.e., α_i and λ_t are now treated as constant. Under such an assumption, (7.3.2) can be rewritten as:

$$y_{it} = \alpha_1 DI_1 + ... + \alpha_n DI_n + \lambda_1 DT_1 + ... + \lambda_T DT_T + x_{it}^{'}\beta + \varepsilon_{it} \qquad (7.3.4)$$

where DI_j's are firm specific dummy variables which take a value of 1 for j firm and 0 elsewhere and DT_k's are time specific dummy variables which take a value of 1 for k period and 0 elsewhere. This equation can be estimated by OLS.[9]

In comparing these two approaches, Mundlak (1978) argues that we should always treat the individual effects as random. The fixed effects model is analysed conditionally on the effects present in the observed sample. One can argue that certain institutional factors or characteristics of the data argue for one or the other, but unfortunately, this approach does not always provide much guidance. From a practical standpoint, the dummy variable approach is costly in terms of degrees of freedom lost. On the other hand, the fixed effects approach has one considerable virtue. There is no justification for treating the individual effects as uncorrelated

[9] This model is usually referred as the least squares dummy variable (LSDV) model.

with the other regressors, as is assumed in the random effects model. The random effects treatment, therefore, may suffer from the inconsistency due to omitted variables.[10]

Therefore, from the literature, there is no consensus as to which method is preferred.[11] Indeed, recent studies find that neither the fixed effects estimator nor the random effects estimator is perfect. As revealed from the literature on union wage effects, although the evidence suggests random effects estimators generally lead to upward-biases, fixed effects procedures generally produce downward-biased estimates.[12]

However, the model used here is not estimated by the above-mentioned methods, because there may be continuous structure changes over the estimation period. Since the Third Plenum of the 12th CCP Central Committee held in 1984, the government has adopted sequential economic structure reform policies, which involve modifying the relationship between the formulation of planning and the power to operate production, the power to distribute profits, the power to allocate funds, the power to assign labour and the power to manage personnel. These continuously shifting industrial policies may induce changes in parameters from time to time. Hence, our estimation should allow the slope parameters to vary over time[13]. Therefore, (7.3.2) should be modified as

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[10] See Hausman Taylor (1981) and Chamberlain (1978).
[11] For more detailed on this argument, one may refer Johnston and Dirardo (1997) and Greene (1997).
[12] Johnston and Dinardo (1997)

$$y_{it} = x_{it}'(\beta + \delta_t) + \alpha_i + \lambda_t + v_{it}$$[14]

(7.3.5)

In comparing to (7.3.5), it is obvious that the use of the time-invariant parameters method as given by (7.3.2) will lead to a heteroscedastic regression i.e. $\varepsilon_{it} = x_{it}\delta_t + v_{it}$, where δ_t is random and independent of x_{it} and α_i. Therefore, the time varying heteroscedasticity remains. This affects the efficiency and consistency of parameters although the typical time-invariant panel estimators (7.3.2) can remove the individual heterogeneity by transforming data or by introducing time dummies.

Nevertheless, this problem can be solved by estimating the model year by year. This method can measure time varying parameters. Under this method, model (7.3.2) is modified into:

$$y_{it} = x_{it}'(\beta + \delta_t) + \lambda_t + v_{it}. \qquad (7.3.6)$$

Hence, this method will give the correct estimate of the coefficient vector ($\beta + \delta_t$). In comparison to (7.3.5), although this cross-section study can identify λ_t[15], it cannot account for the effects of α_i.[16] Nevertheless, this is not a serious problem, because all the firms contained in our data set are SOEs, which have similar structure and the problems they face are more or less the same. Thus, the individual

[13] For detailed discussion on this issue, refer to Bell and Ritchie (1996).

[14] Note that λ_t only captures time-invariant individual differences. The mean coefficient vector still is constant over time and individuals.

[15] It is identified by the intercept of each cross-section study.

[16] Of course, one may estimate more general model (7.3.5). However, I need to estimate SURE model. Unfortunately, it seems to be non-existent for SURE in applied work for (7.3.5).

effect α_i changes little across various enterprises. On the contrary, the continuous reform policies imposed on them has been changing over time. Therefore, variation over time is relatively more significant than variation over individual firms. As mentioned in Bell and Ritchie (1996), cross section estimates under this situation may be more efficient than panel estimates. Such a cross-section study has the advantage that the changing structure of the model can be examined, despite the inefficiency and estimation bias probably arising from the inability of cross-sections to remove individual heterogeneity. In addition, this approach has yet another advantage, in that even if poor estimates may occur in one year, the estimates for other years are not necessarily affected. Thus, it is appropriate for us to use (7.3.6) to estimate this data set.

7.4 Empirical Results

7.4.1) Estimation of Translog and Profit Share Equations

To obtain the estimates of the KLEM model over time- each of which consists of one profit equation (7.2.1c) and two share equations (7.2.2a) and (7.2.2b)- I group the four years model together as 4x3 (i.e.12) seemingly unrelated equations (SURE). The resulting estimators are more efficient than OLS estimation over four years, because this method makes use of the information from the cross-equation correlation among regression residuals over time.

In order to confirm whether the data set is appropriate for modelling changing coefficients, a test for the stability of parameters was performed. The Chi-square test statistic is 49.56 and the hypothesis of time varying parameters is not rejected at one- percent significance level with 18 degrees of freedom. The estimating results are reported in Table 7.1.

As presented in Table 7.1, the parameters are, in general, correctly signed. That is, the estimated shares for fixed inputs must be positive, while for the variable inputs case (i.e. input prices) must be negative[17]. This fulfils one of the regularity conditions for a normalised restricted profit function to reflect well-behaved production structures. Besides, most of the parameters are significant and the $\overline{R}^2$ of the restricted translog profit equations are quite high for the period 1985-88[18].

