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Dietary transformation during social development
A case study of China

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Declaration

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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Abstract

The observed fast increasing obesity rate and related health problems in urban China can be attributed to changing patterns of both diet and physical activity. This thesis focuses on the transformation of at-home dietary patterns and examines this against the background of concomitantly happening rapid social development. "Dietary pattern" is defined by six broad food groups. The three key aspects of social development discussed are the urbanisation process, the ageing population and supermarket revolution. "Community" is taken as the unit of analysis which is distinct from the extant studies that investigate individual, household or provincial level food choice. Thus, the impacts of both economic and social-transforming factors that underlie at-home diet decisions are examined through the food choice of communities. A Linearised Almost Ideal Demand System (LAIDS) model with a standard Tobit structure is adopted to capture the effects of social changes on at-home food choice, and Bayesian approach is followed in the estimation of the quantities of interest.

Based on the estimated results, the ageing population and supermarket penetration are projected to their potential levels in 2050 urban China to investigate the potential impacts of their changes on diet. Findings confirm the differences in food demand between city and town areas. Contrary to the extant evidence, population ageing exhibits a significant negative effect on expenditure share of grains and a significant positive effect on that of less-commonly-eaten animal products. Such inconsistency could result from the interaction term between senior proportion and dietary knowledge included in the estimated demand model and the differently defined food groups. Supermarket penetration does not necessarily increase the expenditure share on snacks and drinks, and this fact also tends to be in contrary to most extant findings. This indicates that supermarket penetration may be linked to an overall lifestyle shift trend which does not necessarily have to be "unhealthy" in terms of its diet component for the overall community. The scenarios of 2050 with projected levels of supermarket penetration and population ageing are augmented by dietary knowledge. Estimates from augmented scenarios confirm the potential health outcomes of diet knowledge on food choice. With the goal of promoting vegetable and fruit consumption and reducing oil and sugar intake in the context of 2050 urban China, the scenario of increasing the convenience of modernised wet markets relative to supermarkets plus improving dietary knowledge could be the optimal choice.

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Abbreviations

AES	Adult Equivalent Scale
AIDS	Almost Ideal Demand System
BMI	Body Mass Index
CCDCP	China Centre for Disease Control and Prevention
CFCT	China Food Composition Table
CHNS	China Health and Nutrition Survey
CNNS	China National Nutrition Survey
CPI	Consumer Price Index
DK	Dietary Knowledge
FDI	Foreign Direct Investment
HPD	Highest Posterior Density
HPS	Health-Promoting Schools
LAIDS	Linearised Almost Ideal Demand System
LES	Linear Expenditure System
MCMC	Markov Chain Monte Carlo
MH	Metropolis-Hastings
NBS	National Bureau of Statistics of China
NCD	Non-communicable Disease
QAIDS	Quadratic Almost Ideal Demand System
SUR	Seemingly Unrelated Regression
WHO	World Health Organisation

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Chapter 1

Background

1.1 Obesity prevalence in China

The issue of overweight and obesity has become increasingly important across the globe over the past three decades. According to the World Health Organisation (WHO), the number of obese people worldwide has doubled since 1980 (World Health Organisation (WHO), 2016). In 2014 among the adults aged 18 and over, 39% were overweight (more than 1.9 billion) and 13% obese (more than 600 million). The situation for children globally is also not optimistic with the estimated number of overweight or obese children under the age of five being 41 million in 2014. It is stated that after centuries of struggling against food scarcity, around the year 2000 for the first time in human evolution, there were more adults who were overweight than underweight (Mendez et al., 2005; Caballero, 2007).

As the most populous developing country that has undergone profound economic and social transformations over the past three decades, China vividly depicts the rapid development of the obesity pandemic. According to the nationally representative China National Nutrition Surveys (CNNS) conducted in 1982, 1992 and 2002 and the latest 2010-2013 National Nutrition and Health Surveillance, obesity started to emerge during the period from 1982 to 1992. Referring to the WHO body mass index (BMI) cut-off points, in 1982, 5.4 percent of adults in China were overweight and 0.1 percent obese. These figures rose to 14.4 percent and 1.4 percent in 1992, and then increased to 18.9 and 2.9 in 2002 (Du et al., 2014), which was followed by a further increase to 27.1 percent and 5.2 percent during 2010 and 2012 (Fang et al., 2015). That is to say the number of people who were overweight combined with obese grew by 191 percent from 1982 to 1992, by 38 percent from 1992 to 2002, and by 48.2% from 2002 to around 2012. Some studies stated that much of this weight gaining actually began during 1989 and 1991 (e.g. Popkin et al., 1995). Local, regional and provincial level data after 2002 have also found continuing and drastic increase in obesity prevalence (e.g. Wang et al., 2007; Gordon-Larsen et al., 2014).

The increase in the obesity rate is leading to deteriorative obesity-related health problems in China. Since the 1990s, the burden of diseases in China has shifted from communicable to non-communicable diseases (NCDs) such as cardiovascular diseases, lung cancer, chronic obstructive pulmonary disease and chronic disabilities (Liu et al., 2013). Many of these NCDs can be directly or indirectly linked to obesity and modifiable risky behaviours, among which the most influential include low quality diet (inadequate intake of fruit, whole grains, nuts and seeds, and excessive intake of sodium), smoking, immoderate drinking and physical inactivity (Wang et al., 2007; Yang et al., 2013). It has been pointed out that the obesity pandemic has posed and will continue to pose a significant burden to China's national health care system (e.g. Popkin, 2008; Zhao et al., 2008; Gordon-Larsen et al., 2014). Specifically, the economic costs of major NCDs associated with being overweight and with obesity have found to be increasing every year, and it is estimated that in 2010 these costs accounted for 4.5% of the total national health expenditure (Zhang et al., 2013). Therefore, understanding the underlying factors contributing to the obesity phenomenon is of crucial importance in order to address obesity-related health problems in China.

Such increases in the obesity rate over the past thirty years are mainly because of changes in dietary patterns and the concurrent changing physical activity patterns (Ng et al., 2012, 2014). The sustained positive energy balance and the observations of both declining calorie intake and energy expenditure from 1990s indicate that decrease in energy expenditure could be more substantial than that of calorie intake among the Chinese population. It is mentioned in much literature that the declining per capita calorie intake could be partly explained by the relatively large-scale reduction in energy requirement of daily activities which could lead to decreasing energy expenditure (Zhong et al., 2012). In an attempt to gauge the relative importance of shifting dietary and physical activity patterns to the energy imbalance among the adult Chinese males, it has been estimated that physical activity roughly accounts for 6 percent of weight gain while nutritional decisions account for about 3 percent from 1991 to 2006 (Ng et al., 2012). Nonetheless, due to its significant and potential impacts on short-term energy imbalance and hence long-term weight gain which may be associated with other potential health risks, changes in diet structure among the Chinese population over the past two decades warrant careful consideration.

1.2 Nutrition transition in China

Changes in diet structure can be delineated within the conceptual framework of nutrition transition. The concept of nutrition transition provides a chronological framework for understanding long-term nutritional development. Five typical stages of nutrition transition have been identified, and these are commonly accompanied by simultaneous transitions in demographics and epidemiology (Popkin, 1993; Lee, 2003; Omran, 2005). The first stage is characterised by *food collection and a Palaeolithic diet* which is high in carbohydrates including fibre but low in fat. The second stage *famine* features the emergence of modern agriculture and enlarged disparities in nutritional status by gender and wealth. The third pattern *receding famine* is the stage where hunger and famine are alleviated and the importance of fruits, vegetables and animal-based foods increases but that of starchy staples decreases, whilst the variety of foods remains constrained. The following pattern features an increased intake of refined carbohydrates including sugar along with total fat and cholesterol, which is normally accompanied by changing lifestyles and shifting physical activity patterns. This stage also witnesses the emergence of nutrition-related *non-communicable diseases* such as obesity and cardio-metabolic diseases. The last stage is the period of health-related *behavioural change* during which awareness of the need to eat healthier is evoked and the desire for an extended life with delayed incidence of chronic and degenerative diseases leads to a further shift in food choice (Carolina Population Center (CPC), The University of North Carolina at Chapel Hill (UNC), 2016).

The patterns of nutrition transition that are of much interest are stages three to five (Popkin, 2003). In low- and middle-income countries the situations of nutrition transition vary depending on the specific conditions of the country under investigation (e.g. Popkin, 2002a). Nonetheless, compared with the experience of nutrition transition from high-income countries, nutrition development in the developing world shares some similarities (e.g. Popkin, 2002b, 2004; Popkin et al., 2012), which can be summarised as: (1) the transition, accelerated by the concomitantly happening economic, technological and social transformations, is rapid; (2) such rapid shifts in dietary patterns towards one leading to nutrition-related non-communicable diseases are occurring at the early stage of economic development; (3) coexistence of over- and under-nutrition is found within one country and within one household (Caballero, 2005; Doak et al., 2005; Roemling and Qaim, 2013).

Looking at diet transformation in the developing world over the past three decades, two separate stages during this process have been identified, i.e. "income-induced diet diversification" and "diet globalisation and westernisation" (Pingali, 2007, p. 282). The first phase is mainly driven by a sharp increase in income brought on by fast economic growth, and the changes in diet feature an absolute increase in consumption quantity across a wide range of traditional food categories as they become progressively affordable to an increasing proportion of population (Drewnowski and Popkin, 1997). However, the traditional attributes of diet persist (Pingali, 2007). As income further increases, people migrate from rural to urban areas and trade liberalisation and global integration progress, and local dietary habits start to deviate from the traditional food choices that have been developed in the region across generations (Mendez and Popkin, 2004). During this phase, the local dietary pattern which is commonly predominated by staples and plant-based foods shifts towards a more "western" style that is high in animal-sourced foods and partially hydrogenated fats but low in fibre (Popkin, 2006). Specific to the situation of the low- and middle-income countries in Asia, it has been observed that the traditional Asian diet which emphasises carbohydrates and is rich in legumes and vegetables and low in fat has been undergoing a change towards one with an increasing proportion of its energy sourcing from fats, animal-based foods and ultra-processed foods that abound in added sugars, highly-processed grains and saturated and trans-fats (e.g., Popkin et al., 2012; Baker and Friel, 2014). These broadly defined two stages of diet transformation have been observed in the world's two most populous counties, India and China, over the past three to four decades (e.g. Ramachandran, 2011; Smith, 2013; Du et al., 2014; Popkin, 2014).

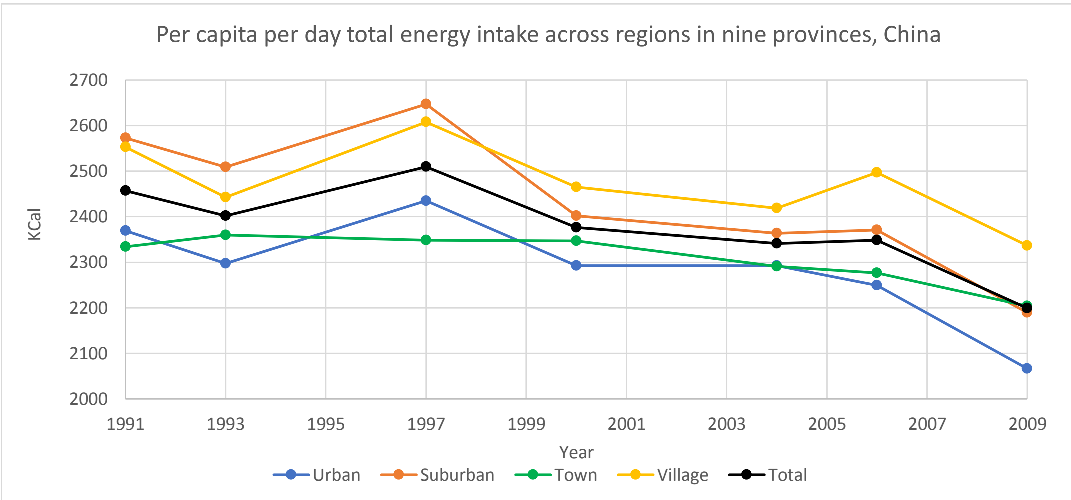
Taking a closer look at nutrition transition in China from the second half of the 20th century, it can be suggested that China has experienced all five nutrition transition phases according to evidence from nationally representative data collected by the National Bureau of Statistics of China (NBS) in Household Survey and China National Nutrition Survey (Du et al., 2014). After having experienced the stage of receding famine between 1962 and 1978, substantial shifts in dietary patterns among the Chinese were accompanied by dramatic economic and social transformations from 1978 during which time a series of economic reforms were formally initiated (Du et al., 2004). From the mid-1980s food production and supply were gradually liberalised and in 1993 the food rationing system in urban areas was fully abolished. These reforms facilitated a large increase in agricultural output and also stimulated further demand for food (Huang and Rozelle, 1998).

Correspondingly, energy intake per capita peaked between the mid 1980s and the beginning of the 1990s and then its slight decrease was accompanied by shifts in dietary patterns towards one with more animal-source foods, vegetable oils and processed foods (Wang et al., 1993; Meng et al., 2009). Putting it into a more general framework of a two-stage nutrition transition as summarised by Pingali (2007), around 1990 could be the dividing crest of these two stages in China. Noticeably, this kind of dietary transformation has been observed happening at a different pace depending on the economic status of an area within the country. In general, the overall trend of the spread of such phenomenon is from the urban population to the rural population and from coastal cities which experience economic development earlier and faster to inland regions (e.g. Ma and Xu, 1999; Li, 2007a; Hu and Zhou, 2015).

The implications of this transforming dietary pattern for nutritional status among the Chinese population from the 1990s can be seen by viewing the trends of change in macronutrients composition. Macronutrients are considered to be the nutrients that function as major energy sources (Chinese Nutrition Association, 2013). The pattern of changing macronutrients composition from 1990s is evidenced by various data sets. The national-wide observation is that per capita total calorie intake has experienced a decreasing trend with the percentage of calorie sourced from carbohydrates declining while that from fats is increasing and that from protein staying relatively stable over the two decades from the 1990s. Following the urban-rural dichotomous classification adopted by NBS, there are differences in the nutrition development between these two areas. In terms of per capita calorie intake, the 1990s, for rural areas, still witnessed a slight increase which is in contrast to the situation in urban areas. From the 2000s such divergence becomes increasingly smaller between these two areas. For the composition of calories, fats have been playing a much more important role for the urban households than for their rural counterparts. Evidence from data collected in nine provinces in China presented in Figure 1.1, 1.2, 1.3 and 1.4 roughly illustrates the trends summarised above. (Table of data used in these four figures is documented in Appendix A.) Instead of utilising the dichotomous definition of urban/rural area, "urban" is further divided into urban and suburban areas and "rural" includes towns and rural villages in these figures. Apart from the most general trend described above, it can be seen that rural villages tend to lag behind in time with other regions, and thus the gradual transition from the most urbanised "urban area" to the least urbanised "rural villages" can be observed (Zhai et al., 2014). Nationally representative data sets including China Nutrition and Health Survey conducted in 1982, 1992 and 2002 (e.g Zhai et al., 2005) and Urban and Rural Household Survey collected annually by the NBS also support such general observations (e.g. Li, 2007b, Section 4.3).

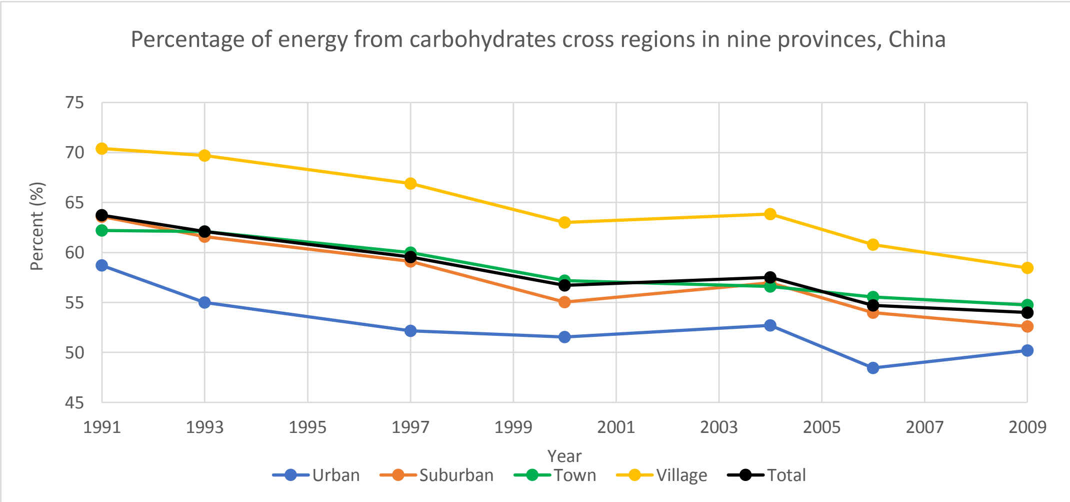
Examining the trend from 2004, these four figures demonstrate that nutrition transition in urban cities tends to be more advanced than other areas in the sense that their dietary energy sourced from protein is substantially higher than that of other regions, while their energy from carbohydrates is much lower than that of the other three regions. In contrast, rural villages constantly have the highest proportion of energy from carbohydrates and the least proportion of energy from protein. Suburban and town areas appear to share a similar level of their dietary energy composition. Moreover, from 2004, it can be seen that differences in energy sourced from carbohydrates, protein and fat between city and suburban areas tend to be smaller than that between city and town areas, which may signify the convergence of food preference between cities and their suburban areas.

Figure 1.1: Total calorie intake by regions: 1991 to 2009



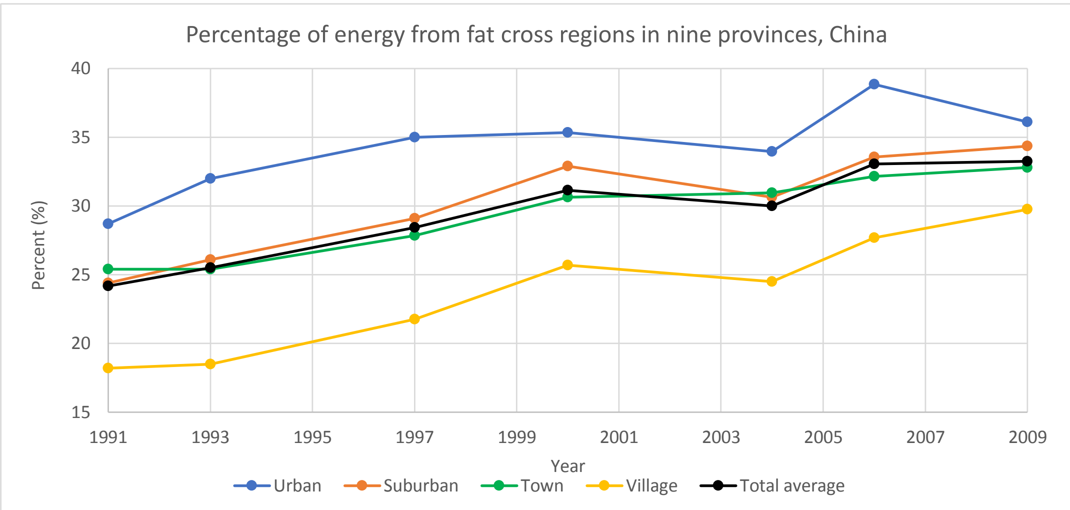
Source: China Health and Nutrition Survey

Figure 1.2: Energy from carbohydrates by regions: 1991 to 2009



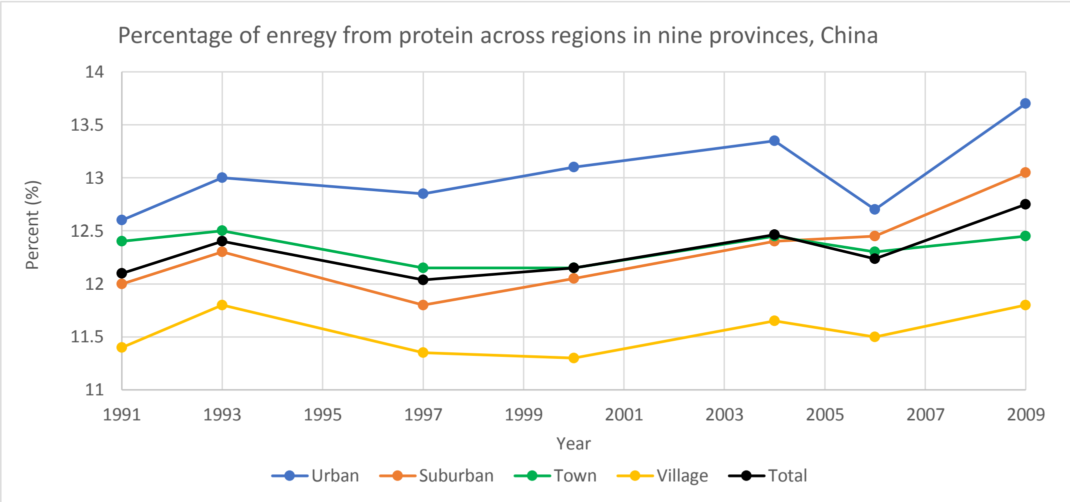
Source: China Health and Nutrition Survey

Figure 1.3: Energy from fat by regions: 1991 to 2009



Source: China Health and Nutrition Survey

Figure 1.4: Energy from protein by regions: 1991 to 2009



Source: China Health and Nutrition Survey

1.3 Driving forces for dietary transformation

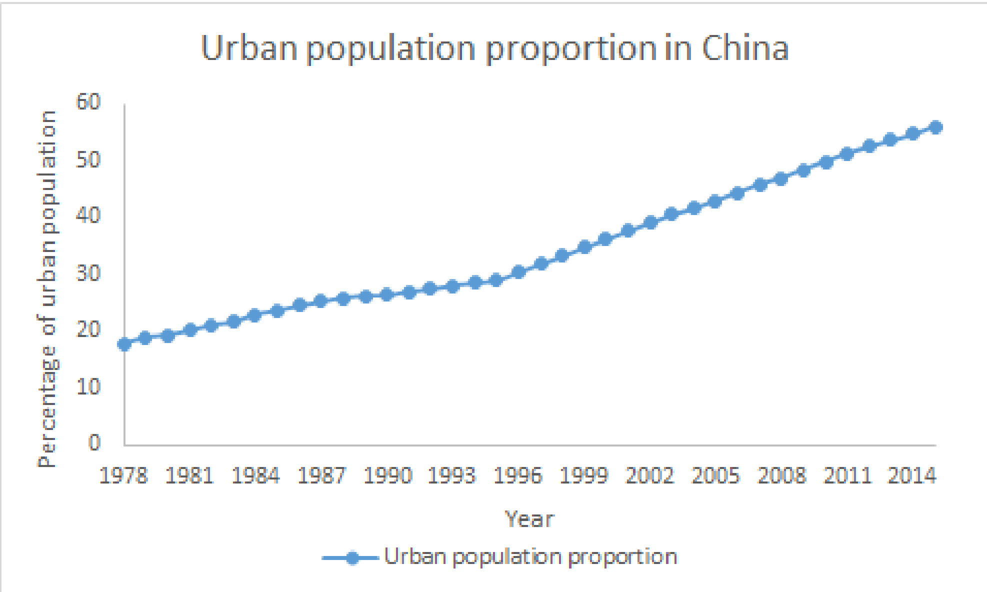
Such noticeable nutrition transition in China needs to be viewed in the context of the fast changing social environment. A rapidly changing social environment features increased urbanicity levels of neighbourhoods and changes in food environment that can directly affect food purchasing behaviour. Meanwhile, increased income, enhanced education and shifting age structures at population level that are linked to changing lifestyles can also lead to shifting food preference and food choice.

Viewing dietary transformation at population level, urbanisation process, population ageing and supermarket penetration are identified as key social development factors. This section introduces these three key aspects of social development as well as the possible driving factors income and education level in China.

1.3.1 Urbanisation process

Urbanisation can impact health through changing lifestyles. In general terms, the concept of "urbanisation" refers to the gradual increase in the proportion of a population living in areas classified as urban (Dyson, 2011), which is often in parallel with "changes in size, density, and heterogeneity of cities" and shifts in society from a rural lifestyle to an urban lifestyle (Popkin, 1999; Vlahov and Galea, 2002, p. S1&4). Changing dietary and physical activity patterns are among the many aspects of changing lifestyle that rapid urbanising progress can bring to people's lives and influence health. China has been undergoing urbanisation at a varying pace since economic reform started in 1978. Specifically, 1978 to 1995 has been identified as a period of stable development and 1996 to 2002 as a period of rapid development (Zheng and Guo, 2015). This trend, as measured by the proportion of urban population at national level, is demonstrated in Figure 1.5. Following the measurement taken by China NBS, the urban population is composed of all people residing in cities and towns. It can be seen from Figure 1.5 that 1996 can be the division year of the urbanisation process, after which growth rate has been at a higher level than before 1996. To be more specific, during the stable development stage between 1978 and 1995 the urban population proportion increased from 17.92% to 29.04% at an average annual rate of change 0.62%; in comparison, from 1996 to 2015 the urban population proportion increased from 30.48% to 56.1% at the average annual rate of 1.28%. In addition, 2011 appears to be the year when the urban population (51.27%) first outnumbered its rural counterparts. Such substantial changes underlie a shift in job patterns from labour intensive agricultural work to more sedentary occupations (Monda et al., 2007) along with nutrition transition towards "western-style" diet that is richer in fat content and processed foods compared with more "traditional" foods (Popkin, 2003).