[17] As the shares (S_i) in the estimation are defined as $-w_i x_i/\pi$, the estimated coefficients shown in table 7.1 are presented in opposite signs.

[18] Normally, the R^2 of the cross section data is much lower than that for the time series.

Table 7.1: Time Varying Parameters Of Translog and Profit Share Function

	Parameter	Estimate	Standard Error	t-statistics
1985	α_0	.8330	.3479	2.3946**
	α_E	.9800	.0482	20.3199**
	α_{EM}	.0168	.0067	2.5145**
	ρ_L	.6080	.1690	3.5984**
	ρ_{LK}	-.0594	.0406	-1.4654
	δ_{EL}	.0176	.0124	1.4163
	$\overline{R}^2_\pi = 0.84$	$\overline{R}^2_{SE} = 0.03$	$\overline{R}^2_{SE} = 0.03$	
1986	α_0	.8726	.4004	2.179**
	α_E	1.0224	.0481	21.2489**
	α_{EM}	.0162	.0060	2.6890**
	ρ_L	.6721	.1905	3.5287**
	ρ_{LK}	-.0732	.0449	-1.6296
	δ_{EL}	.0267	.0120	2.2202**
	$\overline{R}^2_\pi = 0.86$	$\overline{R}^2_{SE} = 0.03$	$\overline{R}^2_{SM} = 0.02$	
1987	α_0	.6921	.4548	1.5217
	α_E	1.0311	.0549	18.7963**
	α_{EM}	.0128	.0064	1.9854
	ρ_L	.6219	.2070	3.0042**
	ρ_{LK}	-0.0664	.0469	-1.4161
	δ_{EL}	.0226	.0133	1.7035
	$\overline{R}^2_\pi = 0.88$	$\overline{R}^2_{SE} = 0.04$	$\overline{R}^2_{SM} = 0.01$	
1988	α_0	.3762	.5539	.6791
	α_E	1.1609	.0686	16.8303**
	α_{EM}	.0195	.0083	2.3463**
	ρ_L	.4846	.2450	1.9780**
	ρ_{LK}	-.0370	.0534	-.69279
	δ_{EL}	.0568	.0159	3.5663**
	$\overline{R}^2_\pi = 0.90$	$\overline{R}^2_{SE} = 0.06$	$\overline{R}^2_{SM} = 0.01$	

Notes:

(1): The $\overline{R}^2$ of the equations of S_E and S_M are small because the dependent variables are the ratios of two variables (i.e. S_E and S_M on this model).

(2): **/* denote that the parameter is statistically significant at the 1% / 5% significance respectively.

(3): The estimation are based on the Young theorem and under the restrictions on parameters as expressed by (6.1.3), i.e.,

$$\theta_{ME} = \theta_{EM}, \ \rho_{KL} = \rho_{LK}, \ \alpha_M = 1-\alpha_E, \ \theta_{EE} = -\theta_{EM}, \ \theta_{MM} = -\theta_{EM}, \ \rho_K = 1-\rho_L$$

$$\rho_{LL} = -\rho_{LK}, \ \rho_{KK} = -\rho_{LK}, \ \delta_{EK} = -\delta_{EL}, \ \delta_{MK} = \delta_{EL}, \ \delta_{ML} = -\delta_{EL}$$

Table 7.2A: Elasticities with Rationing

	$\overline{\xi_{EE}}$	$\overline{\xi_{EM}}$	$\overline{\varepsilon_{EL}}$	$\overline{\varepsilon_{EK}}$	$\overline{\xi_{EQ}}$	$\overline{\xi_{QE}}$	$\overline{\xi_{QM}}$	$\overline{\xi_{QQ}}$	$\overline{\varepsilon_{QL}}$	$\overline{\varepsilon_{QK}}$
1985	-1.0871 (25.8483)***	0.7568 (76.8350)***	0.3510 (1.1641)	0.1546 (.7959)	4.0820 (65.3390)***	-0.1913 (-541.661)***	0.7333 (1520.27)***	2.9251 (8281.77)***	1.0222 (2.54771)**	0.1495 (.3751)
1986	-1.1173 (- 31.9169)***	0.7663 (99.7613)***	0.3622 (1.1346)	0.1239 (.6052)	4.2805 (84.3220)***	-0.2101 (-643.113)***	0.7468 (1909.59)***	3.1443 (9625.52)***	1.1542 (2.61013)**	0.0002 (.0005)
1987	-1.1357 (- 30.3765)***	0.7642 (93.8144)***	0.4097 (1.1394)	0.1519 (.6118)	4.2873 (78.6035)***	-0.2090 (-617.685)***	0.7489 (1832.63)***	3.1794 (9398.11)***	1.0231 (2.25035)**	0.0897 (.198180)
1988	-1.0880 (- 21.8877)***	0.7738 (71.5522)***	-0.0713 (-.2346)	0.3683 (1.8795)*	4.3497 (59.9579)***	-0.2029 (-464.268)***	0.7497 (1420.97)***	3.1797 (7276.52)***	0.7670 (1.39207)	0.3920 (.713558)

Notes
(1) : The calculated t values are in parenthesises.
(2) : ***/**/* denote that the parameter is statistically significant at the 1%/5%/10% significance level respectively.
(3) : '+' indicates complementary
(4) : '-' indicates substitutive
(5) Q: for the output price
(6) E: for the price of energy inputs
(7) M: for the price of material inputs
(8) L: for labour inputs
(9) K: for capital inputs