Figure 1.5: Fast urbanisation in China



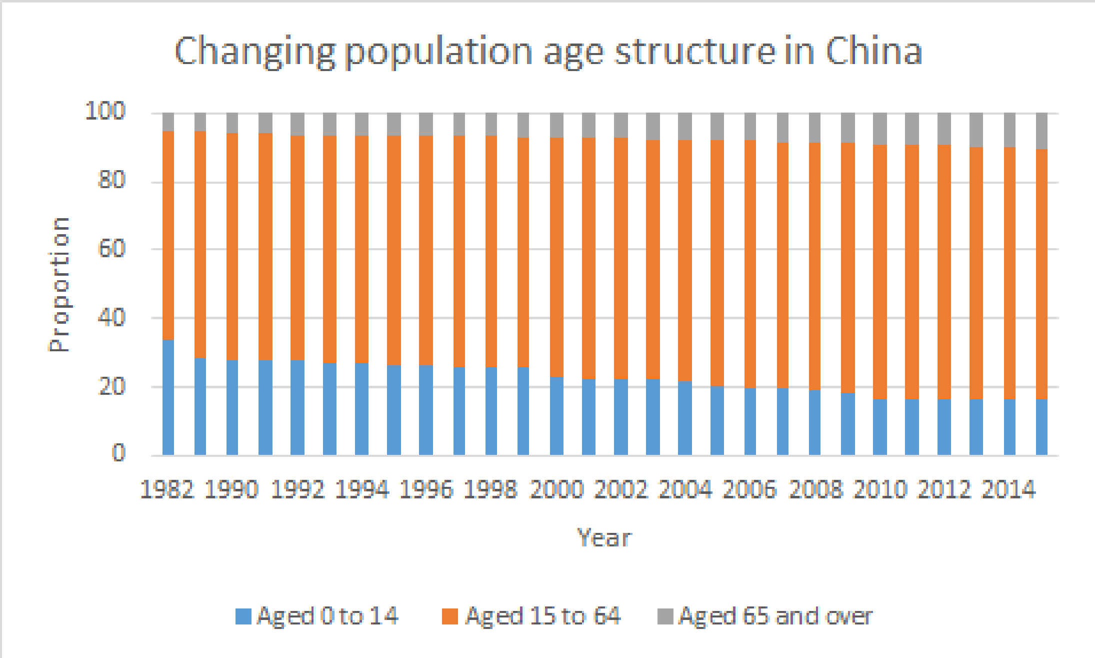
Source: China Statistical Yearbook of various years

A feature of this urbanisation process in China is the prominent role played by the central government which regularly promulgates urbanisation policies in the national "Five Year Plans" (Fang, 2009; Yeh et al., 2011; Chen et al., 2016). Urbanisation policies in the two decades following the incident of economic reform in 1978 put the emphasis on controlling the scale of large cities, facilitating moderate development of medium-sized cities and encouraging the growth of small cities. From the 1990s, the rapid economic development in coastal cities which specialised in labour-intensive manufacturing and construction sectors has attracted a large number of rural migrant workers moving from rural agricultural areas to these cities for higher earnings. The large-scale rural-urban migration in part motivated the adjustment of the urbanisation policy in the twenty-first century. In the 2001-2005 Tenth Five Year Plan, "town-based urbanisation" is articulated. There are three critical aspects pertaining to the "town-based urbanisation". First, for the rural residents that permanently settle in urban towns within their counties, their agricultural *hukou* can be converted to a non-agricultural *hukou*. This means that households registered as agricultural under the household registration system, i.e. the *hukou* system, which was formally launched in 1958 and was strictly enforced from 1960s (Chan and Buckingham, 2008), can choose to convert to non-agricultural *hukou*. Second, farmers are allowed to permanently sell off their farming rights to other farmers with the aim of achieving economies of scale in agricultural production. Third, agricultural land is implicitly approved to be converted to town construction land to promote the industrialisation in towns (e.g. as industrial parks in towns). As a result, the redevelopment of outer urban and suburban areas has been greatly facilitated during this period of time. For instance, non-agricultural *hukou* was abolished in Jiangsu province since 2003 because of the blur in the function of urban and suburban areas (Yangtse Evening Post, 2002). From 2006 in the Eleventh Five Year Plan, national urbanisation policy has started to focus on a "balanced development" between cities and towns, regardless of their size, as the importance of the contribution of large cities to long-term economic development has been made explicit. Thus, promoting the concomitant development of cities and their suburban areas has become the emphasized strategy. For instance, selected suburban and town areas around Beijing, Shanghai and Chongqing are now planned to be developed into the satellite cities or functional areas for these three metropolises (Liu et al., 2005; Song and Zhu, 2013; Zhen, 2015). The next stage of the urbanisation policy demonstrates a divergent focus from land-centred urbanisation to people-oriented urbanisation which is unveiled in the National New Urbanisation Plan (2014-2020). In 2011, urban population has exceeded its rural counterparts, and it is forecast that the urbanisation process in China will further progress but at a slower pace until the urbanisation rate reaches 70% (Yong, 2011). It is projected that in 2020 the urbanisation rate measured by city and town residency to be around 60%, and by 2030 a 70% urbanisation rate might be achieved (Jian and Huang, 2010). Projecting to 2050, 80% of China's population might be urban residents (Gao and Wei, 2013).

1.3.2 Changing age structure

Another critical factor that may affect food consumption is age: at household level age can be measured by that of household head or the age structure of the entire household; at population level age structure of a population can be defined. At household level, age may be related to varied food consumption habits, that is, household with more seniors may consume less fruits and more grains; existence of children indicates increasing consumption of dairy products; and those households with older household heads may follow a more "traditional" diet (e.g. Liu and Chern, 2003; Zheng and Henneberry, 2009). At population level, a larger proportion of seniors implies lower calorie requirements and therefore lower per capita energy intake (Zhong et al., 2012; Nie and Sousa-Poza, 2016). Figure 1.6, drawing on data from NBS, demonstrates the changing age structure at national level from the 1980s in China. It can be seen that the proportion of children aged 14 and below has been experiencing constant decline from the 1980s whilst that of those aged 65 and over has been continuously growing. Since it is expected that people of different ages are likely to demand varied composition of foods, examining the potential impact of the rapid ageing population on food consumption will facilitate the understanding of transforming dietary patterns in China.

Figure 1.6: Population ageing in China



Source: China Statistical Yearbook of various years

Figure 1.6 illustrates that in parallel with the massive urbanisation process happening in China, the Chinese population is also undergoing a shift towards an ageing society. There are two key factors underlying this demographic trend (Smith et al., 2014; Li and Lin, 2016). The first one is the significantly increased life expectancy. In 1980 the national average life expectancy was 69 whereas by 2010 it had increased to 74.8 as the overall living standards and the accessibility to medical treatments had improved. It is projected that the average life expectancy in 2030 may reach 77.8 and in 2050 it will be 80.2 (Zheng et al., 2014). Meanwhile, the fertility rate has been reducing partly due to the "one-child policy" and partly due to a spontaneous decline as the economy has grown. However, the speed of the decline to below the replacement level fertility in China has also been rapid. From earlier in the 1990s, the estimated birth rate in China dropped below 2 births per woman and in the following two decades it has been fluctuating between 1.3 and 1.5 (Guo, 2012) births per woman. Such low birth rates along with increasing life expectancy have led to shifts in the population structure, and an ageing population in China is widely agreed to be unavoidable in the twenty-first century. According to China's national population census conducted in 2010, those 60 years old and over accounted for 13.3% of the entire population. It is projected that by 2030 the proportion of those aged 65 and above will constitute

16.3% of the entire population and by 2050 the number could reach 23.2% (Du et al., 2005). The current stage of population ageing in China demonstrates a difference between the proportion of ageing population in urban and rural areas, that is, the rural population tends to be composed of a higher proportion of the elderly (those aged 60 or 65 above) compared with the urban population. Such divergence may have been triggered by large-scale rural-urban migration and the difference is expected to experience further increase but will even out eventually until more urbanised areas have higher level of aged population (e.g. Zheng et al., 2014). It is projected that around the year 2040 the proportion of the elderly in urban China will catch up with that of rural China at approximately 24%, after which year urban areas will have a higher level of aged population than rural areas (Du and Wang, 2010). The percentages of ageing population in urban China in 2050 is predicted to be about 28%, which could be substantially higher than that of rural China at around 20% (Du and Wang, 2010).

1.3.3 "Supermarket revolution"

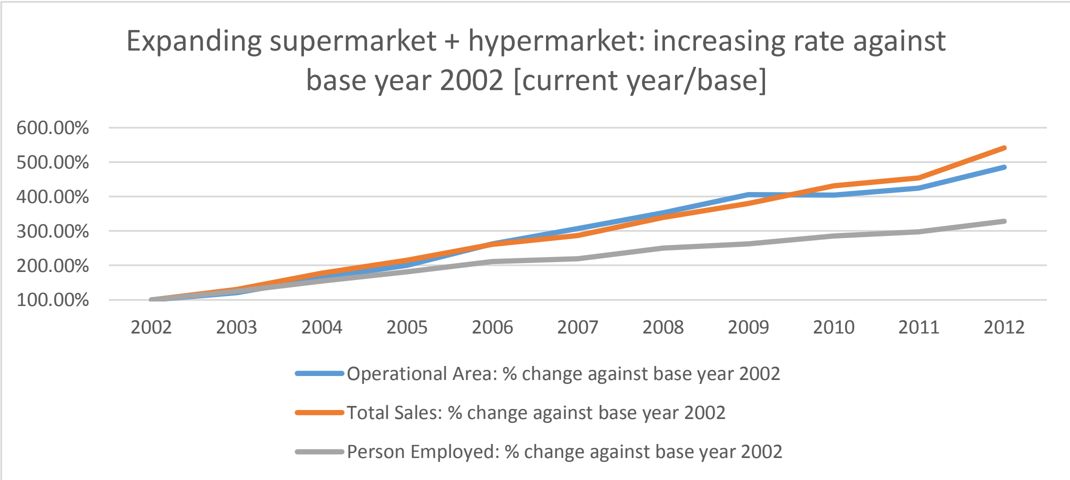
Rapid economic growth and the urbanisation process in China and other developing countries create necessary conditions for the evolution of the food environment. One manifest phenomenon that has been observed during this transformation of the food environment is the emergence of new food retail formats, that is, the proliferation of modern retailers including supermarkets, hypermarkets and chained convenience stores from the 1990s, which is the so called "supermarket revolution" in developing countries (Reardon et al., 2003; Hawkes, 2008). Before the inception of these "new" formats of food retailers, "traditional" formats that had been dominating food retail outlet and shared by most developing areas were wet markets, hawkers, small-scale stores and government-run stores (Reardon, 2011). This section describes the general process of supermarket penetration in developing countries and discusses consumer food choice when modern food outlets coexist with traditional food markets.

Hereinafter, the word *"supermarkets"* is utilised as an equivalent to *modern food retail outlets* and *"fresh markets"* is used interchangeably with *traditional food retailers* when the specific types of markets do not need to be distinguished.

On the premise of economic growth and the progressive urbanisation of the population, the fast diffusion of supermarkets in low- and middle-income countries has been facilitated by two concurrent factors (Reardon et al., 2003). First, from the 1990s foreign direct investment (FDI) from richer countries and regions into emerging economies has soared as many developing countries gradually and systematically reduce the barriers to trade and FDI. The liberalisation in the retail sector has significantly accelerated the evolution of food systems that had been dominated by state-controlled food companies before the 1990s (Reardon and Swinnen, 2004). During this period of time, the revolution and adoption of technologies such as the internet, computers, barcodes and radio-frequency identification (RFID) have substantially increased the efficiency of practices in procurement logistics and inventory management of those modern large-scale retailers, and these features have therefore enhanced their competitiveness against traditional retailers (Kumar et al., 2009; Basker, 2012). This ceaseless flow of FDI and enhanced technologies underlay the take-off and further prompt expansion of supermarkets in the developing world during the following decades.

Different developing countries have experienced the supermarket revolution from the 1990s at different paces; specifically, three waves have been identified (Reardon and Gulati, 2008b). The first one started in the early 1990s, covering countries/regions in much of South America, East Asia (excluding China) and South Africa, and saw a growth in the supermarket share of food retail from 10 percent to around 50-60 percent from 1990s to the mid-2000s. The second wave started in the last half of the 1990s in countries/regions including Mexico, Central America, and much of Southeast Asia, where supermarket share in food retail sales grew from 5-10 percent in 1990 to 30-50 percent by the mid-2000. Comparatively, the third wave happened in the late 1990s and early 2000s across countries represented by China, India and Vietnam, with supermarket sales starting from a niche in the early 1990s and growing at a rate of 30-50 percent every year until it reached 2-20 percent by the mid-2000s. The fast expanding supermarket and hypermarket sector in China is shown in Figure 1.7.

Figure 1.7: Supermarekts' increasing rates



Source: China Statistical Yearbook of various years

In spite of the substantial increase in food share from modern food retailers as the result of this supermarket revolution, in developing countries a significant proportion of foods are still purchased from traditional fresh markets. Such a phenomenon is prevalent especially in regions of Asia, be it in developed or less-developed areas (e.g. Goldman et al., 1999; Maruyama and Wu, 2014; Huang et al., 2015; Kelly et al., 2015). The following paragraphs will briefly review the situation of food retail formats in China and the Chinese consumers' overall preference for different types of food outlets.

Specific to the Chinese context, modern retail formats represented by chained convenience stores, supermarkets and hypermarkets are differentiated by floor space: a convenience store is normally less than $200m^2$; a small supermarket between $800 - 999m^2$; a normal supermarket has $2000 - 5999m^2$; and a hypermarket is usually more than $6000m^2$ (Hu et al., 2004). According to the definition in "Classification of Retail Formats" published by the National Standard of China, a normal convenience store has a merchandise assortment of fast foods and small consumer goods; a supermarket usually sells packaged and fresh foods and household daily goods, and can be differentiated from a grocery supermarket and a general supermarket; the characteristic of a hypermarket is that it sells a complete assortment of clothing, foods and household goods, and often serves as the place of one-stop shopping (Wang, 2011). Comparatively, traditional food retailers usually refer to fresh markets, hawkers and local small food stores (Reardon, 2011; Zhang and Pan, 2013).

Two characteristics of the shopping behaviour of the broad food category among the Chinese have been identified, which include high purchasing frequency of and short travel distance for daily food groceries. Such features have been found consistent over income strata (Wu et al., 2001), over age groups (Wang et al., 2015b) and across regions of various economic development levels (e.g. Chen and Feng, 2009; Li and He, 2010; Han and Song, 2013). At a more disaggregated food category level, studies investigating choice of retail format consistently conclude that consumers in China tend to purchase different types of foods at different food outlets. To be specific, staple grains, processed foods (such as powdered milk, snacks and cooking oils), dairy products and frozen foods are very likely to be purchased from supermarkets, whilst traditional fresh markets still play a dominant role in meat, fruit and vegetable shopping (e.g. Hu et al., 2004; Fuller et al., 2006; Bai et al., 2008a). The divergence in food format choice could be explained by the consumers' perception of the advantages and disadvantages of each type of food outlets (e.g. Veeck and Veeck, 2000; Zhou et al., 2003; He et al., 2005; Ortega et al., 2015). To summarise briefly, supermarket foods are generally believed to be safer, more hygienic and of better quality. The diversity and variety of foods offered by supermarkets are also highly valued by consumers. However, supermarket food prices are usually commented on as being too expensive and the freshness of their vegetables and fruits are often marked as a downside. In contrast, traditional fresh markets are highly rated for the freshness of their fruits and vegetables. Moreover, location convenience and the cheap prices of fresh markets are attractive to consumers. In addition, some studies found that consumers may patronise fresh markets for socialising with other consumers and vendor owners. The negative aspects of fresh markets which are always mentioned include their potential food safety risks and their limited operating hours.

Such divergence in food outlet choice may contribute to the difficulty in supermarket penetration across some food products in China, as has been observed in the stagnating food share sourced from supermarkets compared with traditional wet markets in much more developed Asian region like Hong Kong (Goldman et al., 1999, 2002). Going back to the theory of three levels of supermarket penetration during the retail revolution (detailed description of this theory can be found in section 2.1.3), it might be possible for supermarkets to achieve a relatively complete penetration across socio-economic strata and across geographical regions; however penetration over food products may be much more challenging. On the one hand, the replacement of traditional food retailers by modern food retailers as the main source of highly-processed and packaged foods appears to be evident. On the other hand, in the absence of accurate supermarket food sales data, it is estimated that in 2004 no more than 15% of total vegetables in Beijing were sold through supermarkets (Wang et al., 2009). Similarly, another study suggests that in 2009 only 16.7% of total food retail sales in China were from the supermarket sector (Datamonitor, 2010 cited in Zhang and Pan, 2013). Therefore, the roles of traditional markets as well as modern markets need to be viewed as one entity in order to depict a complete picture of shifting patronage behaviour in the context of the transforming food environment.

Apart from the natural evolution of the food retail sector and consumers' food shopping habits, the role of policy environment in the transforming food environment cannot be overlooked in the Chinese context.

The food retail market, in particular that of fresh produce, has been dominated by wet markets in urban China from the 1980s. After twenty years of development and dominance, the traditional wet market format is now being criticised for the disorganisation of its stores, the poor hygiene standards of their shopping environment and the potential food safety risks due to the intractability of food sources sold by small vendors prevalent in wet markets. In 2002, the government started to formally promote modern supermarkets to sell foods, especially fresh produce, in place of traditional wet markets. A programme aiming at converting traditional fresh markets to modern supermarkets ("Nong Gai Chao" in Chinese) was initiated by the government in 2002. The original objective of this programme was to encourage large enterprises to invest in upgrading traditional wet markets to fresh food supermarkets which would be managed under the modern supermarket business mode that sells standardised fresh produce in a hygienic environment. For instance, the municipal government of Fuzhou introduced the large retailer Shanghai Hualian and assisted the local retailer Yonghui to develop fresh food supermarket chains especially in the establishment of their own fresh food production bases. Thus, the municipal government expected that the procurement process of fresh produce from farmland to food retailers to be simplified by these means. By 2013, 84 traditional wet markets in Fuzhou had been transformed into fresh food supermarkets (Fuzhou Daily, 2013).

However, not all of the attempts to convert wet markets to food supermarkets since 2002 have generated sufficient profits to sustain the businesses in the "modern" mode. Several limitations of the business mode of modern supermarkets in fresh produce retail market have been identified (e.g. Deng et al., 2005; He et al., 2007; Li et al., 2011b; Wang et al., 2015a). First, corporate farms tend to have higher production costs compared with household farmers; second, large-scale producers of fresh produce normally specialise in fewer types of agricultural products, which means that to maintain variety a significant proportion of the fresh produce offered by supermarkets is still sourced from traditional fresh food wholesale markets which is no different to the food source of small vendors in traditional wet markets; third, the vertical integration of production, wholesaling and retailing might have relatively limited potential compared with the government's expectation since most of the fresh vegetables and fruits are still produced by small-scale household farms and there is a relatively low level of participation of these household farms in the co-operatives. Instead of adopting the strategy of transforming traditional wet markets to a modern supermarket chain business mode, some cities have decided to invest in upgrading the existing wet markets to a modernised format in a way that means that small vendors are maintained while the transaction venue is redeveloped into and managed in a "supermarket style" (e.g. Gu, 2015). Similarly, some wet traditional fresh markets are upgraded for their facilities and meanwhile enhanced by relatively small food supermarkets inside the upgraded venue ("Nong Jia Chao" in Chinese). Compared with completely replacing traditional wet markets with modern chained supermarkets specialising in food selling, the business mode of combining traditional wet markets and modern supermarkets appears to be more economically viable and feasible (Ding and Cao, 2003). The transformation of old-style wet markets to modern style wet markets has ensured the wet market's survival in cities like Tianjin and Huzhou (Zhejiang Administration for Industry and Commerce, 2015; Municipal Commission of Commerce, Tianjin, 2016). In the long run, it could be expected that traditional wet markets will be gradually replaced by upgraded wet markets with a "supermarket style", by specialised fresh food supermarkets and by general supermarkets with a rising proportion of floor space allocated to fresh produce.

1.3.4 Consumer-side drivers

Two consumer-side factors, income level and educational attainment, have been extensively discussed in the literature as the potential forces driving dietary transformation at both household level and more aggregated population level.

Most evidently, fast increasing income may well lead to shifting preferences for particular food types and food preparation methods (Popkin, 1998, 2003). To be specific, starting from a relatively low level of food consumption, as people become increasingly affluent their diet becomes more diversified; meanwhile, led by human beings' natural physiological tendencies, it is expected that such diet will be associated with a dietary pattern richer in fats, sugars and energy-dense foods (Drewnowski, 2000; Drewnowski and Levine, 2003). At the same time, concomitant with the growth in wage rate time cost increases, which tends to stimulate the need for time-saving cooking methods and for convenience in meal preparation (Darius et al., 2005). This induces an increasing demand for packaged and highly-processed foods and foods consumed away from home. Findings from papers investigating nutrition transition in China from the 1990s conform to these descriptions (e.g., Guo et al., 2000; Popkin, 2002b; Du et al., 2004).

Much less evident is the confusing relationship between education level and food choice. On the one hand, some studies found that higher educational attainment may enable people to be more aware of their diet and be more responsive to nutritional messages (e.g. Yang et al., 1998; Ruel et al., 2005; Lin and Yen, 2008; Meng et al., 2009). On the other hand, some studies do not find education to have a significant effect on food choice (e.g. Huang and Rozelle, 1998; Jiang and Davis, 2007). Moreover, impacts of the education level of the female household head and the male on household food choice may be different (Bhandari and Smith, 2000; Rashid et al., 2011). Nonetheless, a positive relationship between education level and consumption of "western" style foods and fruits seems to commonly confirmed in the Chinese population (e.g. Bhandari and Smith, 2000; Liao et al., 2007; Wang et al., 2012). Comparable to the measurement of general educational attainment, the impact of diet and nutrition knowledge on food consumption has also been examined. Similar to the situation of education, effects of dietary knowledge on nutritional status are not clear-cut. It has been found that dietary knowledge has a significant positive effect on the consumption of micronutrients-rich foods (Block, 2004); however it has also been found that better nutrition knowledge may not significantly enhance the use of food information even though better use of food information might significantly improve diet quality (Barreiro-Hurlé et al., 2010). In addition, effects of diet knowledge on nutritional status may also be influenced by the expectation of future food availability, a tendency which has been empirically tested with a Chinese population (Shimokawa, 2013).

Hence, these consumer-side potential determinants need to be carefully considered when depicting the mechanism of transforming dietary pattern.

1.4 Aim, objectives and intended contributions

The aim of this thesis is to facilitate the understanding of how community at-home food choice can be influenced by both economic and non-economic factors with a particular focus on crucial elements observed during the process of fast socio-economic development. China is a developing country that has been undergoing rapid and massive social changes and is experiencing a substantial population nutrition transition. It thus provides a case study to investigate the mechanism of how social transformations can shift food consumption patterns.

Previous literature tends to focus on one aspect of diet transformation, be it the economic effects of social changes, shifts in demographics, transformations in living environment, or the responses of food consumption to changes in price and expenditure in China. This thesis intends to differentiate itself from the extant studies from two aspects. First, this thesis takes into consideration economic factors and key aspects of social transformation simultaneously to depict shifting food consumption patterns, and this is projected further into the future as the foundation of the possible situations of food patterns in 2050 urban China. Second, recent studies focusing on the effects of economic factors on food consumption in China follow an economic approach. They apply structural demand models to household level food data. However, by looking at observations at household level, their aim is to recover individual preference and behaviour. As a consequence, the more general potential influencers embedded in social development that may exert similar effects on groups of individuals are usually neglected. Rather than investigating the behaviour of individuals, households or provinces, "community" is taken as the unit of analysis in this thesis. "Community", which is a collective of households living in the same area, is a unit with generality in between individuals, households and provinces. It is thus expected that the understanding of a more collective food pattern compared with that of households and individuals would benefit local governments or social workers in the design of community targeted food and nutrition related promoting instruments. Also, compared with analysis conducted at provincial and national level, it is hoped that this approach will provide a more detailed picture as evidence for the policies made at national level that intend to address the negative dietary outcomes in the process of population nutrition transition.

Understanding the link between economic factors, social development and dietary patterns at the community level is meaningful because theoretically it will shed new light on the mechanism of transforming dietary patterns in China, and practically it will provide reference to local governments that normally function as policy implementers to design community level nutrition and health related policies. This thesis intends to fill the gap of knowledge about the drivers of community level food choices, by using the community as unit of analysis and both economic factors and social development factors are examined within the framework of an economic model.

The first goal of this thesis is to formulate community at-home food choice by taking into account both economic and non-economic drivers. This serves to set up the foundation for the testing and projecting of the impacts of social transformation on food decision. Three specific objectives are within this goal:

1. The first objective is to test if communities located in areas with different level of urbanisation would have varied food demand. This question is triggered by the fact that the urbanisation process is often accompanied by a shifting lifestyle where food choice is one of its key components. Evidence from China has shown that there is a divergence in food consumption patterns between urban and rural areas and that areas at different stages of the urbanisation process have varied dietary choices. This thesis focuses on the situation in urban, suburban and county towns where food markets are relatively well-developed and most foods consumed-at-home can be sourced from local markets. It is assumed that differences in the level of urbanisation of communities can be summarised in either a city(urban and suburban) or a town environment. It is expected that results from this objective would add evidence to the link between the urbanisation process and its dietary outcomes.

2. The second objective is to investigate if the ageing population would change food consumption patterns. This topic is of particular interest at community level since compared with households, observed behaviour of a community as a whole is likely to be closer to the behaviour at national level. Shifting demographics of the Chinese population have been shown to affect the consumption of meats and grain equivalent. However, there appears to be limited research on its impacts on overall food patterns. Taking community as a unit of observation, it is expected that findings will shed new light on this topic.

3. The third objective is to examine whether more convenient supermarket access relative to that of fresh markets affects community dietary patterns. This is proposed in the context of the "supermarket revolution" in China where modern food retailers are replacing traditional food outlets and consumers are diversifying their shopping patterns to multi-platform purchase. Empirical evidence in developing countries tends to blame supermarkets for the increasing consumption of highly-processed foods at the expense of fresh produce, however there is a lack of evidence in China to confirm or refute such findings.

Built on the results from the entire model, community at-home food choice is then projected to the year 2050. Based on the literature on the forecasts of social-demographic changes in China, the progressing urbanisation level and the ageing population are taken as two irreversible trends and therefore their situations in 2050 are taken with no uncertainty. In contrast, the transformation of the food environment may be influenced by government policies and such less certainty is reflected by the two projected scenarios in 2050. Meanwhile, nutrition knowledge could directly affect food choice and its related education programmes are potential means to ameliorate the negative nutritional effects of shifting food patterns. Therefore, projected social environments in 2050 are augmented by a projected level of improved dietary knowledge to see if better dietary knowledge might contribute to the alleviation of the negative impacts of social changes on nutrition. The examination of the nutritional aspect of the at-home diet focuses on the choice of vegetables and fruits, and on oils and sugars. These two groups of foods are chosen because they are relatively unambiguous: the former can be considered as a representative of the positive side of diet while the latter is normally taken as a potential risk. Specifically, the fourth research objective is articulated as follows.

4. The fourth objective is to formulate four scenarios of at-home food choice for 2050 urban China, and to examine food decisions under each of the scenario situations. The first two scenarios projected will represent two different types of food environment: one is dominated by supermarkets run according to the modern business mode (relatively large-scale chained food retailers), the other is dominated by modernised traditional fresh markets that are mainly composed of relatively small-scale vendors. These two scenarios are then augmented by improved dietary knowledge respectively, which form the third and the fourth scenarios. Since both food environment and nutrition

knowledge can be influenced by government policies and food environment is regarded as the main source of uncertainty, the comments on the four scenarios focus on the potential of dietary knowledge to promote more healthy food choices under different food environments.

1.5 Organisation of the thesis

This chapter has reviewed the background of nutrition transition in China and the critical factors underlying this transition. The emphasis is on the rapidly transforming social environment in which shifting dietary patterns are happening. The next chapter (Chapter Two) will review and focus on the *empirical* evidence of the links between the three key social development factors discussed in this chapter and food choice. Chapter Three will outline methods utilised in the formulation of the demand model and the estimation of the effects. Chapter Four will describe data sources, data cleaning process and it will summarise descriptive statistics of the key variables involved. Chapter Five will present and discuss estimation results from the demand model which addresses the first three research objectives mentioned in Section 1.4. Chapter Six will discuss food choice under each projected scenario with the intention of identifying the one with the highest potential to result in improved diet quality for 2050 urban China, which is related to the fourth research objective. The last chapter will summarise the thesis, discuss the limitations and mention possible future research directions.

Chapter 2

Links between food choice and its potential drivers: empirical evidence

In the previous chapter the background of nutrition transition and its critical drivers were outlined and introduced mainly based on the descriptive evidence in the literature. This chapter concentrates on the empirical evidence between those identified factors and food patterns.

2.1 Social development underlying dietary transformation

From the perspective of changing food patterns, three key aspects of social development, the urbanisation process, the changing age structure and the shifting food landscape, have been identified in China and other developing countries. This section reviews their potential association with food consumption with an emphasis on empirical evidence not restricted to China.