Table 7.2B: Elasticities without Rationing

	ξ_{EE}	ξ_{EM}	ε_{EL}	ε_{EK}	ξ_{EQ}	ξ_{QE}	ξ_{QM}	ξ_{QQ}	ε_{QL}	ε_{QK}
1985	-1.1046 (-31.7007)***	-2.8197 (-80.9249)***	0.3061 (3.5132)***	0.6939 (7.9656)***	3.9243 (1.502.)	-0.1922 (-0.731.)	-2.7321 (-1.051.)	2.9243 (1.502.)	0.3978 (8.9587)***	0.6022 (13.5595)***
1986	-1.1341 (-39.6656)***	-3.0094 (-105.260)***	0.2767 (3.3422)**	0.7233 (8.7375)***	4.14349 (1.286)	-0.2109 (-0.396.)	-2.9326 (-0.986.)	3.1435 (1.292.)	0.4031 (8.5222)***	0.5969 (12.6199)***
1987	-1.1488 (-37.4881)***	-3.0299 (-98.8760)***	0.2603 (2.8473)***	0.7397 (7.5232)***	4.17871 (.1.686)*	-0.2096 (-0.778.)	-2.9691 (-1.202.)	3.1787 (1.684.)*	0.3680 (7.2209)***	0.6320 (12.4028)***
1988	-1.1083 (-27.1954)***	-3.0705 (-75.3462)***	0.0628 (.58398)	0.9372 (8.7242)***	4.1787 (.1.879)*	-0.2039 (-0.677.)	-2.9748 (-1.364.)	3.1787 (1.880.)*	0.3414 (6.1464)***	0.6586 (11.8577)***

	ξ_{MM}	ξ_{ME}	ε_{ML}	ε_{MK}	ξ_{MQ}
1985	-3.7259 (-1520.27)***	-.1983 (-80.9249)***	.4043 (9.2919)***	.5957 (13.6910)***	3.9243 (.1.502)
1986	-3.9270 (-1909.59)***	-.2165 (-105.260)***	.4122 (8.8789)***	.5878 (12.6621)***	4.1435 (1.286)
1987	-3.9648 (-1832.63)***	-.2139 (-98.8760)***	.3756 (7.5232)***	.6244 (12.5081)***	4.1787 (.1.686)*
1988	-3.9683 (-1420.97)***	-.2104 (-75.3462)***	.3605 (6.6342)***	.6395 (11.7696)***	4.1787 (.1.879)*

Notes:

(1): The calculated t values are in parenthesises.

(2) ****/**/* denote that the elasticities is statistically significant at the 1%/ 5%/ 10% significance level respectively.

Table7.3 Tests for rationing versus for no-rationing

		ξ_{EE}	ξ_{EM}	ε_{EL}	ε_{EK}	ξ_{EQ}	ξ_{QE}	ξ_{QM}	ξ_{QQ}	ε_{QL}	ε_{QK}
1985	χ^2	5.8764	6403.	0.0287	11.589	6.3752	5.8764	5162	5.8764	2.6735	1.4232
	Pv	0.0154	0.0000	0.8653	0.0007	0.0116	0.0153	0.0000	0.0154	0.1020	0.2329
1986	χ^2	6.8011	1083	0.0881	12.440	7.2860	6.8011	8852	6.8011	3.1440	2.0041
	Pv	0.0091	0.0000	0.7667	0.0004	0.0070	0.0091	0.0000	0.0091	0.0762	0.1569
1987	χ^2	3.7562	9567.	0.2191	7.767	3.9650	3.7562	8278	3.7562	2.2849	1.5791
	Pv	0.0526	0.0000	0.6397	0.0053	0.0465	0.0526	0.0000	0.0526	0.1306	0.2089
1988	χ^2	5.1119	5557.	0.2864	10.761	5.5545	5.1119	4984	5.1120	0.6573	0.2593
	Pv	0.0238	0.0000	0.5926	0.0010	0.0184	0.0238	0.0000	0.0238	0.4175	0.6106

Note: χ^2 and Pv denote Chi square value and P-value respectively.

Table 7.4: Hicksian energy price elasticities and the expansion effects[19]

		Estimates	Standard Error	t-Statistics
1985	Scale Effect	-.2670	.0036	-74.9745***
	Hicksian Elasticities	-.8201	.0456	-17.9779***
1986	Scale Effect	-.2860	.0029	-98.0346***
	Hicksian Elasticities	-.831326	.0379	-21.9205***
1987	Scale Effect	-.2818	.0031	-90.9362***
	Hicksian Elaticities	-.8539	.0405	-21.0917***
1988	Scale Effect	-.2775	.0040	-69.5071***
	Hicksian Elasticities	-.8105	.0537	-15.0923***

Note: *** denotes that the expansion effect and Hicksian Elasticity are statistically significant at the 1% significance levels.

[19] As capital and labour are treated as fixed factor whereas material input is chosen as rationed factor, the Marshallian and Hicksian own price elasicities of variable inputs and scale effect remain for energy only.

7.4.2) The Elasticities

Substituting the estimates of table 7.1 and the formulae derived in section (6.1) and (6.3), the elasticities of no rationing and under rationing can be obtained.[20] The results are reported in Table 7.2A and 7.2B respectively.

Comparing the Table 7.2A and 7.2B, the signs of estimated price elasticities under rationing and no rationing are generally the same (except ε_{mk} in 1988). Hence, it seems that there is no great difference in policy implication. All the magnitudes of elasticities with rationing, however, are lower than without. Moreover, we have tested whether the elasticities have been significantly altered by the imposition of a quantity rationing for material inputs on the firms. Table 7.3 supports the hypothesis that rationing should be taken into account in measuring the input prices elasticities. In other words, if rationing is not considered in estimating price elasticities, the effects of the changes in prices will be exaggerated[21].

Table 7.2A shows that the calculated elasticities of the input demand (energy input) with respect to the changes in fixed factor (K & L) and in rationed inputs (M) are correctly positive signed. Furthermore, as reported in Table 7.4, the net energy price effect (Hicksian elasticity) and the scale effect are negatively signed, the sum of the two effects (Marshallian elasticity) also is negative. This means that when energy price increases, the profit maximising firm alters its input mix and technical substitution will force the firm to employ less energy to produce the same output

[20] Since there are no time trends in our models, θ_T, θ_{TT}, θ_{ET}, θ_{MT}, ϕ_{LT} and ϕ_{KT} are treated as zero in calculating the elasticities.

level i.e., along the same isoquant. On the other hand, higher energy prices will lead the SOEs to produce less output. Since energy is a normal input, energy use will be further reduced. This trend coincides with what was mentioned in section 5.3, that the net substitution and expansion effects always move in the same direction.

7.5 Analyses of the Findings and Policy Implications

7.5.1) Complementarity/Substitutability Among Various Factors

As reported in Table 7.2, the empirical results seem to suggest that energy and capital are complementary.[22] There are three possible explanations for this result. First, before economic reform in 1979, the depreciation rate was set by the government at a rather low level, averaging at 5% (Wang, 1991). This low rate leads low levels of investment in replacing capital and so a huge amount of over-utilised capital goods are accumulated. In addition, a low depreciation rate implies low cost (opportunity cost) of using capital. As a result, SOEs are encouraged to employ the 'over-utilised' capital to produce goods and services. This situation resulted in low marginal product of capital (MPK)[23] and high capital-output ratios that persisted, even in the beginning of the reform. Therefore, when energy prices increased, capital was not worth to keeping and so firms employed less capital i.e., K-E are complementary. Second, in practice, it is not easy to change equipment and there is

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[21] Further discussion will be presented later.
[22] Although the K-E elasticities are not significant over 1985-87, but the elasticity is significant in 1988.

a relatively long adjustment period to replace the existing capital. That is, even if energy prices increase, firms still have to employ the energy-consuming machines, because they can not be immediately replaced by the energy saving capital. Thus, the firms are forced to reduce the use of energy and capital and so generate the present E-K complementarity[24]. Third, in the past, industrial policy was to emphasise the development of the heavy industry[25]. Most SOEs in China, therefore, produced heavy industrial output which normally is energy intensive. Moreover, a low energy price has encouraged SOEs to employ energy-consuming production technology. As a result, the energy intensity (energy consumed per unit of output) is high, especially for the low MPK products. Therefore, the more capital employed, the more energy is consumed, implying capital-energy complementary.

On the other hand, our empirical findings show energy-labour elasticity is not significant, i.e., they are neither complementary, nor substitutive. This finding is different from what Williams & Laumas (1981) found in India. The authors found energy-labour complementary, in a country, which also has a huge population. This finding may reflect the low productivity of labour. China is a country with a large population and one of the main objectives of the state-owned enterprises is to absorb all the labour[26]. Therefore, labour is abundant and a large amount of repressed unemployment occurs. Moreover, most of the workers are not well educated, or

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[23] This can also be revealed from Table 7.2A, which shows that elasticities of output to capital are small and generally insignificant.
[24] For more detail discussion on this issue, please refer to Norsworthy and Harper (1981).
[25] In my data set, 31% of SOEs produce consumer goods whereas 69% of the firms produce producer goods.

trained for their jobs (Gordan and Li, 1995). In addition, the Iron Rice Bowl System (Permanent Employment System) in SOEs leads to poor performance, because under this system, workers have job security which guarantees them the right to share without having to put in additional work. In contrast, a working harder person receives little additional benefit because of lack of additional remuneration when one tries to work harder. Therefore, workers have no need to work hard (Chow, 1993), resulting in low motivation, poor labour quality and low labour productivity.[27] On the other hand, as mentioned above, heavy industrial output comprises a large percentage of total industrial output. Therefore, to produce the same output level, an increase in labour can not compensate for the reduction in capital and energy in producing capital and energy intensive products. i.e., there is no obvious relationship between energy and labour.

Moreover, energy-material inputs complementarity also is found in this study. This finding can be explained similarly by the low productivity in first few years of the economic reform. In view of the magnitudes, as revealed in Table 7.2A, the elasticities of energy consumed response to capital, labour and material inputs are smaller than 0.8. This may reflect that the underlying production technology is inflexible for the substitution of one input into the other inputs over the estimation period.

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[26] Most SOEs have three important goals: maximising profit, generating employment, and increasing wage above the competitive (market-clearing) level in the economy. For more details, please refer to Chan and Lee (1998).

[27] Those problems still occurred even at the beginning of the reforms.

7.5.2) Policy Implications

The above findings of K-E, M-E complementarity imply that high energy price will not only reduce capital formation, but also reduce the uses of material inputs. Therefore, raising the energy price will generate contractionary effects on economic growth,[28] [29]explaining why the price elasticities of output in Table 7.1A is negative. It is noteworthy to mention that if the government enforces hiring, there will be no effect on labour employment, because the energy-labour elasticity is statistically insignificant. As the energy price elasticity is about –1.1 and elasticity of output to the change in energy price is close to -0.22, reducing energy demand by higher prices may cause reductions in energy consumption and output by 1.1% and 0.22% respectively. According to the forecast made in Chapters Two and Three, the predicted demands in 2000 and 2010 are 1,420 and 2,010 Mtce, while supply is forecasted to be 1,370 and 1,826 Mtce respectively. In order to balance the future energy demand and supply in 2000 and 2010, China has to reduce energy demand annually by 1.202% and 0.706% respectively[30]. If this reduction is to be achieved by imposing higher energy prices, given that the energy price elasticity under rationing, $\overline{\xi_{EE}}$ is –1.088, the energy price has to increase by 0.9463% and 0.649%

[28] This implication of findings is similar to the explanation of world recession especially in western economies arisen from energy crisis in 1970's.

[29] Note that Section 2.2 mentions that the increases in energy prices cause consumption efficiency and helps reduce the energy shortfall. This finding neglects the effects of high-energy prices to the output and this is the limitation of the qualitative analysis.