2.1.1 Urbanisation

Empirical evidence examining different levels of urbanicity and food consumption has been documented in studies on different countries. Huang and David (1993) investigated effects of the urbanisation rate on grain consumption in nine Asian countries from 1960 to 1988 and reported that in higher income countries the urbanisation rate would encourage the consumption of non-cereal foods at the expense of grains, whilst in lower income countries urbanisation would increase grain consumption. Across all nations, it is found that urbanisation promotes the consumption of wheat products but decreases that of rice and less-processed grains. Rae (1998) analysed animal product consumption in six East Asian countries during 1980 to 1995 and found that the consumption of animal sourced foods tended to increase with increased urbanisation levels as measured by urban population proportion. Delisle et al. (2012) studied different diets in urban and rural residences in Benin and reported that grains, legumes, fish and fruits had higher consumption in rural areas, whereas in the main city areas consumption of dairy products, vegetables, meat and poultry was much higher. Hakeem et al. (1999) identified rural-urban differences in food consumption among Pakistani children and reported that increased urbanisation level was associated with increased consumption of milk, meat, poultry, chocolates, cakes, ice-cream, fruits and raw vegetables. Generally speaking, relevant literature on the situation in developing countries tends to associate the urbanisation process with the very likely concomitantly happening dietary diversification which is featured by a divergence from local traditional dietary habits (e.g. Mendez and Popkin, 2004; Pingali, 2007; Reardon et al., 2014).

In the context of China, studies either directly compare urban-rural differences or construct an overall urbanicity index as the measurement to capture various dimensions of urbanisation process. Investigating food consumption in the urban-rural context, consistent findings indicate that rural food consumption lags behind urban food patterns in the sense that vegetable-sourced foods in rural areas still play a very important role in daily food consumption. By contrast, in urban areas animal- and vegetable-sourced foods tend to be equally important (e.g. Li, 2007a; Liu et al., 2015). A "modern" diet as observed in urban China is characterised by a greater variety of fruit and animal products, whereas a more traditional diet is featured by relatively heavy pork and vegetable consumption (Jussaume Jr, 2001). Diversification of food led by income growth in urban areas is likely to enhance the consumption of fruits and non-traditional animal products such as seafood at the expense of grains, starches and eggs. This has been confirmed in several studies (e.g. Ma et al., 2004; Zhang et al., 2008). Findings also suggest that at-home consumption of dairy products has increased as part of food diversification (Bai et al., 2008b, 2014; Wu et al., 2014). The relatively stable consumption of "traditional" meat, especially pork, is considered to be a persistent feature of the "traditional" diet (Liu and Zhong, 2009; Li et al., 2015). Meanwhile, findings from studies on rural food choice are less consistent. On the one hand, some studies suggest that rural demand for grains, oils and eggs has approached a stable level while demand for vegetables, meats and aquatic products is still strong (Zhou, 2006; Zhang et al., 2012, e.g.). On the other hand, it is found that rural demand for all these broad food groups are not responsive to income growth (Yu and Xu, 2012). One study on rural households in Beijing area suggested that as incomes grow, rural demand for grains and vegetables would decrease while that for vegetable oils, meats, eggs and aquatic products would increase (Li et al., 2011a). The notable differences in the findings on rural food demand may be due to the remarkable differences in the economic and social development levels of the vast rural areas in China. Nonetheless, studies tend to confirm the difference between urban and rural food choice and suggest that demand for edible oils and animal products in rural areas has been increasing at a greater rate than that in urban areas (Li, 2008).

The other type of studies analyses the impact of urbanisation on diet by constructing an urbanicity index. Such an index is defined as continuous so that urbanicity level of regions or areas under investigation can be marked and hence compared on a continuous spectrum. The idea underlying such a construct is to capture the differences in overall social and economic environment and to minimise the potential inconsistency between dichotomous urban-rural classification and their fast changing urbanicity level. Van de Poel et al. (2009) adopted a data driven approach by applying factor analysis to a set of community characteristics which were selected following a framework that links built environment and health as proposed by Northridge et al. (2003). They used data from the CHNS 1991 and 2004. Their findings suggest that an increasing urbanisation level is related to higher levels of obesity and hypertension. Jones-Smith and Popkin (2010) developed a more comprehensive index based on literature and used information from the CHNS to incorporate twelve dimensions of urbanicity: population density, economic activity, traditional markets, modern markets, transportation infrastructure, sanitation, communications, housing, education, diversity, health infrastructure and social service. Based on this index they found that from 1991 to 2006 in China community urbanicity was positively linked with dietary energy sourced from fats. Both these studies confirm the importance of potential impacts of urbanising environment on diet and health.

Thus, food consumption patterns as a critical aspect of lifestyle can be closely related to the urbanisation process which is an ongoing element of social development in China.

2.1.2 Ageing population

Empirical evidence from developed countries has indicated that food consumption is affected by population demographic shifts. Evidence from the US suggests that the ageing population may increase the demand for fruits and vegetables consumed at home, while at the same time it may decrease the consumption of meats, in particular beef (e.g. Blaylock and Smallwood, 1986; Gossard and York, 2003; Davis and Lin, 2005). Studies in Japan found that older people consume more rice, sake, fresh fish and fresh fruits while the younger cohort tends to demand more beef and beer (e.g. Mori et al., 2000; Tanaka et al., 2004; Mori et al., 2016).

Empirical literature on China examining the effect of the ageing population on food consumption pattern tends to be limited. They tend to analyse household food consumption in China controlling age effects by using the age of the household head and the existence of children and/or seniors in the household. The potential links between population age structure and food patterns are therefore not clear-cut. Huang (1999) defined age structure by proportions of members from different age groups and investigated aggregated household data of China from 1989 and 1991. They also analysed disaggregated household food consumption data of Taiwan in 1981 and 1991. Their findings suggest that per capita consumption of all food groups decreases with increased proportions of either seniors or children. Also, seniors were found to prefer rice to wheat products while younger people were found to like fruits more than the seniors. Comparatively, in Zhou et al. (2012), it is asserted that the larger proportion of aged population decreases the demand for meats, in particular red meats, but increases the consumption of other foods. Zhong et al. (2012) investigated the influence of demographic dynamics on calorie intake by defining and constructing an adult male equivalent scale based on gender and age of the population. They found that calorie intake is affected by dynamic population demographics. Furthermore, Xiang and Zhong (2013) forecast grain equivalent demand in China and found that increasing rates of demand for grain equivalent would be slower than population growth and the projected demand for grain equivalent would be overestimated if the dynamics of population demographic structure is not taken into account. Zheng and Henneberry (2009) analysed the food consumption of urban households in Jiangsu province, China, with household level data and controlled age effects by using the ratio of seniors and ratio of children for each household. Their findings show that households with more seniors consume more grains, oils and fats, eggs and vegetables, while households with more children tend to consume more dairy products at the expense of all other food groups except fruits. This suggests varied food choice patterns between different age groups. Shi et al. (2015) studied the impact of the ageing population on per capita meat consumption in urban households using data collected in six large cities in China between 2007 and 2011. They defined the age structure at household level by the proportion of household members belonging to six different age groups. Findings from this study indicate that the ageing population decreases per capita total meat consumption (including meats consumed at home and away from home) in urban China. Thus neglecting such demographic shifts would lead to expected meat demand being overestimated.

Hence, even though the existing literature on the effects of population ageing on food consumption in China is still limited, links between population ageing and food patterns have been established.

2.1.3 Changing food environment - the "Supermarket revolution"

Empirical studies have tested the effects of supermarket expansion on food choice and dietary outcomes in developing countries.

Specifically, Asfaw (2008) studied urban households in Guatemala and found that more food purchases from supermarkets were associated with increased calorie share from highly and partially processed foods which are mainly composed of pastries, sweets, chocolates, sausages etc., while having an insignificant effect on calorie share sourced from vegetables and fruits and a significant negative impact on the energy from staple foods. Tessier et al. (2008) examined the correlation between overall diet quality and supermarket accessibility and use frequency with urban households in the Greater Tunis area. They found that the diet quality at household level was slightly higher with regular supermarket users, and pointed out that this could result from the fact that supermarket penetration was still at an early stage in that area and wealthier consumers were much more likely to patronise supermarkets for foods. In addition, only cheese and fruit consumption was enhanced by supermarket use which can be partly explained by the increasing, though still limited, purchasing power in the area under study. Their study concludes the findings by emphasising that this is the very beginning stage of supermarket expansion in Tunisia and it is therefore having a very limited influence on the traditional diet so far. Kelly et al. (2014) assessed the relationship between consumption frequency of "healthy foods" and "problem foods" and shopping patterns of individuals in urban Thailand. They found a positive correlation between frequent supermarket shopping and consumption of "problem foods", and a positive correlation between frequent fresh market shopping and consumption of vegetables and fruits. Negative effects of supermarkets on diet were found to be more significant on lower income consumers for some "problem foods". This study explicitly defined six groups of foods as "problem foods" which comprise deep fried foods, soft drinks, snack foods (e.g. potato chips), instant foods (e.g. instant noodles), processed meats (e.g. hot dogs) and western style bakery goods (e.g. cakes), while taking fruits and vegetables as "healthy foods". The selected six problematic groups are believed to be representative of the transitional diet in Thailand. Rischke et al. (2015) investigated households in urban Kenya and confirmed their hypotheses that supermarket purchases tended to increase the consumption of processed foods in terms of both expenditure and calorie shares of this food group at the expense of unprocessed foods, and that daily calorie availability could be augmented because of the decreased price of unit calorie offered by supermarkets. Food groups in their study are defined by level of processing which produces an unprocessed food group, a primary processed food group and a highly-processed food group.

Supermarkets have been found to affect diets through different ways. The possible pathways from supermarket purchasing to food choice lie in supermarkets' marketing strategies taken at different stages of penetration. Those stages of supermarket penetration have been identified are as follows: supermarket diffusion over space, over consumer segments of different socio-economic strata and over products (Reardon and Gulati, 2008a).

As for the spatial diffusion, the advent of supermarkets usually occurs in the largest and wealthiest cities in urban areas where the highest profit per capita can be achieved. Then, as their profit margins decrease and the supply chain becomes more efficient, supermarkets launch their business in intermediate cities and towns. This is then followed by further expansion into small towns in rural areas. Specific to the situation in China, international retailers first entered China by launching their businesses in central urban and inner suburban areas with large-scale hypermarket and supermarket formats. They then gradually diversified their formats as they expanded their business to cover wider geographical areas and to target consumers from various socio-economic groups (Reardon and Gulati, 2008a; Wang, 2011).

In terms of targeting different consumer segments, at the initial stage of development, consumers with higher incomes living in big cities are the targeted segment. The middle class is the next target followed by the lower-income segment in an urban area.

As for product diffusion, to be able to compete with traditional food retailers as they first enter into a new market, supermarkets focus on highly processed and packaged foods (e.g. oils and biscuits). For these products supermarkets can offer relatively lower prices as they can take advantage of economies of scale in their procurement systems and the longer shelf life of these products. Later, offered food categories are expanded to semi-processed and minimal processed/packaged foods (e.g. dairy foods, meat and fruits). Only when their food supply chains become competitive to traditional retailers will supermarkets finally enter the fresh vegetable sector (e.g. Neven and Reardon, 2004; Stringer et al., 2009; Aparna and Hanumanthaiah, 2012).

Such a development trajectory of supermarkets means that different consumer segments are targeted at various stages of penetration. Two crucial aspects of marketing strategies from modern food retailers are expected to impact consumers food choices: 1) pricing strategies which conform to the supermarket's level of development, and 2) relatively short-term sales promotions directly aimed at enhancing sales (Chandon and Wansink, 2012).

1) In terms of supermarket pricing strategies, a stable and predictable pattern has been observed during the supermarket revolution in many developing countries (Minten and Reardon, 2008, p. 487). (The Indian case may be an exception, also refer to Minten et al. (2010)). Specifically, on entering the market, supermarkets tend to charge lower prices for ultra-processed and packaged foods including staples in order to compete with already existent traditional food retailers. Vegetables and fruits are very likely to be sold at higher prices than those on traditional markets. During this stage, ultra-processed and packaged foods and high-value food products are the main interest of supermarkets' food marketing. Gradually, as their procurement and logistics systems of fresh produce become increasingly efficient, supermarkets start to supply more fresh fruits at competitive prices. The last stage involves competing with traditional food retailers in selling highly-perishable vegetables. From the second stage, a wider range of food items of different quality, both over food categories and within each category (product line), will be supplied in the supermarkets aiming at the mass market. Price differentiation by quality appears to be a common practice during this stage depending on the characteristics of the market segments that supermarkets are targeting and the correspondingly adopted marketing strategies.

Case studies on supermarkets' food pricing strategies in countries experiencing supermarket diffusion show that supermarkets have the ability to provide processed and packaged foods at lower prices than traditional retailers; however, in general the fruits and vegetables sold in supermarkets are usually more expensive (and are likely to be of higher quality) than those available in traditional fresh markets. Apart from the evidence provided in Minten and Reardon (2008), very similar trends have also been observed in other studies (e.g. in Bangkok, Thailand: Schipmann and Qaim (2011); in Colombia: Guarín (2013); in Addis Ababa, Ethiopia: Woldu et al. (2013)). This may imply that during the evolution of food retailing from traditional to modern in these countries, consumers choose more than one food retail outlet as their primary food source and have a tendency to purchase different food items in varied markets. For instance, consumers may be more willing to shop for fresh produce, particularly vegetables, in traditional wet markets, while buying processed and packaged foods from supermarkets, which could be a typical shopping pattern of urban lower-income consumers (e.g., Goldman et al., 2002; Goldman and Hino, 2005; Figui and Moustier, 2009). In contrast, the shopping pattern of higher income consumers is more likely to shift to one-stop-all-foods in supermarkets where a wider assortment of products are offered; the higher prices charged are then perceived as differentiated foods of better quality (e.g., Goldman et al., 1999; Hino, 2010). Nonetheless, the general trend which has been observed of a decreasing gap between fresh produce prices in supermarkets and traditional markets implies the supermarkets' influence on daily food purchases of the mass market.

2) Other marketing practices involve the use of price discounts, extra-product price promotions, prize promotions, feature and display promotions and sampling promotions (Hawkes, 2009). The short-term effects of these marketing practices on boosting consumer purchases have been confirmed in many studies (e.g. Blattberg et al., 1995; Glanz et al., 2012). However, findings of the continuing effects of sales promotions on changing long-term food consumption patterns are far from consistent. Nonetheless, it seems that two vague but general conclusions can be reached: (1) marketing practices can encourage instant shifts in food consumption patterns; (2) the influences of marketing practices on food consumption vary depending on the specific type of sales promotions, on the type of foods and on the characteristics of consumers (e.g. Hawkes, 2009; Steenhuis et al., 2011).

From the consumers' perspective, the spread of supermarkets modernises their food shopping environment and the access to supermarkets exposes them to a food environment with highly diversified food options (Hawkes, 2008). At the same time, supermarkets have been linked to increased obesity and related health problem as they lower the unit price of those "unhealthy" foods which encourages their consumption (e.g. Kimenju et al., 2015). In contrast to the concern over the nutritional outcomes of emerging supermarkets as replacements for fresh and wet markets, studies on food environment and diet in developed countries emphasise the positive nutritional impacts of chained supermarkets in comparison to neighbourhood convenience stores which are believed to offer a smaller range of healthy and affordable foods. However, findings on food retail access and diet quality are mixed after controlling for dietary difference across socioeconomic disparities (Bitler and Haider, 2011). On the one hand, it has been found that increased supermarket availability has a very limited effect on enhanced consumption of more healthy foods (e.g. fruits and vegetables) (e.g. Pearson et al., 2005; Kyureghian et al., 2013; Handbury et al., 2016); on the other hand, positive impacts of supermarket density on consumption of healthy foods have been confirmed in many studies (e.g. Rose and Richards, 2004; Larson et al., 2009; Sharkey et al., 2010). Since it is the less-developed countries that are still experiencing the "supermarket revolution" and where traditional fresh markets and street stores are still acting as the main food source in most areas, it is clear that the role that supermarkets play in food choice and purchase can be very different from that in developed countries. Nonetheless, related studies on much more developed regions highlight the potential differences in food demand across socioeconomic groups regardless of food outlet choice (Handbury et al., 2016).

To sum up, the supermarket revolution has significantly transformed the food retail landscape in China. Such changes have been linked in other countries to shifting food choice. However, there is a lack of empirical evidence for this in the case of China.

2.2 Linking social development drivers and dietary patterns

The previous sections demonstrate that the transforming food environment, the rapid urbanisation process and the accelerating ageing population are all aspects of social development which are contributing to the transformation of the Chinese diet. It has also shown that current studies examining the effects of social development on food choice tend to adopt a less structured approach to formulate the relationship between selected social development factors and food choice.

In the next chapter, studies focusing on the link between economic drivers price and expenditure and food choice will be reviewed. Those studies selected take the economic approach which provide a structural framework to incorporate the social drivers reviewed in this chapter.

Chapter 3

Methods

The economic approach provides a structural framework to formulate the link between food choice and its potential drivers that have been identified and discussed in the previous chapters. The chapter first describes demand models that have been widely applied in the empirical literature and the key issues when estimating food demand systems. Second, basic Bayesian parameter estimation procedures, which is the model estimation method adopted in this thesis, are explained. Third, Bayesian estimation procedures of a seemingly unrelated regression (SUR) Tobit AIDS model, i.e. the model estimated in this thesis, is delineated. Fourth, projected scenarios and the estimation of their potential influence on food choice in 2050 urban China are described.

3.1 Food demand modelling

The demand system provides a framework to accommodate all the critical variables involved in the description of food patterns, and can formally describe the generation of the observed food choice from the perspective of utility maximisation theory depending on the specific model chosen. Food demand analysis in China has been conducted since the 1980s. Almost all studies have used data either from the Rural Household Survey or from the Urban Household Survey conducted by the National Bureau of Statistics of China (NBS) every year. The early studies, restricted by the availability of household level data, usually analysed aggregate data. A two-stage budgeting procedure is commonly formulated where the first stage deals with the allocation of income across broad commodity groups including food, clothing, fuel, housing and other commodities, and the second stage focuses on allocating food expenditure to more specific food groups.

3.1.1 LES-type and AIDS-type models

Lewis and Andrews (1989) investigated aggregate time series urban and rural food consumption data from 1982 to 1985 using the linear expenditure system (LES) within the framework of two-stage expenditure allocation. Wu et al. (1995) used cross-sectional urban food consumption data from 1990 aggregated to city level to model food consumption at the second stage as well as the first stage with AIDS. Fan et al. (1995) formulated the two-stage budgeting with LES-AIDS where rural food demand was modelled by aggregate provincial level time series data from 1980 to 1990. A recent study by Zheng et al. (2015) also conducted food demand analysis using both rural and urban time series data from 2000 to 2010 pooled to provincial level. They formulated two-stage budgeting and estimated a QUAIDS (quadratic AIDS) model (Banks et al., 1997). The reason for the choice of aggregated instead of household level data is that their goal was to approximate a nation-wide food consumption pattern in order to forecast future food demand for the entire country. In contrast, the majority of the most recent studies tend to use household level data from the NBS.

All these studies have in common that either LES-type or AIDS-type functional forms have been the primary tools for the empirical examination. (LES type demand system is linear in expenditure.) Mentioned in these empirical works, the advantages of LES include its satisfaction of theoretical restrictions and its straightforward expression of quantity with respect to total expenditure and relative prices. However, the assumed additive form of utility function underlying the LES-type model restricts its flexibility in price coefficients and the LES is often criticised for its linearity in expenditure and Quadratic LES for its linearity in marginal expenditure. Still, the application of the LES to broad aggregate groups (e.g. first stage income allocation across food, clothing, fuel, housing and other commodities) is often argued to be reasonable.

Unlike the LES type models, AIDS-type models do not rely on an additive utility function and can be derived from a second order approximation of any cost function which indicates its flexibility in approaching real behaviour. Its variants, quadratic form allows an approximated quadratic Engel curve; generalised form deals with the integration of demographic shifters into an AIDS model; and its generalised quadratic form takes into account both the nonlinearity in expenditure and the influence of incorporating demographic shifters on the property of the coefficients specified in the original model. Study of Katchova et al. (2004) directly comparing the quadratic LES and the AIDS model using rural household level data in Jiangsu China collected by the NBS in 1994 found the advantage of applying the AIDS model against the quadratic LES to model food demand with Chinese households. Their findings are based on comparing the values and significance of the shared coefficients in both models. A competing functional form to the AIDS-type model is the Rotterdam model. Relatively fewer empirical investigations on food consumption in mainland China have applied this model. Having similar advantages as the AIDS model, the Rotterdam model was tested to be superior to the AIDS model in Dong and Fuller (2010) whose study tested for structural change in urban china food demand, by comparing AIDS against Rotterdam model following the method developed in LaFrance (1998) (where a significance test of the coefficients in a constructed compound model comprising both the AIDS and the Rotterdam was conducted). Another earlier study developed a Rotterdam-type differential mixed-demand system to analyse the impacts of partial rationing on Chinese urban households food demand from 1987 to 1991 (Gao et al., 1996). One of the reasons for their preference towards the Rotterdam model is because its total differential form matches the mixed-demand functional form. Another study on Taiwanese consumers' food consumption from 1970 to 1989 tested between AIDS-type models and Rotterdam models and concluded that the AIDS-type model could be more appropriate to describe Taiwanese consumers' food choice (Lee et al., 1994).

3.1.2 Separability assumptions

Demand studies require food groups to be defined based on the assumption of separability of preference on elementary goods (Edgerton, 1997). This assumption is important for good grouping as it helps to bridge the gap between a large number of miscellaneous good items and more manageable groups for demand analysis, and to restrict interactions among good groups.

There are two different assumptions of separability, weak separability and strong separability. A weakly separable utility function is defined as "if and only if the goods can be partitioned into subsets in such a way that every marginal rate of substitution involving two goods from the same subset depends only on the goods in that subset" (Pollak and Wales, 1992, p. 44). This means that the quantity demanded of one good in the separable group only requires information on the prices of the goods within the same group and the expenditure of this group. For example, if labour supply and commodity demand are assumed to be weakly separable, then the quantity of labour supply and that of commodity demanded can be analysed separately. Otherwise, the joint determination of the demanded quantities of labour and commodity need to be modelled through the allocation of time across these two groups.

By comparison, a strongly separable utility function exists ‘if and only if the goods can be partitioned into subsets in such a way that every marginal rate of substitution involving goods from different subsets depends only on the goods in those two subsets” (Pollak and Wales, 1992, p. 49). This means that any good groups can be combined to produce further separable groups. For example, food, house and friend may be assumed to be strongly separable since each of them could directly satisfy a want and any two can be combined to form a new group that is very likely to be separable from the third group.

Weakly separable utility function can be illustrated with a utility tree which allows a simultaneous decision making process to be split into two (or multiple) steps (Strotz, 1957, 1959). Key implication of weakly separable preference assumption is that demand for a good in one subset is only determined by the price vector and expenditure of the subgroup that this good belongs to; in other words, changes in the prices and expenditure outside the group that the good of interest is directly in will only exert effects on the demand for that good through affecting the expenditure on that group. This concept and its indicating utility tree is closely related to the idea of two-stage budgeting, which separates the decision process of choosing goods in two stages with the first stage being devoted to the allocation of total expenditure on broad good groups and the second stage specialising in allocating group expenditure to the commodities within that group. It has been proved that the weak separability of utility function is a necessary and sufficient condition for the second stage of two-stage budgeting behaviour (Deaton and Muellbauer, 1980, p. 124).

The other assumption of strong separability imposes more restrictive conditions on the substitution matrix between goods in different groups. The determination of all own- and cross- price elasticities in this case only requires information on expenditure elasticities, and inferior goods and complementary interactions between goods are excluded; moreover, expenditure proportionality can be deduced from additive utility functions (Deaton and Muellbauer, 1980, p. 138-139). This means a constant proportion of expenditure will always be spent on a good no matter how expenditure varies. All these implications may render the strongly separable preference assumption too restrictive to describe the real behaviour at more disaggregate good group level. This study adopts the assumption of weak separability.

3.1.3 Censoring

An issue embedded in microlevel data is the existence of zero consumption of specific food groups for some households, the so called censoring. This requires a modified estimation strategy to account for the generation process of those zeros. Apart from the functional form and separability assumption of demand systems, another aspect that has been increasingly examined is the explanation of zeros in the observed expenditure data as the dependent variable.

Mechanisms producing those zeros can be summarised by the general likelihood function laid out in Blundell and Meghir (1987). Three basic possible mechanisms for zeros include consumers decide not to participate in the market; consumers participate in the market however their expenditure is not observed because of the long life of products already in use; and consumers participate in the markets however the combination of relative price and income makes the product not attractive which implies these zeros are the outcome of optimal choice. Such a description separates market participation/purchase decision and consumption decision. The first situation can be formulated by a participation probit function plus a consumption function, and both functions need to give positive answers to realise the observed positive consumption; the second one by a purchase probit function plus a consumption function, and the positive answer from the probit means positive consumption observed; and the third one indicates that consumers' participation decisions and consumption decisions are generated by identical mechanisms therefore only one consumption function is sufficient to describe all the values observed. The first situation can be formulated by a double-hurdle model where a zero has two possible explanations: either a corner solution or the consumer does not use the product (e.g. Haines et al., 1988; Jones, 1989; Blaylock et al., 1991). The second has been described with an infrequency-of-purchase model where a zero also has two possibilities: either a corner solution or the survey period is too short to observe a positive purchase (e.g. Deaton and Irish, 1984; Blundell and Meghir, 1987). The third one would be a standard Tobit model (e.g. Amemiya, 1974). In addition, if all consumers can be observed to use the product in a double-hurdle environment and the survey period is long enough to observe consumers replenish their stocks under a infrequency-of-purchase context, then the double-hurdle or infrequency-of-purchase situation is reduced to a standard Tobit. In many circumstances, since information on the reason for non-consumption for each consumer is often missing in the survey, the different mechanisms for the observed zeros for each consumer can hardly be distinguished.

Empirically, a Tobit demand system can be estimated by using the maximum likelihood procedure (Yen et al., 2003), the maximum entropy estimator (Golan et al., 2001), the two-step Tobit system estimator (Perali and Chavas, 2000) and its generalised-method-of-moments extension (Meyerhoefer et al., 2005) (Cited in Kasteridis et al. (2011)). Different two-step estimators have also been developed for the sample selection model by Shonkwiler and Yen (1999) and Yen and Lin (2006). For the estimation of demand systems, the potential risk of these estimators is its ignorance of adding-up restriction which results in varied estimates of parameters depending on the equation left behind in demand system estimation (Yen and Lin, 2006).

In parallel with the Tobit approach, the constrained utility maximisation problem can be analytically solved by Kuhn-Tucker conditions which can be used in the construction of likelihood function (Wales and Woodland, 1983). Alternatively, a dual approach based on indirect utility function which enables the use of flexible functional forms was developed by Lee and Pitt (1986). The criticism on both primal and dual approaches concentrates on the computation difficulty of its multiple probability integrals in the likelihood function (e.g. Hajivassiliou, 1993), and its statistical incoherency which limits the use of flexible functional forms in demand systems (e.g. van Soest et al., 1993).

Another pathway to overcome these estimation difficulties would be the Bayesian MCMC approach for a Tobit demand system. The adding-up restriction of demand systems, which is one of the integrability conditions that guarantees the consistency between regular preference and demand systems, can be imposed by following the mapping rule between latent and observed expenditure shares proposed by Wales and Woodland (1983). The Bayesian MCMC computation method mitigates the dimensionality difficulty. The data augmentation method has been developed to simplify the computation in a Bayesian Tobit model (Tanner and Wong, 1987; Chib, 1992). Following the Bayesian way, Kasteridis et al. (2011); Kasteridis and Yen (2012) and Bilgic and Yen (2014) estimated a censored linearised AIDS using standard Tobit to account for zero consumption. Tiffin and Arnoult (2010, 2011) developed the Bayesian estimation framework for the infrequency-of-purchase model.

Censoring in Chinese demand studies has been considered by Fang and Beghin (2002) who estimated household demand for edible oils and fats for three urban regions. A two-step estimation procedure developed by Heien and Wesseils (1990) was used. However subsequently, this two-step approach was found to be analytically incorrect by Shonkwiler and Yen (1999). Another attempt to take into consideration the existence of censoring in expenditure was undertaken by Yen et al. (2004) who enhanced a translog demand system with a linear Tobit system following the two-step estimation procedure developed by Shonkwiler and Yen (1999). They estimated their model to analyse urban household food demand in China in 2000. Adopting the same estimation procedure, Liu and Chern (2003) investigated food consumption with household level urban data in 1998 using QUAIDS. Using urban household level data in Jiangsu province collected in 2004, Zheng and Henneberry (2009) estimated a GAIDS model which contains precommitted quantities that is further formulated as a function of demand shifters.

By contrast, this study will follow the framework of Tiffin and Arnoult (2010) to estimate an AIDS but with a standard Tobit model as in Kasteridis et al. (2011). Because this study uses community level food intake data that are aggregated from households, the interpretations of zeros in expenditure shares are assumed to be corner solutions.

3.2 Bayesian parameter estimation

This section sketches the main procedures when applying the Bayesian parameter estimation method. The first part describes how the posterior distribution of the parameters of a SUR model can be obtained given data and prior knowledge. Being a system of equations, the SUR model provides the base for the demand system to be estimated. The second part outlines simulation methods that can be used to obtain the posterior density estimates.

3.2.1 Seemingly Unrelated Regression model

The Bayesian inference is founded on Bayes' theorem, which can be seen directly from the rule of probability. Assuming two random variables A and B (Koop, 2003),

$$p(A, B) = p(A)p(B|A) = p(B)p(A|B) \tag{3.1}$$

Therefore,

$$p(B|A) = \frac{p(B)p(A|B)}{p(A)} \tag{3.2}$$

To make the notation consistent in this thesis, substitute B with θ and A with y, where y stores data matrix and θ represents the parameter matrix in the model explaining y. Then equivalently, Bayes' theorem can be expressed as:

$$p(\theta|y) = \frac{p(\theta)p(y|\theta)}{p(y)} \tag{3.3}$$

Since the interest focuses on the parameter matrix θ, the denominator $p(y)$ can be neglected; thus a simplified version can be written as:

$$p(\theta|y) \propto p(\theta)p(y|\theta) \tag{3.4}$$

where $p(\theta|y)$ is the posterior density, $p(y|\theta)$ the likelihood function and $p(\theta)$ the prior density. Equation 3.4 says that the posterior is proportional to the prior times the likelihood function.

Thus, the primary goal is to investigate the features of posterior density $p(\theta|y)$ by combing prior knowledge $p(\theta)$ and the understanding of the data generation process depicted by the likelihood function $p(y|\theta)$.

For a multiple equation regression formulation, the Seemingly Unrelated Regressions (SUR) model can be applied to this context. The SUR model for m equations formulates the data generating process as (Zellner, 1996, Section 8.5):

$$\begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{pmatrix} = \begin{pmatrix} X_1 & & & \\ & X_2 & & \\ & & \ddots & \\ & & & X_m \end{pmatrix} \begin{pmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_m \end{pmatrix} + \begin{pmatrix} \epsilon_1 \\ \epsilon_2 \\ \vdots \\ \epsilon_m \end{pmatrix} \tag{3.5}$$

where $\alpha = 1, 2, \ldots, m$; y_α is a $T \times 1$ vector of observations on the αth outcome variable; X_α is a $T \times k_\alpha$ matrix with k_α the explanatory variables in the αth equation with coefficient vector β_α which is a $k_\alpha \times 1$ column vector; and u_α is the $T \times 1$ error vector of the αth equation.

Equivalently, 3.5 can be compressed into:

$$y = X\beta + \epsilon \tag{3.6}$$

where $y_1, y_2, \ldots y_m$ stack into y of dimension $(mT \times 1)$; $\beta_1, \beta_2, \ldots \beta_m$ into β of dimension $(k \times 1)$; $\epsilon_1, \epsilon_2, \ldots \epsilon_m$ into $(mT \times 1)$ vector ϵ ; and X is of dimension $(mT \times k)$ with $k = \sum_\alpha k_\alpha$.

The assumptions on X and the likelihood function are:

1. X being taken as either fixed or random but independent of ϵ

2. $\epsilon \sim MVN(0_{mT},\ \Omega)$

where Ω is an $(mT \times mT)$ covariance matrix and $\Omega = H^{-1} \otimes I_T$ where H^{-1} is a positive definite symmetric $(m \times m)$ error precision matrix, and I_T is a $(T \times T)$ unit matrix.

The likelihood function for (β, H^{-1}) has been shown to be:

$$p(y|\beta, H^{-1}) \propto |H|^{\frac{T}{2}}\, exp\left[-\frac{1}{2}(y - X\beta)'H \otimes I_T(y - X\beta)\right] \tag{3.7}$$

The prior is assumed to be an independent Normal-Wishart prior, that is, $p(\beta, H) = p(\beta)p(H)$ and $p(\beta) = f_N(\beta|\underline{\beta}, \underline{V})$ and $p(H) = f_W(H|\underline{v}, \underline{H})$, where f_N denotes the p.d.f of Normal and f_W that of Wishart distribution which is a matrix generalisation of the Gamma distribution.

The posterior density derived from the likelihood and the prior based on the above assumptions does not demonstrate any convenient functional form; however the conditional posterior densities are from the known distributions. Specifically,

$$\beta|y, H \sim MVN(\bar{\beta},\ \bar{V}) \tag{3.8}$$

$$H|y, \beta \sim W(\bar{v},\ \bar{H}) \tag{3.9}$$

where

$$\bar{V} = \left(\underline{V}^{-1} + X'(H \otimes I_T)X\right)^{-1} \tag{3.10}$$

$$\bar{\beta} = \bar{V}\left(\underline{V}^{-1}\underline{\beta} + X'(H \otimes I_T)y\right) \tag{3.11}$$

$$\bar{v} = T + \underline{v} \tag{3.12}$$

$$\bar{H} = \left[\underline{H}^{-1} + (y - X\beta)'(y - X\beta)\right]^{-1} \tag{3.13}$$

Detail functional forms of the SUR model will be gone through in the section delineating Bayesian estimation of a Tobit SUR AIDS model.

To sum up, the Bayesian framework for regression model requires specifications on likelihood, prior and posterior. The characteristics of parameters under investigation given data can be accessed by examining the marginal distribution from the posterior density, and the general form of these features can be summarised as (Koop, 2003):

$$E[g(\theta)|y] = \int g(\theta)p(\theta|y)\, d\theta \tag{3.14}$$

where $g(\theta)$ is the function expressing the features, and it is presumed that $E[g(\theta)|y]$ exists for the assumed density.

The integral involved in equation 3.14 implies the potential difficulty in the derivation of analytical solutions to this expression. Under the circumstances where analytical solutions cannot be found, statistical simulation methods can be implemented to approximate the densities of these marginal distributions by generating simulated samples to sketch the posterior density.

3.2.2 Basic statistical simulation methods

A vast number of simulation methods have been implemented to complete Bayesian estimation. Broadly speaking, one stream falls into the category of noniterative methods and the other into iterative methods (Koop et al., 2007). This section intends to outline several most-widely practised methods in social research. Specifically, the reverse transform method, the acceptance-rejection method and the importance sampling method are described for the noniterative approach, and Metropolis-Hastings sampling and Gibbs sampler are outlined for the iterative sampling method.

3.2.2.1 Noniterative simulation methods

This section starts with the inverse transform method which is described as a very efficient and straightforward sampling method to simulate draws from a univariate distribution (Koop et al., 2007). The idea of this method is to use the cumulative distribution function as the bridge and to simulate samples from probability distribution given this cumulative distribution function. One of the applications of this method is to draw from truncated Normal distribution. Since sampling from truncated Normal density is a crucial component in the Bayesian estimation of Tobit models, procedures of this sampling are explicated as follows (Koop et al., 2007):

Let $x \sim TN_{[a,b]}(\mu, \sigma^2)$, where TN denotes truncated Normal. This notation says that x follows Normal distribution with mean μ and variance σ^2, which is truncated to lie in the interval $[a, b]$. Since $a \leq x \leq b$, the c.d.f of the truncated Normal distribution rescaled from the standard Normal distribution can be expressed as:

$$F(x) = \frac{\Phi(\frac{x-\mu}{\sigma}) - \Phi(\frac{a-\mu}{\sigma})}{\Phi(\frac{b-\mu}{\sigma}) - \Phi(\frac{a-\mu}{\sigma})} \tag{3.15}$$

A single realisation of $F(x)$ can be approximated by a random draw from $u \sim U(0,1)$. Therefore,

$$u = F(x) = \frac{\Phi(\frac{x-\mu}{\sigma}) - \Phi(\frac{a-\mu}{\sigma})}{\Phi(\frac{b-\mu}{\sigma}) - \Phi(\frac{a-\mu}{\sigma})} \tag{3.16}$$

Thus, a realisation of x can be solved through:

$$x = \mu + \sigma\Phi^{-1}\left(\Phi(\frac{a-\mu}{\sigma}) + u\left[\Phi(\frac{b-\mu}{\sigma}) - \Phi(\frac{a-\mu}{\sigma})\right]\right) \tag{3.17}$$

That is, $x \sim TN_{[a,b]}(\mu, \sigma^2)$ can be realised by equation 3.17.

There are two apparent limitations to this method. First, the inverse function needs to be able to be analytically derived and second, it is only directly applicable to drawing from univariate distributions since in general, a unique solution to the inverse in 3.16 cannot be obtained.

Another approach that does not rely on the inverse of $F^{-1}(u)$ and can be applied to the multivariate case is the acceptance-rejection sampling method. The idea of this method is to introduce an envelope function $m \times q(\theta)$ that covers $p(\theta)$, where $q(\theta)$ is the proposal density that is easy to draw from with $m \geq 1$. Then ratio of $p(\theta)$ and $m \times q(\theta)$ at given values of θ is computed to decide if the current draw is accepted or not (Greenberg, 2012). One of the potential limitations of this method is that it may be complicated to find an appropriate envelope function that is well-defined enough to cover the entire $f(x)$ and concomitantly efficient enough to have a relatively low rejection rate when drawing from a high dimensional density.

Following a similar idea of introducing a more convenient density function, which can be called importance function $q(\theta)$, the method of importance sampling calculates weights to be attached to the sampled values from convenient density (Koop, 2003). Similar to the limitation of the acceptance-rejection method, the finding of an efficient importance function can be very challenging for high-dimensional distributions.

Alternative to these strategies that produce i.i.d. random samples, another stream of sampling methods generates correlated samples through a Markov chain whose stationary distribution converges to the target posterior density.

3.2.2.2 Iterative simulation methods - MCMC methods

This section outlines the basic construction of two widely used Markov Chain Monte Carlo (MCMC) sampling methods: Metropolis-Hastings sampling and

Gibbs sampler, where the latter is a special case of the former. Most basic property of a Markov chain says that any value on the chain is only determined by its nearest past and is independent of all other points in the sequence (Liu, 2008). To ensure the fast convergence of a Markov chain to its stationary distribution, it is further required that the chain needs to be irreducible and every state on the chain must be aperiodic (Liu, 2008). "Irreducibility" requires that any state can be reached in finite time regardless of the current state; and "aperiodicity" requires that every state has period one so that every state can be returned to within irregular times. Detailed theories on the properties of a Markov chain, which legitimate MCMC methods, can be found in Liu (2008).

To explain the link between Metropolis-Hastings method and its special case Gibbs sampler, the detail balance condition is adopted as the string to explicate the construction of both samplers.

The essential idea of the Metropolis-Hastings algorithm is to find an efficient transition matrix so as to reach the stationary distribution of the target density $p(\theta|y)$. The stationality of the target distribution is ensured by the property of reversibility of a Markov chain, or equivalently, detailed balance condition, which is a sufficient condition for the convergence to the stationary distribution. The construction of Metropolis-Hastings algorithms can be demonstrated via detailed balance condition (Liu, 2008, Chapter 5; Ross, 2013, Chapter 12).

Given a candidate generating density q, which may play a similar role as the importance function in importance sampling and also serves as the transition matrix in the current situation, detailed balance condition *requires* that:

$$p(\theta = \theta^*|y)q(\theta^*; \theta = \theta^{(s-1)}) = p(\theta = \theta^{(s-1)}|y)q(\theta^{(s-1)}; \theta = \theta^*) \tag{3.18}$$

where $p(\theta = \theta^*|y)$ is the state matrix (or probability mass function) of θ at θ^* given y; and $q(\theta^*; \theta = \theta^{(s-1)})$ is the transition matrix from state θ^* to state $\theta^{(s-1)}$.

In general, this equation may not hold for any arbitrary q. Therefore, the goal is to transform this equation to render it true so that the detailed balance condition can be satisfied. A straightforward way of doing this is to multiply both sides of the equation by the terms on the other side which will lead to a symmetric equation. Define acceptance probabilities α where:

$$\alpha(\theta^*; \theta = \theta^{(s-1)}) = p(\theta = \theta^{(s-1)}|y)q(\theta^{(s-1)}; \theta = \theta^*) \tag{3.19}$$

$$\alpha(\theta = \theta^{(s-1)}; \theta^*) = p(\theta = \theta^*|y)q(\theta^*; \theta = \theta^{(s-1)}) \tag{3.20}$$

where $\alpha(\theta^*; \theta = \theta^{(s-1)})$ denotes the acceptance probability when $p(\theta)$ transits from θ^* to $\theta^{(s-1)}$.

Thus, equation 3.18 can be modified by multiplying the corresponding acceptance probability α on both sides so as to satisfy the detailed balanced condition. This can be written as:

$$p(\theta = \theta^*|y)q(\theta^*; \theta = \theta^{(s-1)})\alpha(\theta^*; \theta = \theta^{(s-1)}) = p(\theta = \theta^{(s-1)}|y)q(\theta^{(s-1)}; \theta = \theta^*)\alpha(\theta = \theta^{(s-1)}; \theta^*) \tag{3.21}$$

Redefined the newly-constructed transition matrix as q', that is,

$$q'(\theta^*; \theta = \theta^{s-1}) = q(\theta^*; \theta = \theta^{(s-1)})\alpha(\theta^*; \theta = \theta^{(s-1)}) \tag{3.22}$$

$$q'(\theta^{(s-1)}; \theta = \theta^*) = q(\theta^{(s-1)}; \theta = \theta^*)\alpha(\theta = \theta^{(s-1)}; \theta^*) \tag{3.23}$$

Equation 3.21 can be rewritten as:

$$p(\theta = \theta^*|y)q'(\theta^*; \theta = \theta^{(s-1)}) = p(\theta = \theta^{(s-1)})q'(\theta^{(s-1)}; \theta = \theta^*) \tag{3.24}$$

Equation 3.24 then satisfies detailed balance condition.

Since detailed balance condition is sufficient to the convergence of a Markov chain to a target stationary density, equation 3.24 says that the stationary distribution of the Markov chain q' is $p(\theta)$. Therefore, in theory we can sample from q' and expect that given sufficient iterations the sample density will converge to the target distribution $p(\theta)$.

Looking at equation 3.21, acceptance probability $\alpha(i, j)$ can be interpreted as the probability that a transition matrix $q(i, j)$ is accepted when $p(i)$ moves from state i to state j, $p(j)$. Similar to the idea in the acceptance-rejection method, a random draw u from the uniform density $U(0, 1)$ is taken and is then compared with α of a draw from q. If $\alpha > u$, then the latest draw from q is accepted; otherwise, the latest draw is dropped and the previous draw is returned to. This procedure underlies the Metropolis sampling method.

In practice, the value of acceptance probability α can be too small to be efficient when compared with u. Therefore, it is necessary to enlarge its value to improve the efficiency of sampling. Since α is embedded with the meaning of probability, it cannot exceed 1. From equation 3.21 it can be seen that both sides of the equation can be scaled up until the α on one side reaches maximum possible value 1. This operation will result in an updated value of acceptance probability, which equals $min[\frac{p(\theta=\theta^*|y)q(\theta^*;\theta=\theta^{(s-1)})}{p(\theta=\theta^{(s-1)}|y)q(\theta^{(s-1)};\theta=\theta^*)}, 1]$. By this means, value of acceptance probability is scaled up without breaking detailed balance condition. This refinement makes Metropolis sampling into **Metropolis-Hastings sampling**.

Another crucial decision is the choice of a candidate generating density q. Either a symmetric or an asymmetric candidate distribution can be selected. A symmetric q means that a candidate is generated from a random walk $\theta^* = \theta^{(s-1)} + z$ where z is termed increment random variable, and the relative probabilities of moving between the candidate and the previous value are identical $q(\theta^*|\theta^{(s-1)}) = q(\theta^{(s-1)}|\theta^*)$. The choice of a q with these characteristics will produce a random walk chain MH algorithm. In comparison to a symmetric q, an asymmetric q implies that $q(\theta^*|\theta^{(s-1)}) \neq q(\theta^{(s-1)}|\theta^*)$ and $q(\theta^*)$ is independent of $q(\theta^{(s-1)})$. The chosen of such a q will produce an independence chain MH algorithm. Asymmetric q assigns weights to candidate values to account for the possibility that some candidate values may be more likely to be selected than others. In the case of a reasonably large sample size, the posterior density would approximate a Normal, and therefore a symmetric candidate generating density q would suffice.

The acceptance probability α can be increased to 1 if the transition Markov chain is composed of a sequence of conditional distributions along the coordinate axis (Liu, 2008). Such sampling strategy of drawing from conditional densities rather than from the full posterior distributions is termed as **Gibbs sampling**. For a Gibbs sampler, only the movements along one coordinate axis directed by the transition matrix each time are retained. Given any coordinate j, one Gibbs draw along this coordinate axis requires that the corresponding transition matrix only imposes influence on this axis, that is to say (Ross, 2013, Section 11.3):

$$q^{Gibbs}(\theta^*; \theta = \theta^{(s-1)}) = \begin{cases} p(\theta_j^*|\theta_{-j}^{(s-1)}, y) & if \ \ \theta^*_{(-j)} = \theta^{(s-1)}_{(-j)}; \\ 0 & otherwise \end{cases} \tag{3.25}$$

where $(-j)$ means excluding j and hence θ is decomposed into (θ_j, θ_{-j}). Based on 3.25, the ratio in the expression of acceptance probability in Gibbs sampler can be expressed as:

$$\frac{p(\theta = \theta^*|y)q^{Gibbs}(\theta^*; \theta = \theta^{(s-1)})}{p(\theta = \theta^{(s-1)}|y)q^{Gibbs}(\theta^{(s-1)}; \theta = \theta^*)} =$$

$$\frac{p(\theta = \theta^*|y)p(\theta_{-j}^{(s-1)}; \theta = \theta_j^{(s-1)})}{p(\theta = \theta^{(s-1)}|y)p(\theta_{-j}^{(s-1)}; \theta = \theta_j^*)} = \frac{p(\theta_{-j}^{(t-1)})|y}{p(\theta_{-j}^{(s-1)})|y} = 1 \quad (3.26)$$

Thus, Gibbs sampler is a special case of Metropolis-Hastings with no rejection.

Therefore, one iteration in Gibbs sampler can be carried out by sampling from the conditional distribution of each parameter given the current value of all the other parameters until all the parameters have been updated by their conditional distributions. This cycle is repeated until enough draws are taken.

To sum up, assuming there are B parameters, then drawing from a basic Gibbs sampler involves (Koop, 2003, p.63, Chapter 4):

- Preinitialise starting value, $\theta^{(0)}$, for $s = 1, 2, \ldots S$:
- Take a random draw, $\theta_{(1)}^{(s)}$ from $p(\theta_{(1)}|y, \theta^{(s-1)_{(2)}}, \theta^{(s-1)_{(3)}}, \ldots \theta^{(s-1)_{(B)}})$.
- Take a random draw, $\theta_{(2)}^{(s)}$ from $p(\theta_{(2)}|y, \theta^{(s)_{(1)}}, \theta^{(s-1)_{(3)}}, \ldots \theta^{(s-1)_{(B)}})$.
- Take a random draw, $\theta_{(3)}^{(s)}$ from $p(\theta_{(3)}|y, \theta^{(s)_{(1)}}, \theta^{(s)_{(2)}}, \theta^{(s-1)_{(4)}}, \ldots \theta^{(s-1)_{(B)}})$.
  ...

B. Take a random draw, $\theta_{(B)}^{(s)}$ from $p(\theta_{(B)}|y, \theta^{(s)_{(1)}}, \theta^{(s)_{(2)}}, \theta^{(s)_{(3)}}, \ldots \theta^{(s-1)_{(B)}})$.

B+1. Return to step 2 until enough draws are taken.

Compared with the MH algorithm, Gibbs sampling performs more efficiently since no rejection is produced during the sampling process. However, its reliance on conditional distribution implies that conditional densities need to be able to be determined from the joint posterior density. Moreover, the strong correlation between simulated samples from conditional densities may lead to slow mixing to the target distribution (Lynch, 2007). Therefore, MH sampling is a more general approach that can be resorted to when Gibbs sampling cannot be implemented or does not produce satisfying samples.

After the simulated samples are obtained, it is important to examine their convergence. First, to account for the iterations prior to the stationary Markov chain in MCMC methods, iterations in the burn-in period need to be discarded and only the simulated samples that are considered to be generated by the target distribution are retained so that features of parameters are computed only using samples outside the burn-in period. Second, the convergence and mixing of the retained samples can be evaluated by several methods. A straightforward approach is by checking the trace plots of the simulated samples. Fast convergence and good mixing behaviour can be a sign that the chain has reached its stationary distribution and has explored its space efficiently (Lynch, 2007).

The following two sections first brief the advantages of the Bayesian approach compared with the frequentist approach, and then apply Gibbs sampling to the estimation of a standard Tobit AIDS model.

3.2.3 Advantages of Bayesian Inference

There can be several advantages of using Bayesian methods compared with frequentist approaches to estimate regression parameters (Lynch, 2007). Fundamentally, the Bayesian approach takes coefficients to be estimated in the regression model as random variables. This randomness is explicitly expressed by Bayes' theorem and sample data are taken as known and fixed information. This angle implies that the goal of Bayesian estimation is to detail the entire distribution of the regression coefficients of interest. By contrast, the frequentist approach considers the regression coefficients in concern having certain fixed yet unknown values and uncertainty lies in the sampling process from the defined population. The aim therefore is to approximate the true values of those coefficients. The differences in these fundamental interpretations indicate that the frequentist approach relies on the Central Limit Theorem which assumes asymptotic normality of the sample statistics when statistical inference on population needs to be made using sample information. Comparatively for the Bayesian approach, since the coefficients taken as random variables are directly modelled within a Bayesian framework and their entire posterior distributions can be simulated, there is no need to rely on the Central Limit Theorem to conduct statistical inference. Second, it is straightforward to obtain distributions of the quantities that can not be directly estimated by the regression model but can be expressed as functions of those that can be directly estimated by the model. In addition, whenever there involves high dimensional integrals in the functions that express features of the parameter densities under investigation, the simulation methods in the Bayesian approach provides a relatively convenient path to approximate those integrals.

3.2.4 Standard Tobit AIDS model

In the context of the AIDS model and taking censoring into account by using the Tobit model (Tobin, 1958), the expenditure function can be formulated as follows:

$$\log e(u,p) = \alpha(p) + u\beta(p) \tag{3.27}$$

where

$$\alpha(p) = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2}\sum_k \sum_l \gamma^*_{kl} \log p_k \log p_l \tag{3.28}$$

$$\beta(p) = \beta_0 \Pi p_k^{\beta_k} \tag{3.29}$$

Substitute 3.28 and 3.29 into 3.27, the cost function expressed in expenditure share can be written as:

$$s_{ih} = \alpha_i + \sum_{j=1}^{m} \gamma_{ij} \log p_j + \beta_i \log \frac{e}{P} \tag{3.30}$$

where P is the price index defined by:

$$\log P = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2}\sum_k \sum_l \gamma_{kl} \log p_k \log p_l \tag{3.31}$$

and the parameter γ is defined as:

$$\gamma_{ij} = \frac{1}{2}(\gamma^*_{ij} + \gamma^*_{ji}) = \gamma_{ij} \tag{3.32}$$

The three restrictions ensuring the consistency between demand systems and the utility maximisation theory impose restrictions on parameters. To be specific:

Adding up restriction requires, for all j:

$$\sum_k \alpha_k = 1,\ \sum_k \beta_k = 0,\ \sum_k \gamma_{kj} = 0 \tag{3.33}$$

Adding up means that the total budget set is exhausted. Adding up is imposed by excluding one equation in demand system for estimation because adding up restriction implies that the sum of all errors equals 0, which makes the errors' covariance matrix singular and it cannot be utilised to depict the distribution of likelihood functions.

Homogeneity is satisfied if and only if, for all j:

$$\sum_k \gamma_{jk} = 0 \tag{3.34}$$

Homogeneity implies that the consumer is insensitive to proportional increases in price and income. *Symmetry* is satisfied provided:

$$\gamma_{ij} = \gamma_{ji} \tag{3.35}$$

Symmetry means that the effect of a marginal increase in the price of i on the quantity demanded of j is exactly the same as the effect of a marginal increase in the price of j on the quantity demanded of i.

In addition, a concave expenditure function requires that the Hessian matrix of the expenditure function, or equivalently its corresponding Slutsky matrix, to be *negative semidefinite*. The elements in the Slutsky matrix (M) can be computed as:

$$M_{ij} = \gamma_{ij} + \beta_i\beta_j \ln\frac{e}{P} - s_i\delta_{ij} + s_i s_j \tag{3.36}$$

$$\delta_{ii} = 1 \;\; if \;\; i = j \tag{3.37}$$

$$\delta_{ij} = 0 \;\; if \;\; i \neq j \tag{3.38}$$

where δ is the Kronecker delta. The negative semidefiniteness of the Slutsky matrix implies that the own-price substitution effects are negative.

These restrictions are imposed on the estimated coefficients in the linearised AIDS model to ensure that the estimated demand system is consistent with the utility maximisation theory and with the underlying well-behaved preference.
Thus, the AIDS model to be estimated is the linearised 3.30 where the price index shown in equation 3.31 is approximated by Stone's price index $\log P^* = \sum w_k \log p_k$. Considering the interpretation of zero expenditure shares, the empirical model of latent shares of LAIDS (Linearised AIDS) is written as:

$$s^*_{ih} = \alpha_i + \sum_{j=1}^{m} \gamma_{ij} \ln p_{jh} + \beta_i \ln\frac{e_h}{P_h} + v_{ih} \tag{3.39}$$

$$i = 1, \ldots, m \tag{3.40}$$

$$h = 1, \ldots, T \tag{3.41}$$

$$(v_{1h}), \ldots (v_{mT})' \sim N(0, \Sigma) \tag{3.42}$$

The mapping that links the observed expenditure shares s_{ih} and the latent shares s^*_{ih} to ensure that all observed shares for each observation sum to unity can be written as Wales and Woodland (1983):

$$s_{ih} = \begin{cases} 0 & if\ s^*_{ih} \leq 0 \\ \dfrac{s^*_{ih}}{\sum_{j \in J} s^*_{jh}} & if\ s^*_{ih} > 0 \quad i = 1, 2, \ldots m \end{cases} \tag{3.43}$$

where $J \equiv \{j : y^*_j > 0\} \bigcap \{1, 2, \ldots, m\}$ is the set of subscripts for all positive shares for each observation. Such mapping guarantees that all expenditure shares for one observation will satisfy the adding up restriction which requires the sum of shares equals 1 when the latent shares are combined with the observed shares. With this mapping mechanism, the joint distribution of shares will not vary after dropping any equation for estimation (Wales and Woodland, 1983).