[30] Assuming that the official forecasts of energy supply remain unchanged and so, to reduce the energy imbalance, the authority has to cut the demand.

respectively[31]. On the other hand, since $\xi_{\overline{QE}}$ equals –2.029, the country will need to pay the cost of a fall in its economic growth rate of output by 0.192 and 0.132% respectively.

Instead of increasing the energy prices, there are three other alternative policies, as shown in Table 7.5 that could close the energy gap completely.[32] First, the authority can mitigate the energy sector in 2000 and 2010 by decreasing supply in material inputs by 1.332% and 0.913% respectively. This approach may slow down the output growth, however, by 0.998% and 0.685%. Second, the government may reduce output price in order to mitigate the shortfall by 0.237% and 0.162%. respectively; but the country in turn will suffer from a negative growth rate of output by 0.753% and 0.516%, respectively. Third, the government can reduce the use of capital by 2.797% and 1.918%, which may also alleviate the excess demand in 2000 and 2010. As the output-capital elasticity is insignificant, however, such a change will not have a deteriorating effect on output[33]. All of these results are presented in Table 7.5.

In order to reduce the energy imbalance, it has been suggested that China should implement a high energy pricing policy, so that the economy will reduce the use of capital goods and encourage firms to employ labour-intensive production

[31] The calculations are based on the energy price elasticities of energy and output in 1988 and assuming that they remind unchanged over the forecast period.

[32] Use the relevant elasticities of 1988 depicted in Table 7.2A and assume that the elasticities remain the same in 2000 and 2010.

[33] As mentioned above, a lot of capitals in SOEs are over utilised, which results in very low marginal product. Therefore, in the short run, a small reduction in capital may not reduce output growth. However, over the long run, if capital inputs decrease continuously, output growth will fall eventually.

techniques. This policy, therefore, will allow the economy to absorb surplus labour and also to reduce energy imbalance in the near future. Although this approach seems sensible, our findings do not support this strategy, because higher energy prices will lead to a lower employment of both capital and material inputs. Thus the growth rate of output will be reduced although there is a stimulatory effect on labour employment. Alternatively, the findings also can be explained by insignificant energy-labour elasticities. Since China has a lot of redundant workers in state-owned enterprises and their labour productivity inevitably is low, it is not easy to use labour to substitute for energy use.

As mentioned above, in order to close the domestic energy imbalance completely, one can increase energy prices. When price elasticities are negative, however, output will be reduced, because capital and material are complements of energy and labour can not substitute for energy. As a result, output elasticity of energy price also is negative. Alternatively, to avoid the trade off between output and energy shortfall, the government may implement energy price changes concurrently with other exogenous policy changes, which are named as A, B and C. For policy option A, the government may change the level of employment of material inputs and energy prices concurrently, so that the energy imbalance can be closed completely by 2000. To do that, the energy consumption must be reduced by 1.2% annually. Under this requirement , we can write,

$$\overline{\xi_{EE}} * \% \Delta w_e + \overline{\varepsilon_{EM}} * \% \Delta M = -1.2 \qquad (7.5.1a)$$

In the above, ($\overline{\xi_{EE}}$ * % Δw_E) is the percentage change in energy consumption resulting from one percent change in energy prices. ($\overline{\varepsilon_{EM}}$ * % ΔM) is the percentage change in energy consumption per one percent change in material inputs.

On the other hand, changes in energy prices and inputs of material will influence the level of output. If the target output growth rate is set at zero, the resulting equation should be:

$$\overline{\xi_{QE}} * \% \Delta w_E + \overline{\varepsilon_{QM}} * \% \Delta M=0, \tag{7.5.1b}$$

where ($\overline{\xi_{QE}}$ *%Δw_E) is the percentage change in output resulting from one percent change in energy prices and ($\overline{\varepsilon_{EM}}$ *%ΔM) is the percentage change in output per one percent change in material inputs.

We can substitute the calculated elasticities under rationing for year 1988, (7.4.1a) and (7.4.1b); the resulting equations will become:

$$-1.088 * \% \Delta w_E + 0.7738 * \% \Delta M = -1.2 \tag{7.5.2a}$$

$$-0.2029 * \% \Delta w_E + 0.7497 * \% \Delta M=0 \tag{7.5.2b}$$

After solving (7.4.2a) and (7.4.2b) simultaneously, the optimal rate of energy price and material inputs changes can be calculated, which are 1.173 and 0.317 respectively. Similarly, the equations for policy option B, which combines the changes in the input level of capital and energy prices are:

$$\overline{\xi_{EE}} * \% \Delta w_E + \overline{\varepsilon_{EK}} * \% \Delta K=-1.2 \tag{7.5.3a}$$

$$\overline{\xi_{QE}} * \% \Delta w_E + \overline{\varepsilon_{QK}} * \% \Delta K=0 \qquad (7.5.3b)$$

where ($\overline{\varepsilon_{EK}}$ * % ΔK) is the percentage change in energy consumption resulting from one percent change in capital input. ($\overline{\varepsilon_{QK}}$ * % ΔK) is the percentage change in output per one percent change in capital input.

For policy option C, output prices are changed concurrently with energy price changes, The corresponding equations should be:

$$\overline{\xi_{EE}} *\% \Delta w_E + \overline{\xi_{EQ}} * \% \Delta P = -1.2 \qquad (7.5.4a)$$

$$\overline{\xi_{QE}} *\% \Delta w_E + \overline{\xi_{QQ}} * \% \Delta P=0 \qquad (7.5.4b)$$

where ($\overline{\xi_{EQ}}$ * % ΔP) is the percentage change in energy consumption resulting from one percent change in output price. ($\overline{\xi_{QQ}}$ * % ΔP) is the percentage change in output per one percent change in output price.

Under the assumption that domestic energy supply and demand must be balanced in 2010, energy consumption should be reduced by 0.706% annually. The optimal policy options also can be obtained by solving (7.5.1a and b), (7.5.3a and b) and (7.5.4a and b) individually. The only change is replacing -1.2 (%) by -0.706 (%) in the three equation systems. The solutions of those equations of policy options A, B and C for 2000 and 2010 are presented in Table 7.6.

As shown in Table 7.6, all three policy options seem to be feasible, because they only require slight changes in the policy variables. If government wants to achieve domestic energy supply-demand balance and the output growth of 2.8%[34,35] simultaneously, however, Table 7.7[36] suggests that firms will have to decrease the use of capital considerably.[37] Indeed, output growth will reduce inevitably if capital inputs keep increasing. It is impossible, therefore, to choose option A. Should firms currently increase either the uses of material inputs or output prices as formulated in B and C, however, the energy prices need to increase concurrently by roughly 20%.

Table 7.5: The Effects of Changes in Policy Variables on Output (Single Instrument)

Target: No Energy Imbalance in the Target Year

	Target Year: 2000		Target Year: 2010	
	Policy Variable	Output Effect	Policy Variable	Output Effect
W_E	0.9463	-0.192	0.649	-0.132
K	-2.797	0	-1.918	0
M	-1.332	-0.998	-0.913	-0.685
P	-0.237	-0.753	-0.162	-0.516

Notes:
1. '+' denotes ecrease', whereas '-' denotes ncrease'.
2. All figures in the Table are measured in % change.
3. Labour policy is not available here because $\overline{\varepsilon_{EL}}$ is not significant.
4. The output effect is zero because $\overline{\varepsilon_{QK}}$ is insignificant.

[34] This figure, obtained by averaging output growth of the SOEs over 1985-88, is much less than the average growth rate of national income which is around 10 %. It is because as mentioned in Section 2.3, the efficiency of state own enterprises is poor.

[35] Note that as energy are complementary to the non-energy inputs in this study, an increase in energy prices will reduce the uses of energy as well as other non-energy inputs, which will result in a lower output. Therefore, to increase output, other inputs must be raised by other policies concurrently with high energy prices.

[36] The calculation procedures are basically the same as Table 7.6 except the right-hand side value becomes '2.8' instead of '0' in 7.4.1b, 7.4.3b and 7.4.4b.

[37] Labour employment policy is not valid because L-E elasticity is not significant. Moreover, 'Note 33' gives the explanation why output growth does not deteriorate from a reduction in capital use.

Table 7.6: Two Instrument Policy Options (No Trade-Off)

Target: Energy Balance and Zero Growth of Output

Policy Option	Policy Variables	Target Year: 2000	Target Year: 2010
A	w_E	1.173	0.804
	M	0.317	0.218
B	w_E	0	0
	K	-2.797	-1.918
C	w_E	1.271	0.872
	P	0.0811	0.056

Notes:

1. The notes are the same as the notes 1-3 in Table 7.5.
2. Since the target output growth rate is zero, given $\xi_{\overline{EQ}}$ is insignificant, solely reduce the use of capital input is enough to decrease energy consumption and so energy prices (w_E) need not change in policy option B. For further explanation, please refer to 'Note 33'

Table 7.7: Two Instrument Policy Options (2.8% Output Growth)

Target: No Imbalance and 2.8% Growth

Policy Options	Policy Variables	Target Year: 2000	Target Year: 2010
A	W_E	21.063	20.695
	M	4.943	4.843
B	W_E	2.8	2.8
	K	-43.564	-42.685
C	W_E	22.598	22.599
	P	1.263	1.263

Notes: the notes are the same as the notes 1-3 in Table 7.5.

In summary, since energy price elasticity of output is negative, whereas material inputs and price elasticities of output are positive, if the government changes only one policy instrument at a time, irrespective as to whether we (i) increase energy prices, (ii) decrease material inputs or (iii) decrease output prices to achieve energy supply-demand balance, the economy may suffer from negative output growth. Also, our findings show that the estimated energy price elasticities of labour and labour elasticity of output are insignificant.

It is not surprising as we have mentioned above, that there are so many redundant workers in Chinese state-owned enterprises, resulting in low labour productivity. Therefore, the scope for labour to substitute for energy use is not large. On the other hand, since the capital elasticity of output is insignificant, there will be no contractionary effect on output growth, if the government wants to mitigate the shortfall gap by reducing the use of capital. However, note that capital cannot decrease persistently or else output growth will fall ultimately. If the government wants to increase output by 2.8%[38] annually and achieve energy balance by high energy pricing policy, in the short run, it needs to either (i) increase the use of material inputs, (ii) reduce capital use, or (iii) raise output price.

After evaluating these three policy options, the second option found to be not feasible, because the reduction in capital is too large. Alternatively, if either material inputs or output prices are increased, the above targets can be achieved by increasing energy prices by more than 20%. Under this situation, raising energy prices becomes a desirable policy, especially, because energy in China still is underpriced.[39] It should be noted, however, that after the substantial rises in energy prices in the early 1990s, there might be no room left for large increases, thus the positive effects on output will be limited.

Besides, as revealed in Table 7.7, policy option C will induce annual inflation. Although the magnitude is not very large (about 1.2 %), this side effect should not be ignored, because it may cause spiral inflation, especially during inflationary periods. For policy option A, to achieve the target of growth and energy balance, material inputs have to increase more than 4.8 %. As there was a shortfall of material inputs until recently, this policy will induce an increase in imports and so deteriorate the trade balance, resulting in negative effects on balance of payments and foreign reserves. Therefore, as China is a developing country, the government should consider carefully the effects of increasing energy prices. Instead, if the labour productivity can be improved, the labour output signed and labour becomes a substitute for energy, then the country is strongly recommended to introduce high energy price policy. This is not only reduces future energy demand, but also increase labour employment.