Stacking all i and h to matrices and deleting the mth equation, model to be estimated 3.42 can be written in a compact form as:

$$s^* = X\Lambda + v \tag{3.44}$$

where

$$X = I_{(m-1)} \otimes x \tag{3.45}$$

$$x_1 = (x_{11}, x_{12}, \ldots, x_{1T})' \tag{3.46}$$

$$x_{1t} = \left(1, \ln p_{1,t}, \ln p_{2,t}, \ldots \ln p_{m,t}, \ln \frac{e_t}{P_t}\right)' \tag{3.47}$$

$$s^* = (s^*_{1,1}, \ldots, s^*_{1,T}, s^*_{2,1}, \ldots, s^*_{2,T}, \ldots, s^*_{(m-1),1}, \ldots, s^*_{(m-1),T})' \tag{3.48}$$

$$\Lambda = (\alpha_1, \gamma_{11}, \gamma_{12}, \ldots, \gamma_{1,m}, \beta_1, \ldots, \alpha_{(m-1)}, \gamma_{(m-1)1}, \gamma_{(m-1)2}, \ldots, \gamma_{(m-1)m}, \beta_{m-1})' \tag{3.49}$$

$$v = (v_{1,1}, V_{1,2} \ldots, v_{1,T}, v_{2,1}, v_{2,2}, \ldots, v_{2,T}, \ldots, v_{(m-1),1}, \ldots, v_{(m-1),T})' \tag{3.50}$$

where $p_{m,t}$ is the price of the mth good to the tth observation; e_t is the total expenditure for the tth observation; P_t is the Stone's price index.

Symmetry restriction requires that:

$$\gamma_{ij} = \gamma_{ji}\,, \quad \forall\ i, j \tag{3.51}$$

Homogeneity restriction requires that:

$$\sum_j \gamma_{ij} = 0 \ \ \forall \ j \tag{3.52}$$

Negativity restriction requires that the eigenvalues of the Slutsky matrix with elements as written in equation 3.38 are smaller than or equal to 0. This restriction will be imposed during the sampling process by an accept/reject filter therefore it is not explicitly included in the constructed restriction matrix in the following paragraph. Adding up restriction is automatically satisfied after scaling latent share s^* through the mapping mechanism expressed in equation 3.43, hence it is also ignored here.

Following Tiffin et al. (2011), the restrictions of homogeneity and symmetry can be expressed as:

$$R\Lambda^* = 0 \tag{3.53}$$

where R is an $r \times (m-1)((m-1)+2)$ matrix defining the restrictions and Λ^* is the restricted Λ. To reparameterise the model to include the restriction on coefficients, first define a $(km-r) \times km$ orthonormal matrix $R_\perp$ such as:

$$RR'_\perp = 0 \tag{3.54}$$

$$R_\perp R'_\perp = I \tag{3.55}$$

The restricted Λ^* can be written as:

$$\Lambda^* = R'_\perp \tilde{\Lambda} \tag{3.56}$$

where $\tilde{\Lambda}$ is a $(k(m-1)-r) \times 1$ vector of distinct parameters, and r is the number of restrictions. The restricted model can be written as:

$$s^* = X_1 R'_\perp \tilde{\Lambda} + v \tag{3.57}$$

$$s^* = W\tilde{\Lambda} + v \tag{3.58}$$

where

$$W = X_1 R'_\perp \tag{3.59}$$

Thus, to sum up, the model to be estimated is:

$$s^* = W\tilde{\Lambda} + v \tag{3.60}$$

$$v \sim MVN(0_{mT}, \Sigma \otimes I_T) \tag{3.61}$$

With an indicator function D indicating if the observed s is censored at 0 or not:

$$D = \begin{cases} 1 & if \quad s = 0 \\ 0 & if \quad s > 0 \end{cases} \tag{3.62}$$

Augmented s, that is s_{aug} can be written as:

$$s_{aug} = Ds^* + (1 - D)s \tag{3.63}$$

This says that the augmented s equals observed s when observed s is greater than 0, while equals latent s^* when observed s equals 0. This augmented s_{aug} then constitutes the new data range for the computation of Gibbs sampling.

3.2.5 Gibbs sampling procedures for the Tobit AIDS model

Gibbs sampling (Casella and George, 1992) is part of a wider class of Markov Chain Monte Carlo methods. It involves drawing from conditional distributions instead of marginal distributions to avoid the difficulty of integrating over the joint distribution for a multivariate distribution.

Gibbs sampling in the context of the Tobit model involves the introduction of latent shares s^* treated as another unknown parameter of interest. These arise in case a community is observed to not have purchased a given food group. The use of latent variables in this way is termed as the data augmentation method, as developed by Tanner and Wong (1987). With data augmentation, there are now three parameters of interest $(\tilde{\Lambda}, \Sigma, s^*)$.

Assuming noninformative priors as $p(\tilde{\Lambda})$, $p(\Sigma) = p(H^{-1})$ and $p(s^*|\tilde{\Lambda}, \Sigma)$ and specifying their distributions with hyperparameters as:

$$\tilde{\Lambda} \sim N(\mu_{\tilde{\Lambda}}, V_{\tilde{\Lambda}}) \tag{3.64}$$

$$H \sim W(a, b) \tag{3.65}$$

A noninformative prior means that only vague prior information is included and therefore information in posterior is dominated by that from the likelihood.

Their posterior density can be expressed as given in Kasteridis et al. (2011):

$$
\begin{aligned}
p(\tilde{\Lambda}, \Sigma, s^*) &\propto p(\tilde{\Lambda})p(\Sigma)p(s^*|\tilde{\Lambda}, \Sigma)p(s|s^*, \tilde{\Lambda}, \Sigma) \\
&= \prod_{t=1}^{T}\Bigg\{\left[\prod_{i=1}^{m-1}\left(I(s_{ti=0})I(s^*_{ti} \le 0) + I(s^*_{ti} > 0)I\left(s_{ti} = \frac{s^*_{ti}}{\sum_{j\in J_t} s^*_{tj}}\right)\right)\right] \times \\
&\quad p(s^*_{ti}|\tilde{\Lambda}, \Sigma)\Bigg\}p(\tilde{\Lambda})p(\Sigma)
\end{aligned}
\tag{3.66}
$$

where $I(.)$ is the indicator function. By decomposing the posterior distribution into its constituent part and obtaining the conditional distributions of each of the three parameters of interest, the Gibbs sampler samples iteratively from the full conditional distributions of $\tilde{\Lambda}, \Sigma$ and s^*, where latent s^* is sampled from the truncated Normal distribution for the censored s.

$$
\tilde{\Lambda}|s, s^*, \Sigma \sim N(D_{\tilde{\Lambda}} d_{\tilde{\Lambda}}, D_{\tilde{\Lambda}}) \tag{3.67}
$$

where

$$
D_{\tilde{\Lambda}} = \left(W'(\Sigma^{-1} \otimes I_T)W + V_{\tilde{\Lambda}}^{-1}\right)^{-1} \tag{3.68}
$$

$$
d_{\tilde{\Lambda}} = W'(\Sigma^{-1} \otimes I_T)s_{aug} + V_{\tilde{\Lambda}}^{-1}\mu_{\tilde{\Lambda}} \tag{3.69}
$$

and

$$
H|\tilde{\Lambda}, s, s^* \sim W\left(a + T, \left[b^{-1} + (s_{aug} - W\tilde{\Lambda})'(s_{aug} - W\tilde{\Lambda})\right]\right) \tag{3.70}
$$

and

$$
s^*|\tilde{\Lambda}, \Sigma, s \sim TN_{(-\infty,0]}(W\tilde{\Lambda}, \Sigma), \;\; if \;\; s = 0 \tag{3.71}
$$

Augmented s_{aug} is shown in equation 3.63. Going through 3.67 to 3.71 constitutes one complete sampling loop, and the Gibbs sampler can be carried out by drawing iteratively throughout this loop until the simulated samples reach the underlying stationary distribution.

After completing these steps many times, estimates of the distributions of the coefficients specified in the linearised AIDS model in latent share form can be obtained. The estimates can then be used to compute price and expenditure elasticities and estimated shares for different projected scenarios.

3.3 Elasticity computation

With the complete information of the linearised AIDS in hand, quantities that are not estimated directly in the AIDS model but can be computed using the estimated parameters can be calculated.

Price and expenditure elasticities are then calculated following Buse (1994) :

$$e_i = 1 + \frac{\beta_i}{s_i} \tag{3.72}$$

$$e_{ij} = -\delta_{ij} + \left(\frac{\gamma_{ij}}{s_i}\right) - \left(\frac{\beta_i}{s_i}\right) s_j \tag{3.73}$$

where e_i denotes the expenditure elasticity of the ith group; e_{ij} the price elasticity of group i w.r.t j; β_i is the estimated coefficient of the real expenditure term in the ith equation; s_i is the expenditure share for the ith group; γ_{ij} is the coefficient of the jth price for the ith group; and δ_{ij} is the Kronecker delta.

3.4 Estimating effects of projected scenarios

Viewing social development in the long term, an attempt is made to project food consumption patterns in 2050 urban China. The goal of doing scenario analyses is to investigate communities' responses in terms of their dietary pattern to a fast changing social environment with a particular focus on its transforming food environment and to examine how these responses can be shifted by improving dietary knowledge level. As a reminder, the focus on these two aspects can be justified by two reasons. First, population ageing and the urbanisation process appear to be irreversible trends in China, whilst the food environment may well be influenced by government policies. Second, dietary knowledge improvement has the potential to enhance population diet quality. Since the health implications of food choice is the major concern, two broad food groups, i.e. vegetables and fruits, and oils and sugars are selected as indicators of the healthy aspect and the relatively unhealthy aspect of diet respectively.

The four scenarios intend to depict the picture of food consumption patterns in the context of 2050 urban China. The baseline situation assumes the proportion of seniors aged 65 and over to reach the level of 28%. Uncertainty in the changing food environment means that it is projected that either modern supermarkets will become more convenient than traditional wet markets or the opposite will happen.

These two situations illustrate two possible directions of the evolving food retail market in urban China. Then, both scenarios are augmented by increasing dietary knowledge with the aim of examining if such efforts may ameliorate diet quality in 2050 urban China.

To be specific, projected scenarios are:

Baseline scenario: Proportion of seniors aged 65 and over projected to 28%.

S1: Increasing relative convenience of modern supermarkets against wet markets.

S2: Decreasing relative convenience of modern supermarkets against wet markets.

S3: Increasing relative convenience of modern supermarkets against wet markets plus improving dietary knowledge.

S4: Decreasing relative convenience of modern supermarkets against wet markets plus improving dietary knowledge.

To estimate the effects of scenarios on food choice, two steps were carried out. First, the projected expenditure share of each food group under four scenarios as well as the baseline scenario were estimated by using the simulated coefficients and the average values of the variables specified in the LAIDS with the one(s) corresponding to each scenario taken to its(their) projected values. Second, the effects of each scenario are reflected by percent change in expenditure share between the four scenarios and the baseline scenario.

3.4.1 Grouping communities based on their healthy and unhealthy food intake

With the long-term goal of improving diet quality, communities are grouped and examined based on their consumption of foods that tend to have unambiguous health implications. Specifically, two food groups are taken as nutrition indicators of a community's diet. One represents the "healthy" aspect of diet which is the vegetable and fruit group; the other is the oil and sugar group that is used to measure the relatively unhealthy side of diet. Based on these two criteria, communities are classified into "most healthy", "median healthy" and "least healthy" communities. Effects of policy scenarios are examined for all communities and six community groups are classified by their vegetable and fruit intake and oil and sugar intake. Besides the average effects for all communities, particular attention is paid to the two least healthy community groups since their diet is the most problematic and this implies greater health risks.

To be more specific, communities are grouped one time based on their oil and sugar intake: Group 1 indicates consumption quantity below the lower boundary recommended in the Chinese dietary guidelines made by the Chinese Nutrition Society in 2007; Group 2 corresponds to those with quantity intake in between the lower boundary and the upper boundary; and Group 3 means an over-intake above the maximum recommended level. Since overconsumption of oils and sugars in China is considered to be a risk factor to obesity and other health problems, restricted intake quantity is often proposed. Therefore, communities which fall into Group 1 indicate the most healthy behaviour in terms of their oil and sugar consumption; whilst those classified into Group 3 are the least healthy in terms of their oil and sugar consumption.

In a similar way, communities are classified into three groups based on their vegetable and fruit consumption. Using the lower and upper boundaries of recommended levels advised in the Chinese dietary guidelines, communities are divided into three groups with Group 1 consuming more than the upper boundary recommended, Groups 2 falling in between the lower and upper boundaries and Group 3 below the lower boundary. Since, generally speaking, vegetable and fruit intake is considered to be healthy and is encouraged, communities classified into Group 1 are considered to be most healthy in their vegetable and fruit consumption behaviour, whereas those in Group 3 are the least healthy for their vegetable and fruit eating habit.

The notations used to label each community group are summarised in Table 3.1.

Table 3.1: Notation used for the healthy and unhealthy community groups

Notation	Group definition	Measurement
All groups	All communities	
Veg Grp 1	Most healthy in vegetable and fruit intake	Most intake in quantity
Veg Grp 2	Medium healthy in vegetable and fruit intake	Medium intake in quantity
Veg Grp 3	Least healthy in vegetable and fruit intake	Least intake in quantity
Oil Grp 1	Most healthy in oil and sugar intake	Most intake in quantity
Oil Grp 2	Medium healthy in oil and sugar intake	Medium intake in quantity
Oil Grp 3	Least healthy in oil and sugar intake	Least intake in quantity

Chapter 4

Data

Secondary data from the China Health and Nutrition Survey (CHNS) is utilised to achieve the research objectives. This chapter first describes the survey method of the CHNS, then delineates the data cleaning procedures, which is followed by a presentation of descriptive statistics of the key variables defined and investigated.

CHNS data excluding community level data can be accessed from the website of the CHNS. Access to CHNS community level data needs to be applied for separately.

4.1 Data source

The CHNS is a joint project between the Carolina Population Centre (CPC), University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety, China Centre for Disease Control and Prevention (CCDCP). The Survey has been conducted in 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011. Eight provinces from northern to southern China including Liaoning, Shandong, Henan, Jiangsu, Hubei, Hunan, Guizhou and Guangxi were covered in the samples before 1997. From 1997 another province Heilongjiang was added and in 2011 three megacities Beijing, Shanghai and Chongqing enrolled into the Survey. After the pilot survey in 1989, from 1991, the CHNS comprised five individual surveys: the Household Survey, the Nutrition Survey, the Physical Examination Survey, the Community Survey and the Ever-married Women Survey. From 1997 a new individual survey of Energy Record was added. From 2004, the CHNS was reorganised into a Household Survey, an Adult Survey, a Child Survey, a Nutrition Survey and a Community Survey. In 2009, three new surveys of Blood Collection, Toenail Collection and Boy Maturation were added and in 2011 the Toenail Collection was removed. According to the information provided on the CHNS website, the CHNS field work conducted in China was carried out by "trained nutritionists who are otherwise professionally engaged in nutrition work in their own counties and who have participated in other national surveys", and a specific three-day training was provided for those who were involved in the collection of the dietary data (China Health and Nutrition Survey (CHNS), 2016).

A sample in each province was drawn following a multistage random cluster process. Counties and cities in each of the nine provinces were stratified by three income levels, i.e. low, middle and high income groups, and a weighted sampling scheme was used to randomly select four counties and two cities in each province. For each sampled city, its urban area was first divided into two geographical regions, then a district was randomly sampled from each region. For each district, a street was then randomly selected, within which a community (an urban community) was finally randomly sampled. Similarly, each suburban area was firstly divided into two geographical regions, then one community (a suburban community) was directly randomly sampled for each region. As for each sampled county, one community in the county seat (a town community) was randomly sampled; and three other communities in this county (three rural village communities) were randomly selected from three townships that were firstly randomly sampled from the three income strata of all townships in this county. Then in each community, twenty households were randomly selected and all household members were surveyed from 1991. In the latest accessible 2011 survey, data of 27447 individuals from 5884 households covering 60 urban neighbourhoods, 60 suburban neighbourhoods, 42 town communities and 126 village communities (in total 288 communities) are documented. The population in the nine provinces covered by the 2011 CHNS accounted for approximately 47 percent of China's 2010 population (Zhang et al., 2014).

The CHNS collected detailed data on diet, physical activity, health (including anthropometrics), income/employment and demography. Comprehensive community economic, social and infrastructural information data were also collected.

Detailed household and individual demographic data including household composition, household assets, income and employment, educational attainment were investigated by the Household Survey, Adult Survey and Child Survey.

Food consumption data were collected at both household and individual level in the Nutrition Survey. Detailed household food consumption data were obtained by calculating changes in home food inventory on three consecutive days randomly selected over a week. Specifically, all available foods in households, including purchased, stored and home produced were recorded before the initiation of the survey. Then all foods that were brought into the household unit were weighed and recorded during the day. Wastage was measured by either weighing or by estimating when direct weighing is not possible. At the end of the survey, all remaining foods were weighed and their weights were recorded again. Specific food items were recorded following the food codes in the Chinese Food Composition Tables (CFCT) published in various years. Thus, the nutrient intake data in the CHNS can be calculated by converting food consumption quantity to nutrient intake quantities based on the unit nutrient values in the CFCTs. In parallel with the collection of the household food intake data, individual food diaries over the identical three days were taken for household members on a 24-hour recall basis during the interviews. Individual level dietary data were then utilised to counter-check those computed from separately collected household level food intake data. Whenever substantial divergences were found between the two, dubious households as well as individuals were revisited to identify and clarify the discrepancies.

Apart from the detailed household dietary data, community level data of food markets and price of market goods and services were collected in the Community Survey. "Community" in this dataset refers to the urban community, suburban community, town community and village community that were sampled. As a term loosely defined, "a residential area and its service facilities constitute a *community*" (Institute of Nutrition and Food Hygiene, China Centre for Disease Control and Prevention, 2006, p. 58). Questions on food markets in the community survey investigates both "free markets" and "large stores, supermarkets, hypermarkets and cooperatives" for the information of their presence, location and size. The name "free market" used in the CHNS refers to fresh markets, wet markets or farmers' markets in the context of China. "Free market" also incorporates small-scale street stores that can be easily found in traditional fresh and open markets (Institute of Nutrition and Food Hygiene, China Centre for Disease Control and Prevention, 2006, p. 62). The "community leader", who is believed to be a "knowledgeable respondent" on community infrastructure and services, and staff of Food Safety/Investigation in the local CCDCP were interviewed for the above information (China Health and Nutrition Survey (CHNS), 2016). If the information could not be obtained from the chosen interviewees, field investigations to the local markets were conducted by the interviewers directly.

Forty-four community level food prices were collected for both free markets and supermarkets. The forty-four food prices are composed of ten broad categories which include nine specific food items belonging to food grains, ten to cooking oil and sugar, five to vegetables and fruits, six to meat and poultry, one to fresh milk, four to preserved milk products, four to fishes, two to bean curd, three to alcohol and two to soft drinks. Except the liquids, the majority of the food prices are those of the raw food materials. The complete price table of food items can be found in the Community Survey. Because of the wide variety and diversity of specific food items available for sale, it was the most commonly and the most often eaten variety of foods that were chosen for their price information (Institute of Nutrition and Food Hygiene, China Centre for Disease Control and Prevention, 2006, p. 61&64). Free markets and supermarkets that were selected for the price information of each chosen food item were those that were visited *most often* by the village/neighbourhood residents for that particular type of food. Prices were collected by asking community officials and by visiting appropriate vendors.

This study merely employed data from the surveys for 2004, 2006 and 2009, and focused on urban, suburban and town areas. Nine provinces covered in the dataset highlighted in dark green are illustrated in Figure 4.1. It needs to be noticed that these nice provinces can hardly be nationally representative. Data before wave 2004 were not incorporated since it is only from 2004 that relatively comprehensive food market data were collected; and household dietary intake data of 2011 is incomplete (only condiments such as oils were recorded) which resulted in the abandonment of the latest 2011 wave data. Rural villages were excluded due to the relatively low level of supermarket penetration during the years between 2004 and 2009 and the commonly seen phenomenon of part self-sufficiency in foods. Community level information was obtained from three waves of Community Surveys; dietary data from Nutrition Surveys; demographic information from Household Surveys; and dietary knowledge from Adult Surveys. It needs to be noted that it is the household food consumption data in the Nutrition Survey that were analysed. Since household food records were taken using the weighing method for three days, it can more accurate than individual food data collected by three-day recall method. Due to the reason that household food intake data focus on food consumed by the entire family at home, foods eaten outside home are excluded. Therefore, this thesis only investigates communities' at-home food consumption pattern. Questionnaires for all the surveys can be accessed from the CHNS website freely.

Figure 4.1: All provinces ever participated in the CHNS

Source: China Health and Nutrition Survey website

4.2 Data cleaning

This section explains the primary procedures performed from raw data to the prepared variables analysed by the model. The first goal of data cleaning is to detect unreasonable data entries for food intake and price data; the second goal is to bridge the gap between highly disaggregated food items recorded in the Nutrition Survey and the limited price information in the Community Survey by constructing *elementary* food groups whose prices can be approximated by the available price data; the third goal is to define food groups that will be analysed within the framework of demand system modelling; and the fourth goal is to define constructed variables that are included as key driving factors in the model.

(Only data from 2004, 2006 and 2009 and only those of city, suburban and town areas were extracted from original dataset for analysis.)

4.2.1 Detecting potential outliers in household nutrition data

Food names in the Nutrition Survey are recorded by food codes in accordance with those in Chinese Food Composition Table (CFCT) Book 1 and Book 2. CFCT Book 1 documents the unit nutrient information of 1506 food items and CFCT Book 2 documents that of 757 food items. CFCT Book 1 specialises in raw food materials (core foods) and commonly-eaten foods whilst Book 2 tends to focus more on highly-processed and novel foods with only 100 kinds of core foods frequently consumed recorded.

The cleaning of household food intake data had two steps. The first was to match food codes in dietary data with food codes in CFCTs in both Book 1 and Book 2. Those unmatched entries were taken as tempos and were deleted. This operation detected 864 suspicious entries which accounted for 0.69% of all food records. Negative and missing values in food quantity were also considered as mistakes and were deleted. This resulted in a loss of 5371 entries which accounted for 4% of data. Second, per capita per day calorie intake was calculated for each household, and those detected having extremely large or small values were also identified as potential mistakes created during data entry and were left out of the analysed data. Household per head per day calorie intake value was computed by dividing household total calorie intake by household total person days adjusted by an adult equivalent scale (AES) coefficient. (The AES coefficient table is documented in Appendix B.) Household person day information was recorded in company with the household food intake data in the Nutrition Survey. One person and 24 hours constitute one person day (Institute of Nutrition and Food Hygiene, China Centre for Disease Control and Prevention, 2006, p. 56). That is, if one person has all three meals (breakfast, lunch and dinner) during one day his/her person day value would be 1. The concept of "person day" accounts for the number of persons who actually have meals at home and the number of meals that are actually eaten at home. By taking into consideration both of these two numbers, a more accurate match between household food consumption quantity and household size can be achieved. The AES coefficient takes care of the substantial differences in the household calorie requirements resulting from varied household composition. Based on gender, age and physical activity level information of individual household members, AES coefficients from "Chinese DRIs" (DRI stands for Dietary Reference Intakes) were fetched for each individual and was used to adjust computed individual person days (Chinese Nutrition Association, 2013). According to "Chinese DRIs", a "standard" individual is a male aged between 18 and 50 with low physical activity level. Then adjusted individual person days were added for each household and household per capita per day calorie intake was calculated. The extreme values observed in the computed household per capita per day calorie intake were therefore regarded as mistakes and the corresponding households were dropped. Extreme values were decided to be those that were larger than 15000 KCal/day or smaller than 500 KCal/day. This operation detected in total 28 suspicious households that were excluded.

After getting rid of households with "unreasonable" food quantity data, food items from CFCT Book 2 were excluded and only food items from CFCT Book 1 were included in the demand system analysis. The reason for the abandonment of the entire Book 2 is due to the very limited food price information. Most available prices were those of the raw food materials or lightly-processed food items (for example bean curd) whose prices could be far away from those of the highly-processed novel foods which dominate Book 2. To avoid wild approximation for the elementary level food group prices, only food items in CFCT Book 1 were maintained. As a consequence, 4% food records covering 339 unique food items were lost. The remaining 96% food records coming from 1025 unique food items were then aggregated to form the elementary forty food groups.

To put the very specific 1025 food items into 40 groups, first 1025 foods were categorised into 92 food groups following the food classification definition in CFCT Book 1. These food groups were then made into 40 food groups based on the similarities in terms of their food nature and their consumption habit and have 40 food prices available. Thus, it needs to be noticed that even the elementary level 40 food group prices were approximated heavily. Until this stage, household level food quantity data were cleaned and prepared.

4.2.2 Preparing elementary level data for communities

The next step was to aggregate household food quantity data to community level and to approximate community food intake by calculating the community per capita per day intake quantity for the elementary 40 food groups. Total community food intake quantity was computed by adding up the quantities of households within that community, and the total number of community members generating that amount of quantity was calculated by summing up the households' person days. As described in the paragraph examining household per head per day calorie intake, compared with using the sum of household size, total person days could be closer to the actual number of individuals and the actual number of meals corresponding to the food quantity. It needs to be noticed that person days were not adjusted by the AES in the calculation of the community per capita value with the aim to maintain the heterogeneity in food preference because of differences in community age structure.

Up to this step, community level food intake data at elementary 40 food group level were prepared. In total, 328 communities were included in the cleaned food consumption data, with 108 for wave 2004, 110 for wave 2006 and 110 for wave 2009.

The cleaning of community food price data involved three steps. First, missing values in the raw supermarket prices were cleaned following the same rule of cleaning the missing in fresh market prices adopted by the CHNS. (Fresh market prices had been cleaned by the CHNS team.) Specifically, missing supermarket prices were imputed in the sequence of:

1. imputed from fresh market prices of the same community
2. imputed from previous survey prices
3. imputed from subsequent survey prices
4. imputed by taking the mean of province + urban/rural status
5. imputed by taking the mean of province

The reason for prioritising the similarity of prices within the same community in the same year instead of the same community but different years or the averaged provincial level price of the same year, is that chronologically the first interval across two years from 2004 and 2006 and the second interval over three years from 2006 to 2009 are not short periods of time, and hence it is expected that prices in the same community could have changed substantially over these intervals, and geographically the communities surveyed might vary significantly in their economic development status which means it is more likely that prices within the same community would be more similar compared with the prices of different communities/provinces. Therefore, missing supermarket and large-store prices were first replaced by fresh market prices of the same community of the same year. Cleaned supermarket prices were then compared with their fresh market counterparts. If there was a five times difference between the two types of prices for the same food product, the price of the supermarket product was replaced by its fresh market counterpart. Since fresh market prices had been cleaned with no extreme values left, the effects of "unreasonable" extreme records in supermarket prices could be reduced.