[38] As depicted before, the average real growth rate of SOEs is only 2.8% over the estimation period since the efficiency of SOEs is generally poor.

[39] However, the energy prices need to increase concurrently with either exogenous policy changes.

7.6 Conclusion

In this chapter, the data set, estimation of the translog profit function and the econometric technique in use were discussed. The empirical findings suggest that time varying approach is more appropriate than the time invariant approach.

In general, the estimation results are satisfactory. Based on the estimated coefficients and the formulae derived in Chapter 6, various elasticities can be calculated. After testing, it was found that the elasticities with rationing is more appropriate with China data set. Besides, the findings show that there are complementary relationships between energy and capital as well as material inputs, and no significant relationship between energy and labour, over the estimation period.

Comparing the predicted future demand and supply obtained in Chapters 2 and 3 respectively, imbalances are likely to intensify in 2000 and in 2010. Our findings show that except for decreasing the use of capital, increasing in energy prices, reducing supply of materials and output price are not appropriate to narrow the energy shortfall because these three policies will deteriorate the rate of output growth. Moreover, unless energy-labour are significant substitutes, encouraging firms to employ labour intensive techniques still cannot alleviate energy imbalance.

To avoid the adverse effects on output growth, the government has suggested to implementing two instruments simultaneously, rather than exclusively use single instrument. If the government not only aims at reducing energy shortfall, but also wishes SOEs maintain a 2.8 percent of average growth rate over the estimation period, capital inputs has to be reduced by over 40 percent. This option does not seem to be viable. Alternatively, firms may raise energy prices by over 20 percent if they concurrently increase either output price, or the use of material inputs. However, the increase in energy prices may cause spiral and adverse effects on balance of payments and foreign reserves. Therefore, the government should take all these factors into account prior to raising energy prices. Alternatively, the improvement in productivity- not only in capital, but also in labour, energy and material inputs-may be the most important task that the government aims to achieve.

Chapter 8: Conclusion

This chapter summarises the main conclusions of the thesis, which has concentrated on exploring

1) China's ability to handle energy imbalance,

2) the predicted size of the energy deficit,

3) the role of government energy pricing policies in China.

I deal with each of these in turn.

8.1 Assessment of China's ability to handle the energy Constraint.

As we have seen in Chapter 2, after the economic reform of 1979 China started to experience high economic growth and so energy demand increased drastically. As a result, China faces the challenge of an energy bottleneck, which must be overcome in order to sustain continued economic growth and to improve further the living standards of its people. In order to overcome this problem, the government has initiated a number of policies, such as the development of small coal mines, the rapid build up of electricity generation capacity, adjusting prices, i.e., raising the planned prices to international market levels and the improvement in energy consumption efficiency. These policies have been quite successful in mitigating a widening gap.

As the country is expected to grow relentlessly over the next few decades, China still needs to confront a number of future problems, although the deficit has largely been kept to a manageable level over the last few years. First, the oil deficit is growing. Second, coal supply is uncertain, especially since importance of small coal mines is expected to decline in the twenty-first century. Third, the shares of state investment in both the energy sector and the coal industry have been declining drastically. Fourth, there has been only little progress in reforming state-owned enterprises. Last, regional imbalances are intensifying.

In view of the above, the growth rate of energy supply is unlikely to catch up with demand; the shortfall gap, therefore, is expected to become bigger over time. In order to manage the problem, China must initiate polices that address both the supply and demand sides of the energy sector. On the supply side, efforts should be intensified towards discovering new oil fields. In addition, the government should strengthen its role in the coal industry, by increasing its investment in state mines. To generate enough funding for investment, the government needs to reform its existing polices on such sectors as state-owned enterprises, financial markets and foreign investment. On the demand side, energy demand can be reduced by increasing the efficiency of consumption, particularly of heavy energy users, by rationalising the economic structure and by raising the scale of production of small firms.

8.2 Predicting the Size of the Deficit.

As mentioned in Chapter 1 and Chapter 2, China's energy production has increased less than its consumption, the energy sector has changed from a situation where production exceeds consumption to the one where consumption exceeds production. Due to the availability of data related to energy supply, this thesis focuses mainly on issues relating to energy demand management. To accomplish this task, it is necessary to forecast future energy demand. As a first step, the energy consumption behaviour of China is analysed. In contrast to previous studies, this analysis is based on cointegration and vector error-correction techniques because they can solve two econometric problems that were frequently encountered in earlier econometric studies. The first is spurious regression, which arises when variables that are driven by time trends may appear to be correlated in finite sample regression, even though there is no true relationship among them. The second concerns the fact that many explanatory variables in energy demand equation, such as income and price, are likely to be endogenous and so estimating energy demand by a single equation may produce simultaneous bias, producing unreliable forecasts.

In formulating a model suitable to China, it is found that not only such conventional variables as energy price and income are important but that also the share of heavy industry output in the national income plays a significant role. On the basis of a vector error-correction model, it was predicted that China will need approximately 1.42 billion tons of standard coal equivalent by the end of this century, representing a 44 per cent increase, as compared to 1990.

China is very different from other developed countries in that coal is the major energy source. Chapter 4, therefore, contains an analysis and forecast of the country's demand for coal as it moves toward the next century. To accomplish this task, three different methods have been applied to contrast their performances in fitting the Chinese data: Engle-Granger's type error correction model, Hendry's type error correction model and Hendry's general-to-specific approach. It was found that the Engle-Granger outperforms the other two approaches in terms of having the smallest ex-post forecast errors. By using the Engle-Granger methodology, the model predicts that the Chinese economy will experience a five per cent shortfall by the year 2000.

In summary, Chapter 3 and 4 highlight the need for an effective management policy in handling the country's largest energy sector, as China progresses toward the new century. The relevant polices have been mentioned in Chapter 2. Here, the analyses were mainly qualitative. In chapters 5, 6 and 7, however, energy pricing policies that might be used to narrow the imbalance were evaluated by quantitative means.