After obtaining the cleaned fresh market and supermarket price data, prices of cottonseed oil, tea oil and liquor Maotai were exluded since their values are missing for at least one entire wave. The price of the liquor Luzhou Laojiao was also dropped since its price can be too expensive to be representative to the approximated price of commonly taken spirits which is a component of drinks. The prices of solid food items were measured in Yuan/gram, however those of the liquids were in Yuan/ml. To ensure the consistency of unit with the measurement unit in CFCTs, liquid volume was converted to mass by assuming their density as 100 g/cm^3 (as water density). Thus, the price unit of five liquids fresh milk, local beer, local liquor, coca-cola and Jian Li Bao were converted to Yuan/gram in this way.

Next, fresh market prices and supermarket prices were mixed by taking their geometric averages. Geometric averages were taken instead of arithmetic averages with the aim to alleviate the influence of potential extreme values.

Lastly, since three years' prices were involved, prices in 2004 were chosen as the base year and prices in 2006 and 2009 were deflated using consumer food price indices at provincial urban/rural level documented in provincial government Statistical Yearbooks. Since the consumer price index (CPI) presented in the government Statistical Yearbooks is chained and uses the previous year as the base year, a fixed-base index with 2004 as the base year was calculated by multiplying the chained index. Original general CPI and food CPI as well as converted fixed-base general and food CPI for urban and rural areas by province can be found in Appendix B.

Thus, forty cleaned food prices were prepared and ready to be matched with the forty elementary food group quantities.

4.2.3 Aggregating food groups from elementary level to the defined six groups

40 elementary level groups of food quantity and price data were then aggregated to six broad food groups so that it is feasible to answer the research questions by estimating the specified demand system.

40 food groups were classified into six food groups with the aim of directly address the research questions. As presented in Table 4.1, the six defined food groups are: 1) grains; 2) commonly eaten animal products including pork, poultry

and egg and their products; 3) less commonly eaten animal products including dairy products, beef, lamb and fish and their products; 4) vegetables, fruits and legumes; 5) oils and sugars; and 6) snacks, drinks and other condiments. Comparing this grouping method with the food groups suggested in the Chinese food guide pyramid and dietary guidelines, the fourth group, vegetables and fruits, tend to be considered as healthy foods, while the fifth and the sixth group are usually considered as "unhealthy" in the sense that there would be a recommended restricted amount for their intake (The Chinese Nutrition Society, 2011).

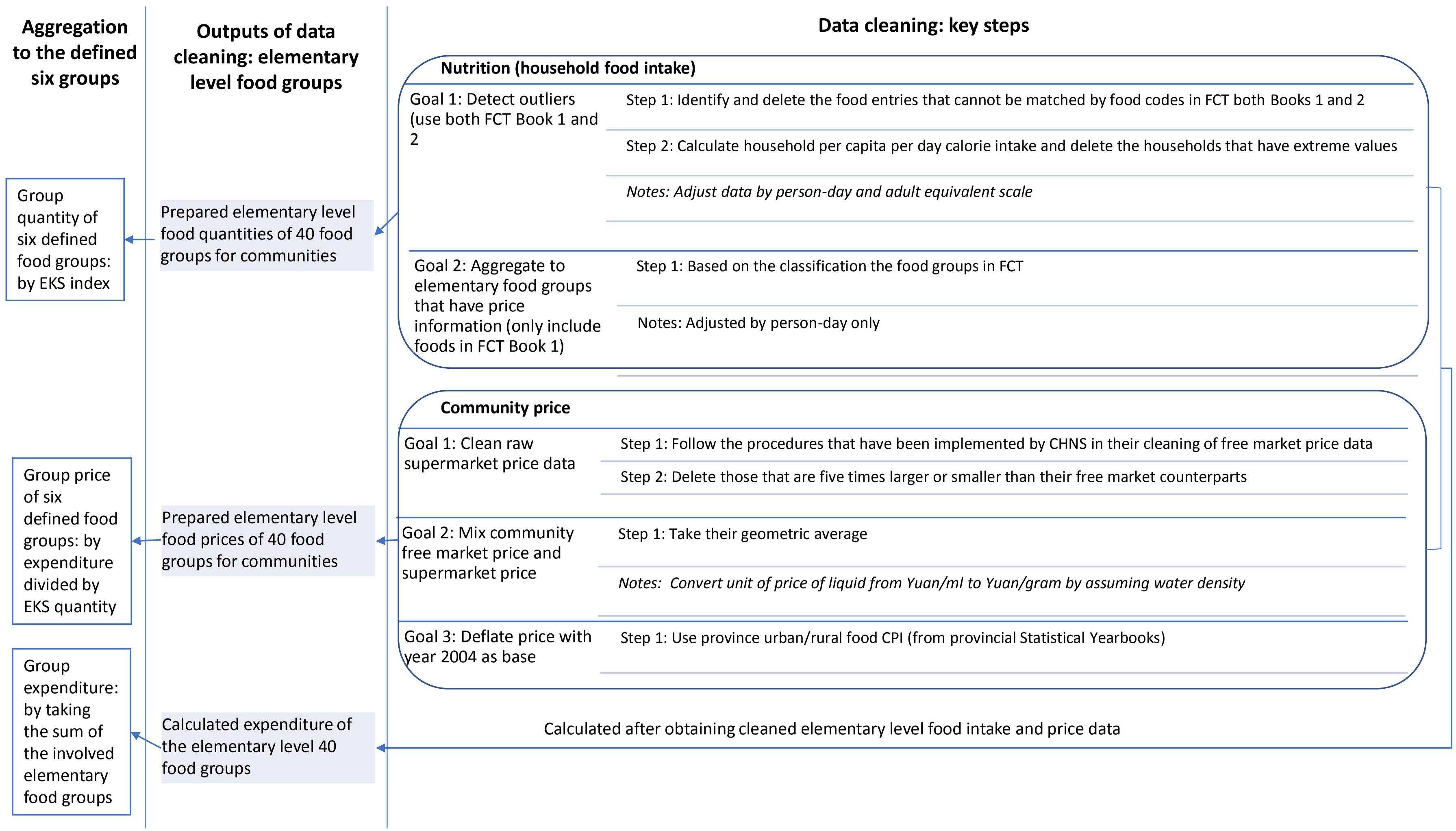
Compared with other food demand studies in a Chinese context, animal products were categorised into commonly-eaten and less-commonly-eaten groups, whereas most studies differentiated between meats, poultry, eggs and aquatic products. The differentiation between most common animal products and less common ones would enable the investigation on how social development factors would affect the diversity of animal food consumption, which is an important aspect of overall diet diversification during nutrition transition. In addition, limited data size and price data restrict more disaggregated food grouping which would describe a more detailed picture of food consumption patterns adopted by the communities under study.

Since the prepared quantity and price data at elementary level contain 40 groups, aggregated group quantities were calculated as group quantity index numbers following the procedures of constructing an EKS index number (Coelli et al., 2005, Chapter 4, Section 4.8). By weighing group quantity with its subgroups' prices and computing it as a chained index number, the aggregated group quantity is transitive which means multilateral comparison between the quantities of all communities is enabled. Moreover, the EKS index belongs to the superlative index family which is close to the theoretical index that measures cost of living (Diewert, 1976). After obtaining the quantity index of the aggregated groups, group price was computed by dividing group expenditure by its quantity index. Aggregated group expenditure was prepared by multiplying the price and the quantity of the 40 elementary groups and then adding up to the defined six group level before the computation of group price.

After these steps, food price and quantity data that would be directly processed by the chosen demand model were ready for communities.

The key steps in the cleaning of household nutrition and community price data described in this section are summarised in Figure 4.2.

Figure 4.2: Major steps in nutrition and price data cleaning



4.2.4 Defining key explanatory variables

The three key aspects of social development that have been discussed, changing age structure, urbanisation process and transforming food environment, and the two important consumer factors, income and diet knowledge, are defined and approximated with the information available in the surveys. Since the unit of analysis is community and the cleaned food data correspond to community per capita food information, wherever appropriate, the defined explanatory variables were constructed to reflect community average level.

The different urbanisation levels of communities were measured by the location of a community, that is whether it is located in an urban, suburban or a town area. It is therefore assumed that urban and suburban areas tend to share a similar overall urban environment, which may be divergent from most town areas in China. The possible convergence of urban and suburban development can be seen from the suburbanisation happening in many peri-urban areas as urban land expands dramatically and suburban agricultural land is converted to construction land. It is estimated that from 1996 to 2012 the national urban land increased by 2380 square kilometres annually on average (State Council of China, 2014). Since "towns" were sampled from rural area, even though some are county seats, literature on food choice in China always signifies the difference in food consumption between urban and rural areas which is a dichotomous classification developed and utilised in policy design during the period of command economy in China. Therefore, a dummy variable differentiating between urban(suburban) and town location of a community is adopted to capture the variance in communities' general urbanisation levels.

The changing population age structure is captured by the ageing population measured by the proportion of seniors (age 65 and above) in a community.

The transforming community food environment is approximated by the convenience of supermarkets *relative to* fresh markets which is measured by the *relative* distance to the nearest supermarket and fresh market for each community. The shorter the distance, the more convenient. To be specific, first, based on distance data (measured as continuous variables) to the nearest wet market and supermarket, all communities were classified into three groups: shorter distance to fresh market; equal distance to supermarkets and fresh markets; and shorter distance to supermarkets. Then for the first and the third group, the difference between the maximum and minimum in distance is further equally divided into three levels. That is, in total seven levels of relative convenience were generated with 1 representing the least convenient supermarket (i.e. no supermarkets, only fresh markets exist for the community), 4 equalling the convenience of a supermarket and a fresh market (i.e. identical distance to both types of markets), and 7 representing the most convenient supermarkets (i.e. only supermarkets exist for the community, with no fresh markets available). This makes the variable supermarket convenience relative to fresh market convenience as a variable defined from 1 to 7, and it is taken as a continuous variable in the demand model. In the cleaned dataset, since there is no community that only has supermarkets but no fresh markets, the maximum of this defined variable was reduced from 7 to 6.

The decision to use relative distance of markets is consistent with the observed food shopping behaviour of Chinese consumers in general, which signifies two features: high frequency and short travel distance (e.g. Wu et al., 2001; Han and Song, 2013; Wang et al., 2015b), which highlights the importance of the "convenience" of community food retailers.

The other two critical factors that are expected to impact food choice are community income level and community averaged dietary knowledge. Community income level is captured by community per capita values that were calculated by dividing the aggregate household level income data in each community by the number of individuals surveyed. To be specific, household income data used was gross household income that did not contain any negative values. Per capita value was then computed by the sum of all households' income divided by the sum of household size. Then three level of income groups were defined, with the lowest 30%, middle 40% and top 30% being Level 1, Level 2 and Level 3. The reason to convert the continuous income variable into a categorical variable is to capture the discontinuous effects of income on food choice, and by doing so, income is taken as a relative measurement rather than as an absolute level.

Dietary knowledge is measured by nine questions directly targeting health and food as well as two questions on physical activity. All these questions are documented in the Diet Knowledge section in the Adult Survey. One statement on physical activity stating that "Sweaty sports or other intense physical activities are not good for one's health" was excluded since the answer to this question may very much depend on habitual physical activity patterns that can hardly be absolutely positive or negative for different individuals. Answers to the included questions were obtained for all members aged 12 and over (even though these questions are documented in the Adult Survey of the CHNS). Since answers to these questions are recorded as a Likert scale, first, answers were turned to the same direction then values were added as the overall diet knowledge score for individuals. Community dietary knowledge level is defined as the averaged dietary knowledge score surveyed within the community.

Variable codes in the original datasets that were used in the construction of these variables are summarised in Table 4.2. The meaning of these codes can be found in the codebooks on the CHNS website. Based on the definition of constructed variables and following the procedures described above, these original variables were redefined into the explanatory variables analysed in this thesis.

Table 4.2: Summary of constructed key variables

Variable name	Definition	Intend to meansure	Original variable codes involved	Nature of constructed variable
Income L2; Income L3	Community income level (based on per capita income) L2: medium 40% L3: highest 30%	Community income level	hhincgross, hhsize	Dummy
Senior >= 65 (%)	Community proportion of seniors aged 65 and over	Community ageing population level	age	Continuous
Dietary knowledge (DK)	Community average dietary knowledge score (only include individuals aged 12 and over)	Community dietary knowledge level	U377, U378, U379, U380, U381, U382, U383, U384, U385, U386, U388, U389, U390, U391, U392, U393	Continuous (The higher the value, the higher the DK.)
Relative conv. Spmkt vs. wet mkt	Relative convenience of modern supermarkets compared with wet markets	Community food environment	O288, O289, O290, O291, O292, O293, O310, O312	Continuous (The higher the value, the more convenient the supermarkets.)
Town	Community located in town rather than in urban or suburban areas	Community urbanisation level	T2, T4	Dummy

Furthermore, taking the potential interaction effect between age structure and dietary knowledge on food expenditure shares, another variable (dietary knowledge $\times$ senior%) is included in the demand model.

In addition, two dummy variables indicating wave 2006 and wave 2009 were included to control for any systematic environmental changes from 2004. Potential inconsistency in the survey method across years is also expected to be controlled by these two dummies.

After merging all the prepared variables and deleting the communities with missing information, 278 communities which were composed of 86 in 2004, 95 in 2006, and 97 in 2009 were retained for further analysis. These are the communities that were incorporated in the estimation of the LAIDS demand model.

Descriptive statistics of the key variables are shown in Table 4.3 and Table

4.4 with the former documenting the mean values and the latter the corresponding standard deviations. Considering the two dummy variables, year (2004, 2006 and 2009) and location (urban and suburban vs. town), descriptive statistics are presented by wave and location. Mean income value is presented for each income level. Averages over all waves in different areas and over both areas for all waves are also shown as reference. Additionally, mean and standard deviation of the expenditure shares of the defined six food groups are presented in the two tables.

Table 4.1: Aggregating to the defined six food groups

Food group	Group composition
Grains and starches	wheat and wheat products rice and rice products corn and corn flour millet other cereals starch and flour
Commonly eaten animal products	pork and pork products poultry and poultry products eggs
Less commonly eaten animal products	beef and beef products lamb and lamb products other meats fish and other seafoods liquid milk milk powder other dairy products infant formula infant formula: substitute formula
Vegetables, fruits and legumes	vegetables bean curd all other legumes fruits nuts and seeds
Oils and sugars	sugars other oils rapeseed oil soybean oil peanut oil soy sauce
Snacks, drinks and other condiments	ethnic food cake convenience food snack sweets ice-cream non-alcoholic drinks beer liquor vinegar sauce and pickles

Table 4.3: Descriptive statistics of variables in the AIDS model: Mean

	Aggregate over all waves		Aggregate over all areas			Urban+Suburban			Town		
	Urban+Suburban	Town	2004	2006	2009	2004	2006	2009	2004	2006	2009
Mean income of three income levels											
Lowest 30%	5205.69	4751.27	3972.85	4333.14	6703.53	4079.39	4497.90	6704.20	3783.44	3985.32	6701.77
Mdium 40%	8642.91	9548.99	7405.72	7772.09	11463.94	7401.77	7753.23	11129.02	7417.13	7824.90	11977.49
Top 30%	16440.50	15853.61	13284.88	15315.89	19773.41	13287.76	15468.12	20456.59	13277.06	14916.28	18407.05
Senior %	15.82%	14.78%	16.12%	14.97%	15.46%	15.68%	15.38%	16.41%	17.18%	13.95%	13.63%
Dietary knowledge mark	41.09	41.14	41.33	40.80	41.20	41.23	40.94	41.11	41.57	40.44	41.38
Spmkt vs. wet market convenience	3.95	3.44	3.65	3.97	3.74	3.79	4.15	3.89	3.32	3.52	3.45
DK * (senior%)	6.52	6.08	6.66	6.13	6.39	6.47	6.32	6.77	7.12	5.63	5.64
Expenditure share of:											
Grains	0.12	0.15	0.13	0.13	0.12	0.12	0.12	0.12	0.15	0.17	0.13
Commonly-eaten animal products	0.24	0.26	0.26	0.24	0.23	0.27	0.24	0.22	0.24	0.26	0.27
Less-commonly eaten animal products	0.27	0.25	0.27	0.25	0.28	0.26	0.27	0.29	0.27	0.21	0.26
Vegetables and fruits	0.17	0.16	0.14	0.17	0.18	0.15	0.18	0.18	0.13	0.16	0.17
Oils and sugars	0.07	0.09	0.08	0.08	0.07	0.07	0.07	0.07	0.09	0.09	0.08
Snacks, drinks and other condiments	0.13	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.12	0.11	0.09

Source: Cleaned data from CHNS 2004, 2006 and 2009

Table 4.4: Descriptive statistics of variables in the AIDS model: Standard deviation

	Aggregate over all waves		Aggregate over all areas			Urban+Suburban			Town		
	Urban+Suburban	Town	2004	2006	2009	2004	2006	2009	2004	2006	2009
Mean income of three income levels (Yuan)											
Lowest 30%	1804.45	1813.92	979.00	1276.80	1640.05	1095.95	1201.56	1704.51	748.47	1432.81	1567.81
Mdium 40%	2094.31	2603.50	1234.19	1249.21	1564.90	1238.15	1280.86	1451.55	1297.22	1220.46	1641.43
Top 30%	4855.94	5187.33	3323.36	4779.61	4156.58	3306.54	3901.41	4345.12	3635.93	6902.05	3563.91
Senior%	10.30	8.04	10.21	9.27	9.62	10.73	9.81	10.53	8.93	7.79	7.34
Dietary knowledge (DK)	1.21	1.44	1.18	1.39	1.22	1.13	1.28	1.20	1.27	1.60	1.24
Spmkt vs. wet market convenience	1.50	1.58	1.42	1.55	1.63	1.33	1.43	1.71	1.60	1.78	1.44
DK *(senior%)	4.27	3.33	4.21	3.84	4.00	4.42	4.08	4.38	3.68	3.17	3.08
Expenditure share of :											
Grains	0.05	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.07	0.06	0.05
Commonly-eaten animal products	0.08	0.10	0.09	0.09	0.08	0.09	0.08	0.07	0.11	0.10	0.09
Less-commonly eaten animal products	0.12	0.11	0.11	0.13	0.12	0.11	0.13	0.13	0.11	0.11	0.10
Vegetables and fruits	0.05	0.06	0.05	0.06	0.05	0.05	0.06	0.05	0.06	0.07	0.06
Oils and sugars	0.04	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.07	0.07	0.06
Snacks, drinks and other condiments	0.08	0.10	0.09	0.09	0.09	0.08	0.09	0.08	0.10	0.08	0.11

Source: Cleaned data from CHNS 2004, 2006 and 2009

4.3 Characteristics of communities classified by their healthy and unhealthy food intake

Characteristics of communities classified by their at-home consumption of vegetables and fruits and oils and sugars are summarised in Table 4.6. Deflated per capita income uses 2004 as the base. Average working age proportion is the proportion excluding seniors and children. The urbanisation index is a holistic index constructed and is especially used to measure community development levels in the CHNS, which is briefed in section 2.1.1. Overweight and obesity rates are calculated following the overweight and obesity BMI criteria by age developed among the Chinese population (Li et al., 2010). Those aged two years old and younger are not included in the calculation of overweight and obesity rates of communities. The overweight and obese cut-off points based on the BMI for both adult males and females (aged 18 and over) are 24 and 28. The detailed cut-off points for other ages adopted in this thesis are documented in Appendix C.

As has been explained, with the main concern in health implications of food choice in the future, communities are further classified into three groups based on their healthy vegetable and fruit intake. The boundary values used to do the classification are shown in Table 4.5. It can be seen that per capita per day intake of vegetables and fruits needs to be over 900 grams to be categorised into the most healthy group. This is realistic in the context of China since vegetables are normally taken as main dishes for at-home meals and instead of eating raw fresh vegetables, they are always cooked which encourage their consumption. In addition, the overlaps of communities that belong to the same group (1, 2 or 3) but are picked up by both criteria are not serious since the two least healthy community groups only share 17 communities. This means that if effects of projected scenarios on food choice of the concerned community Group 3 varied largely, the majority of the communities benefiting from one scenario targeting one aspect of their diet (either vegetables or oils) would not be negatively affected in terms of the other aspect of their diet (either oils or vegetables).

Demographics information as well as averaged consumption quantities for each community group are summarised in Table 4.6. Looking at the number of communities that fall into each community group, most communities consume a relatively adequate amount of vegetables and fruits; only 40 out 278 communities intake less than 500 gram of vegetables and fruits at home and these are classified into the least healthy Group 3. In contrast, overconsumption of oils and sugars can be a more serious and prevalent problem. 152 communities out of 278, that is almost

55%, consume an amount over the recommended highest level. Considering the fact that data analysed here do not cover foods eaten outside home, the overconsumption of oils and sugars might be even more serious. For the "veg and fruit" criterion, it can be seen that the least healthy group tends to have the lowest per capita income, a higher proportion of children and a slightly smaller working age adult proportion. Its education level and urbanisation level also appear to be slightly lower than the other two community groups. From the perspective of "oil and sugar" consumption, the least healthy group also has the lowest per capita income, but has a relatively higher working age adult proportion and tends to be more urbanised. Comparing the two Group 3 communities, those who consume the least vegetables and fruits tend to be those with more senior family members and children but with fewer working age adults. These kinds of communities might be those with a relatively large number of "immigrant workers" who travel outside their home town for work and those remaining back home are mainly seniors and children. In contrast, communities that consume most oils and sugars tend to be those more "active" communities in more urbanised areas.

Looking at overweight and obesity prevalence for the classified community groups, communities having the least amount of at-home vegetable and fruit consumption intake do not have the highest level of overweight and obesity rate. Instead, overweight and obesity rates are of the lowest level for this community group compared with the other two. Apart from having the lowest level of vegetable consumption, the intake quantities of other food groups of this community group are consistently less than those of the other two community groups. Combined with the demographic information of this community group, the food pattern of this community group may lag behind the other two groups. However, its averaged overall overweight and obesity rate still reaches 36.07% in the first decade of the twenty-first century.

In contrast, the total overweight and obesity rate for the community group that has the highest intake of oils and sugars is only slightly larger than that of the other two groups. Another notable observation would be that, the least healthy group (Oil Group 3) has the highest level of obesity rate but the lowest rate of overweight. This may indicate more serious health risks for these communities. Moreover, this community group not only consumes the largest amount of oils and sugars but also other food groups, except grains. This evidences the relative abundance of foods in general terms for this community group. Such diet status might be ahead of that of the other two groups on the nutrition development spectrum at the beginning of the twenty-first century in urban China.

Therefore, the social environment and food status of these two Group 3 communities are significantly different.

Meanwhile, it can be seen that average age and average dietary knowledge tend to be at a very similar level for all classified community groups. The similar average age across all these community groups highlights the importance of considering community age structure. Similar dietary knowledge level means that the potential effects of dietary knowledge on food choice need to be examined with a more delicate method.

Thus, this chapter has gone through all the critical data and variables involved in this thesis. With the LAIDS model and estimation methods specified and depicted in the previous chapter, the results can be produced and are summarised and discussed in the next two chapters.

Table 4.5: Definition of community groups based on either the healthy or the unhealthy aspect of diet

	Criteria boundary (gram)		No. of shared communities
Community group	Veg + Fruit (healthy)	Oil + Sugar (unhealthy)	
Most healthy (Group 1)	>= 900	<= 50	2
Medium healthy (Group 2)	[500, 900)	(50, 80]	54
Least healthy (Group 3)	<500	>80	17

Notes: Criteria boundary is based on recommendations in China dietary guidance.

No. of shared communities reflects the overlap between community groups classified by the two criteria.

Table 4.6: Characteristics of community groups classified by their healthy or unhealthy food intake

	Veg + Fruit criterion			Oil + Sugar criterion		
Characteristics	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
No. of communities	57	181	40	41	85	152
Per capita income_deflated	11076.29	10219.37	7673.39	9990.57	10837.29	9586.89
Average age	41.33	42.19	41.02	44.08	41.26	41.57
Senior %	16.99%	20.63%	19.70%	24.26%	18.87%	19.03%
Children %	11.73%	12.78%	14.98%	12.02%	13.15%	12.97%
Working age adult %	71.28%	66.59%	65.31%	63.71%	67.98%	68.01%
Average education	2.53	2.24	1.83	2.12	2.27	2.26
Average DK	41.42	41.08	40.74	40.67	41.34	41.09
Urbanisation index	82.97	80.50	79.07	79.46	78.73	82.31
Overweight %	33.49%	30.62%	28.23%	32.31%	31.26%	30.25%
Obese %	11.24%	9.01%	7.85%	7.44%	8.46%	10.27%
Overweight+obese %	44.74%	39.63%	36.07%	39.75%	39.73%	40.52%
Per capita consumption quantity of (kg)						
Grains	0.49	0.44	0.39	0.43	0.45	0.44
Com meats	0.25	0.22	0.17	0.18	0.21	0.23
Less com meats	0.35	0.28	0.16	0.23	0.27	0.29
Veg & fuits	1.10	0.67	0.42	0.62	0.70	0.76
Oils & Sugars	0.13	0.10	0.08	0.04	0.06	0.14
Snacks & drinks	0.38	0.24	0.10	0.19	0.23	0.27

Source: Cleaned and computed data from CHNS 2004, 2006 and 2009

Chapter 5

Discussion: Demand model coefficients and elasticity matrix

The basic form of the demand model adopted in the description of the community food choice is the LAIDS model. Socio-demographic factors underlying community food decisions are included in the LAIDS model as intercept shifters. As a reminder, population ageing is captured by the proportion of seniors aged 65 and over, the transforming food environment is measured by the relative convenience of modern supermarkets against wet markets, and the different levels of community urbanisation are described by the dummy variable which distinguishes between city (including urban and suburban areas) and town areas. Community income is divided into three levels, i.e., top 30%, medium 40% and bottom 30%. Dietary knowledge is captured by the dietary knowledge score. The potential interactive effect between dietary knowledge and age structure is also included. Additionally, year 2006 and 2009 are incorporated to capture the systematic differences in the survey methods and in the overall social environment across three waves. All waves' data are taken as cross-sectional.

From the findings in the previous literature, there are a few relatively consistent expectations for the estimated effects of the underlying driving factors. First, the proportion of seniors is expected to be positively related to more "traditional" food groups like grains and vegetables, and negatively associated with animal foods. Second, being in a town area (as opposed to a city area) could be related to more consumption of grains and less consumption of relatively newly introduced foods such as snacks and less common animal products. Third, the "supermarket revolution" may increase the consumption of highly-processed foods represented by snacks and drinks, and might also encourage the consumption of oils and sugars. A higher income level is associated with diet diversity which may indicate more consumption of less-commonly-eaten meats. More dietary knowledge may contribute to healthier food choices which might be related to more consumption of fruits and vegetables and less intake of oils and sugars. It needs to be noticed that these expectations based on the existing findings are from analysing individual, household and provincial level data in China and the food groups defined in these studies can only be roughly comparable with the food grouping in this thesis.

The following sections present and discuss estimated results from the LAIDS models, which include estimated coefficients and estimated uncompensated price elasticities and expenditure elasticities.

The MCMC Gibbs sampler was run for $12,000$ iterations where the first $2,000$ draws were discarded as burn-in. Hence, $10,000$ iterations were collected to obtain the means, standard deviations of the posterior distributions of the parameters which are then used to compute price and expenditure elasticities, estimated shares of each policy scenario (which is summarised in the next chapter) and highest posterior density (HPD) intervals. Gibbs sampler convergence is checked by using trace plots which are presented in Appendix E. The trace plots provide evidence that Gibbs sampler has converged since the retained simulated values appear to fluctuate around their stable means.

5.1 Estimated coefficients in the demand model

The estimated means of the coefficients in the LAIDS are presented in Table 5.1. (The standard deviations of the estimated demand model coefficients can be found in Appendix D). Among all estimates, 40% are significant at 90% HPD level and 32% are significant at 95% HPD level. For the economic explanatory variables including log prices and real expenditure, 50% and 44% are significant at 90% and 95% HPD level respectively. All prices in log form are significant in their own demand equation. For the non-economic explanatory variables, 31% and 22% are significant for 90% and 95% HPD level respectively. Income is significant in the demand functions for grains, less commonly-eaten animal products and oils and sugars. Town location significantly affects the expenditure shares of grains, less common meats and oils and sugars. Dummy variable wave 2006 has significant effects for grains, commonly eaten meats, oils and sugars and snacks, drinks and condiments. Dummy variable wave 2009 only shows significant effects for commonly eaten meats and snacks, drinks and condiments groups.

None of the estimated coefficients of the variable proportion of seniors aged 65 and over is significant. The situation for the interaction term between dietary knowledge and senior proportion is the same. The estimated coefficients of dietary knowledge are significant in the equations of grains and less common meats. The variable senior proportion on its own appears to be significant in the demand equations of grains and less common animal products (see Table 5.3 for details), and the variable dietary knowledge on its own is significant in the demand equations of the two animal product groups (see Table 5.2 for details). The relative convenience of modern supermarkets against fresh markets does not show significant effects in any of the six equations.

The significance results of the directly estimated coefficients in the LAIDS in general say that for the communities' demand for the six defined broad food groups, the economic factors tend to play a more significant role than the non-economic factors. In addition, the overall significance level of estimated coefficients of the model is low: even at 90% HPD level, less than 50% of all included factors demonstrate statistically significant effects on food decisions.

Table 5.1: Estimated coefficients in the LAIDS: Mean

	Estimated coefficients (mean) in the equation of					
Explanatory variables	Grains	Commonly-eaten meats	Less-commonly-eaten meats	Vegetables and fruits	Oils and sugars	Snacks, drinks and condiments
Constant	0.9493**	0.5833	-0.8617*	0.3480	0.2200	-0.2389
ln(p-grain)	0.0711**	-0.0212*	-0.0283**	-0.0115	-0.0009	-0.0092
ln(p-common meat)	-0.0212*	0.1493**	-0.0434**	-0.0365**	-0.0077	-0.0406**
ln(p-less common meat)	-0.0283**	-0.0434**	0.1067**	-0.0235**	-0.0048	-0.0067
ln(p-veg and fruit)	-0.0115	-0.0365**	-0.0235**	0.1051**	-0.0234**	-0.0102
ln(p-oils and sugars)	-0.0009	-0.0077	-0.0048	-0.0234**	0.0380**	-0.0011
ln(p-snacks and drinks)	-0.0092	-0.0406**	-0.0067	-0.0102	-0.0011	0.0679**
ln(expend/P)	-0.0536**	-0.0231	-0.0165	0.0039	0.0388**	0.0505
Income L2	-0.0210*	-0.0024	0.0435**	0.0005	-0.0265**	0.0060
Income L3	-0.0240*	0.0041	0.0756**	-0.0097	-0.0373**	-0.0087
Senior >= 65 (%)	-3.0672	0.5431	0.9460	-0.8122	-0.4673	2.8576
Dietary knowledge (DK)	-0.0155**	-0.0091	0.0237**	-0.0044	-0.0031	0.0084
Relative conv. Spmkt vs. wet mkt	-0.0009	0.0016	0.0036	-0.0024	0.0023	-0.0042
Town	0.0186*	0.0041	-0.0329**	-0.0011	0.0208**	-0.0095
DK*(Senior >= 65)	0.0719	-0.0131	-0.0183	0.0185	0.0105	-0.0696
2006	-0.0311*	0.1137**	-0.0110	0.0222	-0.0269*	-0.0669**
2009	-0.0202	0.1189**	-0.0274	0.0031	-0.0154	-0.0590**

Note:(*) indicates that the 90% HPD interval covers the true parameter
(**) indicates that the 95% HPD interval covers the true parameter

5.2 Effects of the non-economic explanatory variables on food choice

The low level of significance among the estimated coefficients for the non-economic explanatory variables in the demand system could be explained by the relatively high level of aggregation adopted as the unit of analysis. In studies analysing food demand at national level using aggregated provincial or city level NBS surveyed data and applying demand system models (e.g. Fan et al., 1994, 1995; Wu et al., 1995; Zheng et al., 2015), non-economic explanatory variables seem to be rarely controlled for, which is in contrast to the detailed demographic information appearing in models aiming at household and individual level behaviour. In the CHNS, around 20 households are typically surveyed for each community, which is far smaller than a sample size for a province in the Household Survey conducted by the NBS (normally more than 2000 households for each province in urban household survey). Thus critical non-economic variables are still included to account for the potential systematic influences of non-economic factors thereby capturing their effect on expenditure shares which would have otherwise, maybe erroneously, been attributed to price and expenditure effects.

5.2.1 Income and dietary knowledge

Income has significant effects on the expenditure shares of grains, less common animal products and oils and sugars. An increasing income level is associated with a decreasing expenditure share on grains at a decreasing rate. When income level moves from the lowest level to the middle level, the expenditure share on grains tends to decrease by 2.1%, but only decreases by 0.3% when income further increases to the highest level. Since the traditional Chinese diet is plant-based and rich in starches and vegetables, this finding may evidence the persistence of grains in the Chinese at-home diet after income reaches a certain level.

As for the expenditure share on less common animal foods, the average difference between middle income group and low income group is 4.35% and between high income group and low income group it is 7.56%, which implies the difference between high and middle income group is around 3.2%. This suggests that higher income communities tend to spend more on less commonly consumed animal products. At the same time, the increase in expenditure share is more substantial from low to middle income communities compared with from middle to high income communities. This means that if a low income community initially becomes more wealthy, it tends to increase its demand for less common animal products. Once a community has acquired a certain level of income, having additional income does not increase demand for less common animal products that much suggesting that such products are seen as relatively less of a novelty and therefore less desirable compared to the situation when the community was poorer. This indication is consistent with the observation at household level. At household level, income is expected to be more positively associated with more diversified animal product consumption especially beef, dairy products and aquatic foods for higher income consumers (Gould and Villarreal, 2006; Wang et al., 2008b; Liu et al., 2009).

In addition, increasing income level is related to a decreasing expenditure share on oils and sugars. Specifically, the middle income group spends 2.6% less on oils and sugars compared with the lowest income group, and the highest income group spends 1.1% less compared with the middle income group. This indication tends to be more consistent with findings in city areas in China which appear to have bypassed the fast increasing stage of increasing oil consumption (Du et al., 2004). Considering the relatively large expenditure elasticity of oils and sugars(1.54, see section 5.3 for detailed elasticity results), this finding also signifies the different roles played by income and food expenditure at community level. It could be the case that a preference for oils and sugars that have clear negative associations with health can be considered increasingly negative as community income grows and community members become more health conscious. However, a direct increase in expenditure may not reflect the potential shifts in preference that is induced by income growth. Also, it needs to be noticed that consumption of added sugars may be still on an increasing trend in both urban and rural areas in China (Popkin, 2014). Overall, this finding suggests a possible positive nutrition effect of increasing income on diet by improving the diversity aspect of animal food intake compared with the situation in which only common traditional animal products are eaten, and of a decreasing expenditure share on oil consumption at community level.

Since an interaction term between dietary knowledge and age structure is incorporated in the model, the pure effects of dietary knowledge on expenditure shares of the six food groups were computed and documented in Table 5.2. (The mean senior proportion (15.50%) of the entire dataset was adopted in the approximation of the pure effects of dietary knowledge.) Average community dietary knowledge is negatively associated with grains, common meats, vegetables and fruits, oils and sugars and snacks, drinks and condiments, and is positively related to less common meats. The significant positive effects on less frequently eaten animal products may be due to the fact that better dietary knowledge can be linked to a higher education level which implies relatively higher living standards that can be associated with enhanced accessibility to a wider range of animal foods; therefore common meats that in general are regarded as part of a traditional diet might be partly replaced by more novel less common animal products. Instead of considering education level, dietary knowledge is taken as a more direct and responsive indicator that can be linked to food decision since collectively at community level, educational attainment may be stable over a certain period of time and highly correlated with income level. However, dietary knowledge could be improved by health and nutrition education interventions.

Moreover, dietary knowledge in general can indicate different levels of health consciousness. Since the most important traditional animal food source in China, i.e. pork, is criticised for its relatively less nutritious component in terms of its high fat content, being more health conscious might induce the decrease in pork consumption, which is a phenomenon found in Mao et al. (2016). Similarly, since snacks and drinks are likely to be highly-processed, energy-dense and nutrient-poor, being more health and nutrition conscious might have the potential to reduce their consumption. Thus, improving community dietary knowledge might slightly improve the "quality" of animal product consumption by enhancing animal food diversity and might contribute to decreasing expenditure shares on oils and sugars and snacks and drinks.

The potential negative association between dietary knowledge and expenditure share of vegetables and fruits might be explained by several reasons. First, dietary knowledge is defined by a dietary knowledge score which is measured by individuals' answers to eleven nutrition related questions. Since these questions are designed as Likert scale questions with the aim of investigating a general opinion or attitude instead of hard knowledge on nutrition and health, individuals' answers might heavily depend on their baseline consumption level. For instance, there is one question stating that "Consuming a lot of animal products daily (fish, poultry, eggs and lean meat) is good for one's health". For those individuals that do not have easy access to these foods, "a lot of" might be desirable which may lead to the answer "strongly agree" regardless that they know overconsumption of any foods would have a negative impact on health. Moreover, in the context of the Chinese language, the use of extreme phrases such as "a lot of" might produce a negative impression. For example, one question states that "Choosing a diet with a lot of fresh fruits and vegetables is good for one's health." Even though it is well-known that vegetables and fruits are beneficial to health, individuals might have a tendency to answer it as "agree" or even "neutral" rather than "strongly agree" because of the extreme implication of "a lot of" in Chinese. Comparatively, for the question such as "Consuming beans and bean products is good for ones health.", better diet knowledge would more likely to produce the answer of "agree" or "strongly agree". In addition, vegetables and fruits in terms of their images associated with health among the Chinese could be different. The highly favourable nature of fruits such as their sweetness, might be associated with an impression of limited intake; by contrast, vegetables tend to be plain and "neutral" in their flavour and thus more likely to be regarded as generally healthy. Hence, "dietary knowledge" might have varied implication for its effects on vegetables and fruits. Nonetheless, the defined variable dietary knowledge tends to have expected signs on other food groups. Its significant positive impact on less common animal products is consistent with the finding that diet diversity is considered to be beneficial to health and for those who are more nutrition conscious and who with higher education level it is a common practice to enhance their diet diversity (Sakamaki et al., 2005).

Table 5.2: Approximated effects of dietary knowledge

	Estimated pure effects of dietary knowledge on the expenditure shares of food groups					
Explanatory variables	Grains	Commonly-eaten meats	Less-commonly-eaten meats	Vegetables and fruits	Oils and sugars	Snacks, drinks and condiments
Dietary knowledge (DK)	-0.0044	-0.0114**	0.0210**	-0.0017	-0.0017	-0.0018

Note: (*) indicates that the 90% HPD interval covers the true parameter

(**) indicates that the 95% HPD interval covers the true parameter

5.2.2 Region, proportion of seniors and relative convenience of modern supermarkets

An objective of this research was to investigate the impacts of urbanisation on food choice. In this study, community location either in a city and or in a town is chosen as the measurement of the different levels of urbanisation for each community. Consistent with the literature suggesting that urbanisation influences health by changing lifestyle where diet choice is a key component, estimated coefficients of being in a town say that on average being a town community would decrease the expenditure share on less common animal products by 3.29% while it would increase that on grains by 1.86% and on oils and sugars by 2.08%. Meanwhile, expenditure shares on common meats, vegetables and fruits and snacks and drinks may not be significantly changed. This finding provides evidence of the difference in city and town food preference, that is, as a town area becomes more urbanised, it might spend larger expenditure shares on novel animal products, while reducing expenditure share on oils. Viewing such patterns along with the effects of different levels of income, more urbanised and higher income communities spend proportionally more on less common meats and less on oils and sugars.

The approximated pure effects of community senior proportion were calculated by taking into account both the effect of the variable senior proportion and its potential interaction effect with dietary knowledge. The mean value of dietary knowledge of the entire dataset (41) is utilised to approximate the overall impact of senior proportion on expenditure shares which is shown in Table 5.3. The potential links between senior proportion and expenditure shares of grains, vegetables and fruits and oils and sugars can be negative, while that of two meat groups and snacks, drinks and condiments are estimated to be positive. Suggestions from Table 5.3 tend to be inconsistent with findings in extant literature. Based on household level data, literature usually considers the effect of age from two aspects: the age of the household head or the age structure of the overall household. It finds that having seniors, or a higher percentage of seniors (> 60 or > 65) or an increasing household head age increases the consumption of rice but decreases the consumption of other grains and decreases the consumption of meats. Consistent with most findings in other studies, fruit consumption is usually negatively associated with increased age (Gould and Dong, 2004; Gould and Villarreal, 2006; Wang et al., 2012).

The divergence between the existing findings and those in this thesis could mainly be due to two reasons. The first one is because of the potential interaction effect between senior proportion and dietary knowledge is incorporated in this thesis, and the second could be the differently defined food groups. The second row in Table 5.3 presents the dietary knowledge score that is required to reverse the effect of the senior proportion on food decision. It can be seen that except for the food group of less common animal products, a slight increase in the averaged dietary knowledge from the current level (which is 41.1049) would alter the direction of their potential associations, and this would result in similar implications, as suggested in the extant literature. Besides, a slight improvement in dietary knowledge from 41 to 44 may change the overall impact of senior proportion on expenditure share on vegetables and fruits to be positive. However, it also needs to be noticed that such a slight increase in dietary knowledge might change the negative link between senior proportion and expenditure share on oils and sugars to positive. The second reason underlying the inconsistently found relationship between age and food choice signifies the difference in food grouping between this study and others. The highly aggregated and mixed nature of food groups defined in this thesis may not be able to reflect the increasing heterogeneity in consumers' food choice. For instance, grains can be composed of less common other grains (e.g. millets and oats) as well as commonly eaten rice and wheat products. The elderly in the first decade of the twenty-first century might tend to stick to more "traditional" starches like rice and wheat compared with younger people pursuing a variety of grains. The relatively monotonous choice of traditional grains that are normally cheaper than other grains by the elderly might give rise to the negative association between senior proportion and expenditure share on broadly defined food group grains. Additionally, the positive association between senior proportion and less common animal products indicates that those aged 65 and above have a more diversified animal food assortment. This could be because seniors aged 65 and over might be more health conscious than younger people and therefore are willing to spend proportionally more on a wider variety of less common animal products such as on aquatic animal protein that tend to be more expensive than "traditional" pork, poultry and egg products.

In brief, the opposite sign between the interaction term of dietary knowledge and senior proportion and the variable senior proportion alone in particular of vegetables and fruits and snacks and drinks may highlight the potential of applying dietary knowledge intervention as a policy instrument to improve food "quality" to address nutrition related problems as communities experience intensifying population ageing.

Table 5.3: Approximated effects of senior proportions

	Estimated effects of senior proportions on the expenditure shares of food groups					
Explanatory variables	Grains	Commonly-eaten meats	Less-commonly-eaten meats	Vegetables and fruits	Oils and sugars	Snacks, drinks and condiments
Senior >= 65 (%)	-0.1136**	0.0041	0.1951**	-0.0518	-0.0359	0.0021
Dietary knowledge score that will change the sign of the effect of senior proportion	42.6635	41.4163	51.4903	43.5846	44.5286	41.1337

Note: (*) indicates that the 90% HPD interval covers the true parameter
(**) indicates that the 95% HPD interval covers the true parameter

In terms of the impacts of the supermarket revolution on food choice, the relative convenience of modern supermarkets against wet markets has no significant effect on any of the expenditure shares of the defined six food groups. This finding may be underlined by the deep reach of fresh markets as part of community life as well as the incomplete penetration of supermarkets across food products. In Beijing area, Reardon (2012) found that all supermarkets (leading chains and major local chains) under their investigation sold packaged rice and some even sold loose rice to mimic wet markets in 2009. In their study, it is observed that common loose rice was sold in supermarkets at a similar price as in traditional stores, whilst fine loose rice was sold at a higher price in supermarkets. On the one hand, this signifies the supermarkets' attempt to differentiate their food products from traditional wet markets. On the other hand, this may also imply that wet markets still play an important role in the retailing of essential food items.

Other studies also find the persistence of fresh markets as the main meat shopping outlet. For instance, Zhang (2003) surveyed Shanghai consumers about their food choice and shopping behaviour at the beginning of the twenty-first century. In their study two attributes of meats products, freshness and hygiene were ranked as the most critical determinants, and more surveyed consumers decided that freshness was their primary concern when buying meats. Since fresh markets are often associated by Chinese consumers with "freshness", it is not surprising that traditional fresh markets are competitive for selling raw foods. Accordingly, Bai et al. (2008a) found that in consumers' choice of different food outlets, traditional wet markets still play the dominant role in all fresh produce purchases.

Since the variable supermarket convenience relative to that of the fresh market is directly comparable to the relative distance of these two retail outlet formats for a community, a high level of supermarket convenience can be directly linked to the overall community retail environment. In contradiction to the empirical evidence analysing individual food behaviour in other developing countries which blames supermarkets for highly-processed and packaged foods that are considered to be energy-dense and nutrient-poor compared with "traditional" local foods offered in fresh markets (Tessier et al., 2008; Kelly et al., 2014; Rischke et al., 2015), findings in this thesis suggests that when viewing a community as a whole, the supermarket revolution might have the potential to decrease the expenditure share on snacks and drinks (since the magnitude of its effect on the snack and drink group is noticeably larger than that of other food groups even though none of its estimated effects are statistically significant). Reasons for this finding can be explained by the fact that in China the supermarket revolution started from city central of the most urbanised areas and then gradually diffused to a city's peri-urban areas and to town areas (Hu et al., 2004). During the first decade of the twenty-first century, supermarket outlet diversification was still at an early stage of development and communities that find supermarket(s) to be more convenient than fresh markets are more likely to be those which are highly urbanised with relatively well-developed business facilities, and their supermarkets are more likely to be large-scale general supermarkets rather than small-scale chain food stores (Reardon et al., 2004; Wang et al., 2008a; Zhang and Pan, 2013). Hence, the observed difference in supermarket convenience and expenditure share of snacks and drinks could be mainly attributed to preference difference that could be mostly captured by income level and overall living environment (such as city or town). Moreover, large scale supermarkets tend to offer a wider variety of food items not restricted to snacks and drinks. For example, dried and semi-processed food products other than grains which also have a relatively long shelf life but are "natural" can always be found in those supermarkets. This argument can be backed up by its potential positive effects on the two groups of animal products, where a larger impact on less common animal products compared with commonly consumed meats signifies the supermarkets' role in supplying a wider assortments of animal products. However, with more convenient supermarkets, expenditure shares of oils and sugars may increase and that of vegetables and fruits may decrease. The decrease in vegetable and fruit expenditure share may indicate the persistently important role played by fresh markets in providing fresh produce during the survey years, which has been confirmed in many other studies (e.g Goldman et al., 2002; Mai and Zhao, 2004; Ho, 2005; Bai et al., 2008a; Maruyama et al., 2016).

5.3 Price and expenditure elasticities

The estimated uncompensated price and expenditure elasticities are presented in Table 5.4. Their corresponding estimated standard deviation is documented in Appendix D. The price elasticities indicate by what percentage the quantity demanded changes if prices change by one percent, and the expenditure elasticities indicate how demand changes as food expenditure changes by one percent. Overall, at 90% HPD level, 58.33% of price elasticities are significant and at 95% HPD level 50% are significant. Only looking at own price elasticities, all are significant at 95% HPD level. Focusing on cross-price elasticities, 40% and 50% are significant at 95% and 90% HPD level respectively.

As the negativity constraint was imposed during the estimating process, all own price elasticities that are highlighted in blue on the diagonal are negative. Own price elasticity for less commonly eaten meats is significant and is the largest in absolute term (−0.61), which is followed by that of the snacks, drinks and condiments, and oils and sugars (−0.50). Vegetables and fruits and commonly-eaten animal products are of the same level of responsiveness to their own price changes (−0.36). The grain group has the smallest own price elasticity in absolute terms (−0.33). For the cross-price elasticities on the non-diagonal position, only grains demonstrate a substitute relationship to oils and sugars, while all other food groups express themselves as complements to each other. However the only positive value of cross-price elasticities is not significant at both 90% and 95% HPD levels. Also, compared with own price elasticities, the magnitudes of cross-price elasticities are generally smaller. This implies that communities' food demand for the defined six groups are more responsive to changes in their own prices.

In terms of expenditure elasticities, all estimates are positive and significant at 95% HPD level. The largest expenditure elasticity is for oils and sugars with the value of 1.54, which is followed by that of snacks, drinks and condiments (1.39) and vegetables and fruits (1.03). Expenditure elasticities for grains and two groups of meats are below 1, with that for grains being the smallest (0.54). Commonly eaten animal products and their less commonly eaten counterparts have similar values (0.91 and 0.94 respectively). Thus, grains are the least responsive to food expenditure changes whilst oils and sugars are the most sensitive to expenditure changes.

In summary, the quantities demanded for the defined six broad food groups tend to be most responsive to the changes in expenditure and least responsive to changes in other groups' prices, with that to their own price changes in the middle.

Table 5.4: Uncompensated price and expenditure elasticity matrix: Estimated mean values

	Price of						
Food group	Grains	Commonly-eaten meats	Less-commonly-eaten meats	Vegetables and fruits	Oils and sugars	Snacks, drinks and condiments	Expenditure
Grains	-0.33**	-0.07	-0.12	-0.02	0.03	-0.02	0.54**
Commonly-eaten meat	-0.08	-0.36**	-0.15**	-0.14**	-0.03	-0.16**	0.91**
Less-commonly-eaten meats	-0.09**	-0.13**	-0.61**	-0.07*	-0.01	-0.02	0.94**
Vegetables and fruits	-0.07	-0.23**	-0.15**	-0.36**	-0.14**	-0.07	1.03**
Oils and sugars	-0.07	-0.24	-0.22*	-0.42**	-0.50**	-0.09	1.54**
Snacks, drinks and condiments	-0.12**	-0.42**	-0.17*	-0.15**	-0.04	-0.50**	1.39**

Note:(*) indicates that the 90% HPD interval covers the true parameter

(**) indicates that the 95% HPD interval covers the true parameter

5.4 Implications of elasticity matrix

The following paragraphs will discuss the price and expenditure elasticities reported in Table 5.4. Since almost all studies analysing food demand pattern in China use NBS's Household Survey data and consequently define food groups based on the food classification adopted by the NBS, a direct comparison between the estimated price and expenditure elasticities in this thesis and those in other studies is not possible. Nevertheless, estimated own price and expenditure elasticities from selected studies are summarised in Table 5.1 and Table 5.2 with the aim of providing a rough impression of the position of the estimated elasticities in this thesis. It can be seen from Table 5.1 that earlier studies using aggregated data at city and provincial level produce relatively small own price elasticities within the range similar to that in this thesis. A recent one analysing provincial level data from 2000 to 2010 yields larger own price elasticities but still comparatively smaller than those estimated from household level data (Zheng et al., 2015).

Looking at the estimates in more detail, it is found that all estimated price elasticities are smaller than 1, implying the inelastic nature of demand for the defined food groups with respect to price changes. The reason for the comparatively small estimated price elasticities could be because of the high level of aggregation in both the food groups defined and in the food consumption data aggregated to community level. The high level of aggregation over food groups conceals the flexibility of substitution between more specific food items, and similarly, compared to household behaviour, a community as a whole would show a more stable and less diverse choice pattern. Another study using provincial level data in China from 2000-2010 investigating the consumption of 10 food groups by estimating a QAIDS model finds elasticities of sizes that are comparable to the ones reported in this study (Zheng et al., 2015).

What is notable about the price elasticity matrix is that the own price elasticity of the commonly eaten animal products is the second smallest of all six food groups whereas it is the highest for the less commonly eaten animal products. Since the common animal food group is mainly composed of pork, eggs and poultry, its low level of demand responsiveness to own price changes means that the demand for these foods tends to be relatively stable in an at-home diet. Taking into account its inelastic response to expenditure changes, common animal foods are still important in daily diet. Liu and Zhong (2009) also found that pork has survived as an important component of the traditional Chinese diet. In contrast, demand for less commonly eaten animal products is relatively responsive to its own price changes which signifies its novelty nature and more flexible role in daily diet. However, this group does not show elastic response to expenditure change either. The inelastic nature of expenditure elasticities of both these two animal food groups indicates the persistently important role of animal protein in a community averaged daily diet during the first decade of the twenty-first century in urban China. Moreover, their similar level evidences the critical role that is still played by more traditional animal products in food choice as diet diversification progresses. The finding of a slightly higher expenditure elasticity for less common animal foods than for common animal products is in line with the studies which have found that for households less common animal products such as aquatic products tend to have a more responsive expenditure elasticity than traditional meat such as pork (Zheng and Henneberry, 2009).

Third, this thesis finds that demand for oils and sugars is most sensitive to expenditure changes among the defined six food groups. This is in contrast to studies on urban household food consumption which find relatively inelastic demand for oils and fats to changes in food expenditure (Zheng and Henneberry, 2009; Zheng et al., 2015). There could be two reasons underlying such a discrepancy. The first reason could be the differently defined food group as sugars are combined with oils to form one group in this thesis, and sugars have been found to play an increasingly important part in Chinese diet as income grows, however still not yet consumed in large amount (Yu and Abler, 2009; Popkin, 2013). The second reason is that studies of rural household demand for foods in China tend to find a relatively large expenditure elasticity of oils and fats compared to those analysing urban households. This suggests that the food choice behaviour of the communities included in this study collectively might deviate from the urban households investigated in other studies. One evidence of this argument is that the averaged per capita income of the communities used in this thesis is smaller than the national urban average of each year. To be specific, the nominal national per capita income for urban households is 9422 yuan, 11759 yuan and 17175 yuan for 2004, 2006 and 2009 (China Statistical Book 2005, 2007 and 2010), while the nominal per capita income in this thesis for each wave is 8185 yuan, 9403 yuan and 14696 yuan respectively. Regarding demand for oils, it has been found that the higher income group tends to have a smaller expenditure elasticity in absolute terms and the lower income group tends to have a larger value in absolute terms (Zheng and Henneberry, 2010), therefore the lower averaged income of the communities analysed by this thesis may imply a relatively more responsive oil demand as expenditure changes.

In terms of grains, as expected, its own price elasticity and expenditure elasticity are both the smallest in absolute terms. This implies their surviving role as the "traditional" plant-based eating pattern moves towards a diversified and heterogeneous pattern.