8.3 Evaluation of the Role of Government Energy Pricing Policies in China.

As mentioned in Chapter 2, it is believed that the low energy prices are one of the main causes of energy deficits. Since economic reform began in 1979, the Chinese government has reformed the under-pricing system and gradually increased energy prices. As revealed from western studies, however, the effects of higher pricing polices on the economy hinge on the substitution possibilities among energy inputs and other (non-energy) factors of production in response to price changes. A knowledge of the substitution possibilities is of paramount importance in the management of the energy sector. For instance, if capital and energy are substitute inputs, other factors being fixed, rising energy prices will encourage more rapid capital formation and induce more labour productivity.[1] Alternatively, if energy and capital are complements, the higher price for energy will tend to reduce the future rates of capital formation and so labour productivity will decline, reducing output growth. Hence, the third part of this thesis is to compute cross- and own- price elasticities of demand for all inputs.

In Chapter 5, after reviewing the literature on energy-capital relationships, it was found that the relationship has proved to be controversial, resulting in opposing energy pricing policies aimed at alleviating the imbalance. These controversies exist mainly because different estimation techniques are employed in the studies, such as functional forms and various dynamic specifications. It is believed, however, that the

[1] As mentioned in Chapter 5, this is only the short run effect. Over the long run, output will decrease ultimately if the capital inputs increase persistently. This is because the marginal product of capital will diminish if other factor inputs remain constant.

existence of rationing, a typical constraint in China, may provide an alternative explanation for the controversies. It was decided, therefore, to incorporate rationing behaviour in this study.

To examine the relationships among various factors, input demand functions were derived. In order to derive the input demand equations and the price elasticites, (i) the dual approach provides an easier method than the primal approach, (ii) the profit function has advantages over the cost function and (iii) the translog functional form is more appropriate than other functional forms. Therefore, the translog profit function by the dual approach has been employed to derive the input demand functions and the relevant elasticities. This method is particularly appropriate for use with China's data set of firms.

As the traditional translog profit function approach neglects the influence of rationing on the input demand functions and price elasticities, new formulae were developed for use in Chapter 6. The concepts of virtual pricing developed by Neary and Roberts(1980) and Squires(1994) were followed. This approach has the advantage over the auxiliary constraint approach, in that it allows the parameters of the constrained profit function to be recovered from the unconstrained profit function. Therefore, in this approach, it is not necessary to know ex ante whether there are input quantity restrictions upon output supply, factor demand, and profitability for a profit maximising producer. It is necessary only to estimate the traditional translog profit function and substitute the estimated parameters into the formulae derived from that function, which is incorporated into the virtual prices for the rationed input. Moreover, by comparing the formulae of the elasticities under and with no rationing, one can test which type of elasticities are more appropriate for use with the data.

In Chapter 7, I explained how to estimate the translog profit function and I discussed the econometric technique. From the empirical findings, it was found that a time varying approach is more appropriate than a time invariant approach. This finding verifies the fact that China has implemented sequential industrial reforms with respect to state owned enterprises and so caused continuous structural change over the estimation period.

Generally, the results are satisfactory. By substituting the estimates of the translog profit function into the formulae derived in Chapter 6, various elasticities can be calculated. By performing various tests, it was found that the elasticities under rationing are more appropriate than those under no rationing and many of them are significant at the 5 % significance level. Moreover, the empirical results suggest a complementarity between energy and capital and no significant relationship between energy and labour, over the estimation period.

When the future demand predicted in Chapter 3 is compared with the predicted energy supply obtained in Chapter 2 for the years 2000 and 2010, it can be concluded that energy deficits are likely to intensify. To remove the insufficiency, the government can balance future energy production with consumption by reducing energy demand. Based on the magnitudes of the calculated elasticites under rationing in 1988 and the forecasts of energy demand obtained from Chapters 2 and Chapter 3, in the short run, the government can implement four different policies to remove the energy shortfall in 2000 and 2010, i.e., either i) increase energy prices by 0.9463% and 0.649% or ii) decrease supply of materials by 1.332% and 0.013% or iii) reduce output price by 0.237% and 0.162% or iv) reduce the use of capital by 2.797% and 1.198%. Our empirical findings, however, show that except for policy (iv) with no effect on output in the short run, the other three policies will result in lower output growth rates. Conversely, as the relationship of energy and labour is insignificant, encouraging firms to employ labour intensive techniques will not be appropriate to reduce the energy deficits.

The government has to implement two instruments simultaneously, rather than use one instrument exclusively. If the government not only aims at reducing energy imbalance, but also wishes to maintain the average growth rate of SOEs at 2.8% and higher over 1985-88, it has to decrease the use of capital by over 40% which seems to be invalid. Alternatively, firms may increase energy prices by over 20% if they concurrently increase either output price, or the use of material inputs. As energy prices were held arbitrarily low before the price reform, there was some room for increasing prices at the outset. As reform has been continuous, however, the room for further increases is small. On the other hand, as mentioned above, a high energy pricing policy may no longer be effective, even if it is implemented with other policy instruments. Besides, it may cause spiral inflation and negative effects on balance of payments and foreign reserves.

Unless labour is changed to be a substitute for energy and there is a positive effect of labour on output. The adverse effects of increasing energy prices mentioned above, are inevitably harmful to China's economy as well as to the continuity of economic reform, especially when the country remains at the developing stage. Therefore, to manage possible energy deficits in future, China should not solely emphasise the adjustment of energy prices but also the implementation of various policies on both the supply and the demand sides of the energy sector. Those remedies have been stated in Chapter 2. Among them, the first priority may be the focus on improving the productivity of various input factors. However, their real effects on the energy sector is a subject that require further investigation.

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