As regards the relative high expenditure elasticity of vegetable and fruit group, this can be attributed to the potentially large expenditure elasticity of fruits which has been confirmed in a few studies on food consumption in China (e.g. Wu et al., 1995; Gould and Dong, 2004; Zhang, 2013). Liu and Chern (2003) analysing urban Chinese household food demand also found expenditure elasticities of vegetables and fruits both close to 1. Since vegetables and fruits play very different roles in the Chinese diet, where vegetables are traditionally consumed with main meals during the day in large quantities while fruits are more likely to be taken in small quantity between meals, the large expenditure elasticity of this combined group may overestimate vegetables' responsiveness to the increase in expenditure, especially when considering it as community averaged response. Also, it is expected that as incomes increase the demand for fruits could increase proportionally more than the increase in expenditure as people look for a more diversified and "healthier" diet.

The snacks, drinks and condiments group has the second highest expenditure elasticity and also a relatively large own price elasticity. Since oils as a main condiment in the Chinese diet have been excluded from this group, this indicates that, compared with other food groups, demand for snacks and drinks may be increasingly important as part of daily Chinese diet. However it has not yet become a habitual consumption. Additionally, even though not significant at the community level, the results indicate that snacks and drinks are potential substitutes for oils and sugars. The reason for this positive cross price elasticity could be because both these two groups tend to be highly palatable on their own while also enhancing the palatability of other foods. If the desire for palatable dishes that incorporate fatty and sweet tastes (Drewnowski, 1997; Yanovski, 2003; Berner et al., 2008) cannot be satisfied, people might resort to snacks and drinks that may produce similar satiety.

Figure 5.1: Estimated own price elasticities from other studies

Summary of estimated own price elasticities in selected studies

		Aggregated level				Household level			
Own price elasticities		Wu et al. (1995)	Fan et al. (1994)	Fan et al. (1995)	Zheng et al. (2015)	Liu & Chern (2003)	Yen et al. (2004)	Hovhannisyan et al. (2010)	Zheng & Henneberry (2009)
Grains					-0.739		-0.9		-1.221
	Rice	-0.7	-0.547	-0.709		-0.862		-0.286	
	Wheat		-0.455	-0.641					
	Coarse grain		-0.458	-0.263		-0.925			
	Beans				-0.156	-0.971			
Meats			-0.604	-0.384	-0.827				-0.853
	Pork	-0.65				-0.924	-0.21	-0.336	
	Poultry				-0.794	-0.907	-0.75	-0.869	-0.347
	Eggs	-0.47			-1.018	-0.914	-0.7	-1.081	-0.849
	Beef						-0.96	-0.611	
	Mutton								
	Aquatic products	-1.4			-0.806	-0.828	-0.37	-0.781	-0.101
Vegetables		-0.88	-0.472	-0.409	-0.896		-0.72	-0.313	-0.5
	Fresh vegetables					-0.832			
Fruits		-1.14			-0.974		-0.76	-1.312	-0.865
	Fresh fruits					-0.905			
Dairy products					-1.064			-1.588	-1.209
	Fresh milk					-1.066	-1.4		
Oils and fats					-0.338	-0.786	-0.55		-1.312
Other foods							-1		-1.609
	Alcohol	-0.796	-0.373						
	Sugar					-0.895			
	Nuts					-0.706			
	Cakes					-0.619			

Figure 5.2: Estimated expenditure elasticities from other studies

Summary of estimated expenditure elasticities in selected studies

		Aggregated level				Household level			
Expenditure elasticities		Wu et al. (1995)	Fan et al. (1994)	Fan et al. (1995)	Zheng et al. (2015)	Liu & Chern (2003)	Yen et al. (2004)	Hovhannisyan et al. (2010)	Zheng & Henneberry (2009)
Grains					0.662		0.82		0.795
	Rice	0.98	0.313	0.702		1.068		0.74	
	Wheat		0.589	1.092					
	Coarse grain		0.026	0.371		0.858			
	Beans				0.645	0.958			
Meats			1.783	1.271	0.922				1.04
	Pork	1.17				0.995	0.94	1.09	
	Poultry				1.017	1.054	1.26	1.22	1.001
	Eggs	0.54			1.003	0.81	0.77	1.22	0.824
	Beef						1.41	0.77	
	Mutton								
	Aquatic products	0.2			1.613	1.128	1.41	0.69	1.198
Vegetables		1.19	1.199	0.946		0.978	0.83	1.68	0.814
	Fresh vegetables				0.839				
Fruits		1.45					0.6	0.67	0.978
	Fresh fruits				0.976	1.033			
Dairy products					1.867			1.22	1.372
	Fresh milk					1.055	1.4		
Oils and fats					0.569	1.17	0.98		0.717
Other foods							1.31		1.18
	Alcohol		3.391	1.644					
	Sugar					0.961			
	Nuts					0.727			
	Cakes					0.947			

Chapter 6

Discussion: Food choice under projected scenarios

The potential impacts of socio-demographic factors on food choice have been discussed in the previous chapter. With the continuing progress of social development, those discussed key drivers that influence food decision are expected to transform as well. This chapter builds on the results of the estimated LAIDS and considers the possibilities in the future by depicting four projected scenarios of changing food choice in 2050 urban China. With the concern of health outcomes during dietary transformation, all communities are first examined as an entity then those that have been identified to be the most vulnerable in terms of their vegetable and fruit and oil and sugar intake are singled out for a closer look.

6.1 Projected scenarios: A picture of 2050 urban China

The level of China's modernisation that will be achieved by 2050 has been envisioned as a moderately developed society with the possible eradication of absolute poverty. A blueprint of China in 2050 depicts a Chinese population of around 1.4 billion whose average life expectancy is approaching 80, among which approximately a quarter would be 65 and above, and of which about 80% would be urban residents. The minimum monthly income of this Chinese population is expected to reach 1300 US dollars, and social services will be available to all (China Center for Modernisation Research, 2006). From the perspective of the food environment, and the food retail sector in particular the fresh produce food markets might be overtaken by supermarkets which are being run in a modern supermarket business mode. Taking into consideration the persistence of consumers' habit of shopping at traditional wet markets and the upgrading of these traditional food outlet formats, the role of fresh markets in meals prepared-at-home may not vanish. In addition, since this preference for the fresh produce offered by traditional wet markets that is regarded as a Southern Asia phenomenon has been observed in Hong Kong and Singapore which are well ahead in development compared with urban China, it is expected that wet markets may still play an important role in fresh produce retailing in urban China in 2050.

As a brief summary, the three key social elements identified at population level that are likely to influence food choice in China (i.e. population ageing, urbanisation process and supermarket revolution) are projected to their situations in 2050 by the following means. Since population ageing in China is an irreversible trend, its level in 2050 in urban China is projected to be 28% (the current average proportion is 15.50%), and it is taken as the basic situation with no uncertainty. Varied urbanicity level of communities in 2050 is captured by the previously defined dichotomous urban-rural variable. It is therefore assumed that in 2050, urban-rural difference in food preference will remain at a certain level due to their substantially unbalanced development level in China since the 1950s. Since the peri-urban areas are geographically surrounding the most developed urban regions, it is expected that cultures and habits of urban and their suburban areas might converge to some extent, and as cities expand and their functions are reallocated or spread to their approximate areas, some suburbs may experience suburbanisation. If in 2050 80% of China's population are urban residents, the average scale of agricultural production unit will have to be significantly increased compared with those in the first decade of the twenty-first century. This means that some suburban agricultural activities may transfer to and may be integrated into rural villages that specialise in agricultural production. Communities in county towns that are classified as rural in the dichotomous classification are assumed to maintain a relatively varied food preference compared with their urban and suburban counterparts. The uncertainty of this transforming food environment is summarised by two situations by examining the relative penetration level of supermarkets managed in a modern business mode and wet markets that could have already been upgraded to have a "supermarket style" but are however still composed of relatively small scale vendors. The current government programme of transforming wet markets to supermarkets may indicate the further penetration of modern supermarkets' control over fresh produce provision, and meanwhile local governments' encouragement of upgrading traditional wet markets to a "modern style" may imply the coexistence of both modern supermarkets and "modernised" wet markets. The survival of wet markets as the main source of fresh produce in Hong Kong, Taiwan and Singapore may indicate that this Southern Asian phenomenon will be observed in 2050 urban

China. Therefore, the relative convenience of modern supermarkets against wet markets of communities is projected to be either increased to level 5 or decreased to level 2 (The current average level is 3.7914.).

Dietary knowledge has the potential to affect food choice and intuitively it is expected that enhancing dietary knowledge could improve dietary quality. There have been government programmes that focus on nutrition education and therefore its value is projected to the largest value (45) that exists in the extant dataset so as to examine if increasing dietary knowledge to this level could ameliorate food quality of communities in 2050 urban China. Since income is taken as a categorical variable to capture the discontinuity in the effects of different levels of income on food choice in the first decade of the twenty-first century, such income effects are further applied to the situation in 2050.

As a reminder, the base scenario in 2050 urban China projects that the percentage of seniors aged 65 and over will be 28%. Built on this assumption, four scenarios in 2050 urban China include: (S1) Increased relative convenience of modern supermarkets against wet markets to level 5; (S2) Decreased relative convenience of modern supermarkets against wet markets to level 2; (S3) Increased relative convenience of modern supermarkets against wet markets to level 5, and enhanced dietary knowledge score to 45; (S4) Decreased relative convenience of modern supermarkets against wet markets to level 2, and enhanced dietary knowledge score to 45. Thus, uncertainty is seen to lie in the changing food environment brought by the supermarket revolution, and improving dietary knowledge is considered to be a potential means to influence food choice during the uncertainty of this transforming food environment. All communities are categorised into three groups according to their per capita per day oil and sugar and their vegetable and fruit at-home consumption quantity, with group **3** indicates the **least healthy group** (most intake of oils and sugars or least intake of vegetables and fruits), **2** the **medium healthy group** and **1** the **most healthy group** (most intake of vegetables and fruits or least intake of oils and sugars). Estimated coefficients and average values of the involved variables in the demand model that are based on data from the first decade of the twenty-first century (year 2004, 2006 and 2009) are used in the approximation of expenditure shares of the six defined food groups in 2050 urban China. Effects of projected scenario on food choice are computed by the difference between expenditure shares of the projected scenarios and of the base scenario which is divided by that of the base scenario. Thus, the calculated percentage changes measure the static effects of four scenarios in 2050 urban

China.

6.2 Effects of projected scenarios on food choice

Estimated effects of four scenarios on food choice of all communities and communities grouped by their oil and sugar and vegetable and fruit consumption quantities are presented in Table 6.1, Table 6.2, Table 6.3 and Table 6.4. "All groups" highlighted in blue in each table presents percentage change of expenditure shares under each scenario situation for all communities; "Oil grp 1" to "Oil grp 3" present results for community groups from the most healthy to the least healthy according to their oil and sugar intake; similarly, "Veg grp 1" to "Veg grp 3" show the results for the most to the least healthy community groups based on their vegetable and fruit consumption. The results of particular concern in terms of oil and sugar intakes are highlighted in yellow, and in terms of vegetable and fruit consumption they are highlighted in amber.

Table 6.1: Effects of Scenario 1 on expenditure shares: Percent change

Scenario 1: Increasing supermarket relative convenience to level 5						
	Grains	Commonly-eaten meat	Less-commonly-eaten meats	Vegetables and fruits	Oils and sugars	Snacks, drinks and condiments
All groups	-1.10%	0.67%	1.65%	-1.85%	3.94%	-4.82%
Oil Grp 1	-1.00%	0.70%	1.78%	-2.02%	4.46%	-5.14%
Oil Grp 2	-1.31%	0.85%	2.09%	-2.20%	5.42%	-6.35%
Oil Grp 3	-1.00%	0.56%	1.38%	-1.60%	3.11%	-3.95%
Veg Grp 1	-1.27%	0.73%	1.64%	-1.85%	3.66%	-4.21%
Veg Grp 2	-1.03%	0.63%	1.56%	-1.70%	3.74%	-4.43%
Veg Grp 3	-1.23%	0.75%	2.04%	-2.63%	5.40%	-8.97%

Table 6.2: Effects of Scenario 2 on expenditure shares: Percent change

Scenario 2 Decreasing supermarket relative convenience to level 2						
	Grains	Commonly-eaten meat	Less-commonly-eaten meats	Vegetables and fruits	Oils and sugars	Snacks, drinks and condiments
All groups	1.64%	-0.99%	-2.45%	2.75%	-5.84%	7.15%
Oil Grp 1	1.37%	-0.95%	-2.43%	2.76%	-6.09%	7.02%
Oil Grp 2	1.28%	-0.83%	-2.04%	2.15%	-5.30%	6.21%
Oil Grp 3	1.95%	-1.09%	-2.67%	3.10%	-6.04%	7.67%
Veg Grp 1	1.83%	-1.05%	-2.36%	2.66%	-5.28%	6.07%
Veg Grp 2	1.69%	-1.04%	-2.58%	2.81%	-6.16%	7.31%
Veg Grp 3	1.19%	-0.73%	-1.98%	2.55%	-5.22%	8.68%

Table 6.3: Effects of Scenario 3 on expenditure shares: Percent change

Scenario 3: Increasing supermarket relative convenience to level 5 + dietary knowledge taken to its maximum in existing values (45)						
	Grains	Commonly-eaten meat	Less-commonly-eaten meats	Vegetables and fruits	Oils and sugars	Snacks, drinks and condiments
All groups	15.21%	-17.06%	29.15%	0.57%	2.03%	-46.02%
Oil Grp 1	14.71%	-18.86%	33.17%	0.77%	2.18%	-51.62%
Oil Grp 2	13.22%	-15.98%	28.12%	-0.05%	3.46%	-47.03%
Oil Grp 3	16.64%	-17.17%	28.67%	0.88%	1.32%	-44.06%
Veg Grp 1	15.65%	-16.72%	26.29%	0.33%	2.06%	-36.68%
Veg Grp 2	15.25%	-17.30%	29.53%	0.68%	1.80%	-45.08%
Veg Grp 3	14.53%	-16.50%	31.56%	0.34%	3.13%	-75.38%

Table 6.4: Effects of Scenario 4 on different community groups: Percentage change

Scenario 4: Decreasing supermarket relative convenience to level 2 + dietary knowledge taken to its maximum in existing values (45)						
	Grains	Commonly-eaten meat	Less-commonly-eaten meats	Vegetables and fruits	Oils and sugars	Snacks, drinks and condiments
All groups	17.94%	-18.72%	25.05%	5.16%	-7.74%	-34.06%
Oil Grp 1	17.09%	-20.52%	28.96%	5.55%	-8.37%	-39.47%
Oil Grp 2	15.81%	-17.65%	24.00%	4.30%	-7.26%	-34.47%
Oil Grp 3	19.59%	-18.83%	24.61%	5.58%	-7.83%	-32.45%
Veg Grp 1	18.74%	-18.50%	22.29%	4.84%	-6.88%	-26.40%
Veg Grp 2	17.97%	-18.97%	25.38%	5.20%	-8.10%	-33.34%
Veg Grp 3	16.95%	-17.98%	27.54%	5.53%	-7.48%	-57.73%

First, results for all communities (all groups) are examined. Looking at results of Scenario 1, if convenience of modern supermarkets exceeds that of wet markets in 2050 urban China, community expenditure shares on grains, fruits and vegetables and snacks, drinks and condiments may decrease by 1.1%, 1.85% and 4.82%, whilst that of animal proteins including both common and less common meats, and oils and sugars may increase by 0.67%, 1.65% and 3.94%. On the contrary, if modernised wet markets survive in their competition with modern large-scale supermarkets in the fresh produce retail market (Scenario 2), their success may increase expenditure shares on grains, fruits and vegetables and snacks, drinks and condiments by 1.64%, 2.75% and 7.15%, while at the same time decreasing that of both common and less common meats as well as that of oils and sugars by 0.99%, 2.45% and 5.84%. If, at the same time, dietary knowledge can be enhanced, the effects imposed by the changing food environment on some food groups could be changed. Specifically, if modern supermarkets further penetrate communities and become more convenient than wet markets, while, at the same time, community average dietary knowledge level improves by 10% (from 41 to 45: $(45-41)/41$)(Scenario 3), then the positive effects of increasing modern supermarkets' convenience on expenditure shares of common meats will be turned to negative, with the specific magnitude to be -17.06%. At the same time, expenditure share on grains and vegetables and fruits may change the sign from negative to positive that is from -1.10% to 15.21%. Comparatively, enhancing dietary knowledge along with decreasing relative convenience of modern supermarkets (Scenario 4) would change the positive effects of decreasing supermarkets' convenience on expenditure shares of snacks, drinks and condiments to negative (from 7.15% to -34.06%), and change the negative effects on less common meats to positive (from -2.45% to 25.05%). Under this scenario, improving dietary knowledge reinforces the effects of the changing food environment except in these two food groups.

Second, focusing on the food choice of fruits and vegetables that are considered healthy and therefore increased intake is encouraged, enhancing the convenience of modern supermarkets may be related to decreasing expenditure shares on this healthy food group, and such a decrease would be more pronounced for the community group that currently intakes the least amount of fruits and vegetables (Veg Grp 3). This means that compared with the average effects across all communities (All groups), communities that are the most reluctant in fruits and vegetables consumption may lessen their expenditure shares on fruits and vegetables even more if wet markets become less convenient. However, the increasing convenience of wet markets would not vastly increase the expenditure share on fruits and vegetables of this community group (Veg Grp 3). Instead, expenditure share on this healthy food group of the medium healthy community group (Veg Grp 2) would be mostly stimulated by increasing wet markets' convenience. Considering the impact of dietary knowledge on expenditure shares, improving its score to a certain level (45) with the changing food environment may mitigate the potential negative impacts on nutrition. Such positive effects of dietary knowledge is especially expressed with the community group that intakes least amount of fruits and vegetables (Veg Grp 3) for both directions of the changing food environment. With better dietary knowledge, the negative effects of increasing supermarket convenience on fruits and vegetables would be reversed to positive, and the positive effects of increasing relative convenience of wet markets would be reinforced. Thus, improving dietary knowledge would have the most noticeable positive effects on the most vulnerable communities identified by their vegetables and fruits intake, and increasing the relative convenience of wet markets together with enhancing nutrition knowledge (Scenario 4) would be the most prominent scenario to stimulate community expenditure share on vegetables and fruits in the context of 2050 urban China.

Third, taking a closer look at communities' choice on oils and sugars which are, in general, regarded as unhealthy and a restricted amount of intake is always suggested, the increasing convenience of modern supermarkets against wet markets would increase their expenditure shares and such an effect appears to be most phenomenal with the medium healthy community group defined by their oil and sugar consumption (Oil Grp 2). The community group that currently intakes the most amount of oils and sugars (Oil Grp 3) would be the group that increases their expenditure shares on this group comparatively slightly, which is less than the average level of all groups. Comparatively, increasing wet market convenience would decrease expenditure share on oils and sugars and a similar level of effects appear for the least and most healthy community groups (Oil Grp 1 and Oil Grp 3), which is greater than the averaged effect for all group communities. Augmenting community dietary knowledge level to 45 may ameliorate the negative health impacts brought by increasing supermarket convenience, and may reinforce the positive health influence of surviving wet markets. Such effects are most evident for the most healthy community group (Oil Grp 1) and least obvious for the least healthy (Veg Grp 3). Thus, the currently most risky communities in terms of their oil and sugar intake would not be those most noticeably affected by dietary knowledge augmentation, but this community group would still be benefited by dietary knowledge improvement. Scenario 4 which increases the wet market's relative convenience and simultaneously enhances nutrition knowledge level would be the most effective to reduce community expenditure share on oils and sugars.

As for other food groups, similar patterns of effects of projected food environment and dietary knowledge can be found. The positive health effect of improving dietary knowledge to the projected level can also be seen from the positive influence on the expenditure shares of less common meats and negative effects on snacks, drinks and condiments. Since preference for less common animal products can be a sign of diet diversification, it is generally taken as a positive aspect of diet transformation. The negative association between nutrition knowledge and expenditure share of snacks, drinks and condiments indicates its potential to limit the expenditure share on this food group which is always considered relatively unhealthy as it can be dominated by energy-dense and nutrient-poor food items. Another observation would be the considerable impact of dietary knowledge on the more "traditional" food groups, grains and commonly-eaten meats. With a higher level of dietary knowledge, the expenditure share on common animal products would be remarkably reduced in any projected food environment, and that on grains would be increased substantially. Thus, with the exception of the ambiguous nutritional implications on increasing expenditure share on grains, better dietary knowledge is likely to contribute to more nutrition conscious food choice.

To sum up, from the perspective of promoting the expenditure share of vegetables and fruits and reducing that of oils and sugars, Scenario 4 which increases wet market convenience in relative to modern supermarkets and simultaneously improves dietary knowledge to the level of the current maximum would be the optimal choice. Under this scenario, diversification of animal food products and decreased expenditure of snacks and drinks would also be achieved. Despite the ambiguous nutritional implications, expenditure shares on grains would also be substantially increased. The most vulnerable community group in their vegetable and fruit consumption would be mostly benefited under Scenario 4 and the most healthy group in terms of their oil and sugar choice would be mostly benefited under this scenario. However, the differences between the magnitudes of effects on the three community groups appear to be small.

6.3 Policy implications of enhancing dietary knowledge to improve diet quality

The above findings highlight potential benefits of improving nutrition knowledge on community diet quality in 2050 urban China under projected changing food environment scenarios, and, as such, provide direction for policy implications.

Dietary knowledge can be promoted through education programmes. Nutrition education and intervention in China have been implemented at provincial level on a large scale, and at local level where intensive education programs are designed to target patients with specific diseases. An example of large-scale nutrition promotion programme which has been implemented in China is the health-promoting schools (HPS) project, a collaboration between the Government of China and WHO (Glasauer et al., 2003). This project was based at the Health Education Institute of the Zhejiang Provincial Centre for Disease Control and Prevention and was implemented in nine schools across the entire province. Compared with traditional health promoting programmes that only concentrate on providing health and nutrition curriculum, HPS provides a holistic framework that integrates school activities, related aspects of school environment and engagement with families and the wider school community (Bowker et al., 1998; Wang et al., 2013). Studies have found its effectiveness in boosting students' diet and health knowledge, in changing students' attitudes towards foods (e.g. be more health and nutrition conscious), and in further shifting health-related behaviour (e.g. eating more nutritiously) (e.g. Xia et al., 2004; Aldinger et al., 2008). The effectiveness of the HPS approach on improving nutrition knowledge and diet behaviour has been compared with less comprehensive programmes concentrating only on health education, and it is found that although both two types of programmes significantly enhance nutrition knowledge, the more holistic HPS framework tends to be more effective and its positive effects on influencing students' actual eating behaviour can also be more significant (Wang et al., 2013). Nonetheless, evidence from school-based education programmes have shown the positive link between enhancement of nutrition and health knowledge of children and improved health-related behaviour (e.g. Kain et al., 2004; Hu et al., 2010; Sylvia et al., 2013). At local level, relatively small-scale intensive nutrition and health education programs are designed to target patients with specific diseases such as hypertension and diabetes (e.g. Jiang et al., 2008; Wang et al., 2014; Li et al., 2016). Local level evidence has also confirmed behaviour changes after intensive disease-related education aimed at individuals with health risks (e.g. Cheng et al., 1992; Lin et al., 2001; Fu et al., 2007; Zhang, 2010).

The effectiveness of these nutrition education programmes are often examined within the framework of a knowledge, attitude and practices (KAP) model. Behaviour change in this basic model is assumed to be influenced by changes in knowledge level and/or attitudes (Schwartz, 1975). Many studies have found a positive relationship between knowledge level and overt behaviour or between attitude and overt behaviour. There does, however, seem to be a gap between the extent of improvement in knowledge/attitude and in actual behaviour (e.g. Bettinghaus, 1986; Clayton et al., 2002). With specific reference to eating behaviour changes, it appears that enhancement in nutrition knowledge can contribute to positive changes in diet decision, but it is very likely that the extent of improvement in eating behaviour will be smaller than the improvement in dietary knowledge (e.g. Doak et al., 2006; Wang et al., 2013). Therefore, the potential difference between dietary knowledge and food practice needs to be taken into consideration. In addition, the relative success of the HPS project implemented in China highlights the importance of imposing influence on the general environment in which food decisions are made, rather than only focusing on one stage during food choice.

The simulated positive impacts of dietary knowledge at averaged community level, which are found in this study, evidence the potential of nutrition knowledge promoting programs targeting overall community instead of households or individuals, which could act as supplements to the existing government-led programs such as HPS. The key social transforming drivers at community level together with other socio-demographic factors underlying food decision provide guideline to identify community segments in terms of their urgent need of diet improvement in their intake of healthy vegetables and fruits and unhealthy oils and sugars. To be specific, the least healthy communities with respect to their vegetable and fruit consumption are characterised by relatively lower income level, lower education level, lower proportion of working age adults, less urbanised, having the lowest overweight and obesity rate and consuming the least amount of all other food groups (see Table 4.6 in Data chapter). This could mean that before considering any nutrition education programmes aimed at promoting vegetable and fruit intake, their detailed diet composition and overall food security status at more disaggregated level needs to be further examined. Nutrition education programmes targeting this community group need to be able to link the potential needs of this segment with their vegetable and fruit consumption. Conventional style government-led promotion programmes that are implemented by community or district authorities might be effective with these communities. In comparison, community groups that have been identified to consume the most oils and sugars are characterised by higher urbanisation levels and higher percentage of working age adults which might suggest that they might be less responsive to conventional government-led programs. Other dietary knowledge promotion methods such as through the practice of social marketing might be more effective with this community group (e.g. Dutta and Youn, 1999; Grier and Bryant, 2005; Hu et al., 2011). Advantages of programmes designed at community level could be their relatively lower costs compared with household and individual targeted programmes, their attention to the more holistic living environment, and their potential to overcome the essential differences in food preferences of different socioeconomic groups by influencing the overall community social environment pertaining to food preference.

Thus, to avoid the potential negative health effects of nutrition transition in 2050 urban China, the major policy suggestion would be to implement dietary knowledge promotion programmes aimed at entire communities, and the design of these programmes needs to consider carefully the different characteristics of the communities that face the most urgent nutrition consequences caused by their food decisions. In addition, local governments' efforts in modernising traditional wet markets would play a positive role to maintain a certain healthy part of traditional diet that emphasises vegetables and fruits intake. However, whether wet markets will be replaced by modern supermarkets or not, or to what extent modern supermarkets could become a major source of daily foods especially that of fresh produce, remains unclear. Nonetheless, regardless of the direction of food market evolution in 2050, improving dietary knowledge has the potential to improve community averaged diet quality.

Chapter 7

Conclusions

7.1 Summary of the thesis

The observed fast increasing obesity rate and related health problems in China can be attributed to the changing patterns of both diet and physical activity. This thesis focuses on changing food patterns and examine them in the background of concomitantly happening rapid social development. The food patterns analysed are restricted to foods eaten at home and are defined with six broad food groups. The three key aspects of social development discussed are the urbanisation process, the ageing population and the supermarket revolution. Community level data are adopted to capture the effects of social changes on food choice. Based on the estimated effects, the ageing population and supermarket penetration are projected to their possible levels in 2050 urban China, and varied urbanicity levels are captured by city-town differences. Since population ageing in China seems to be an irreversible trend, its forecast level is treated as the baseline situation in 2050 urban China. Also, since urbanicity level is described by the dichotomous classification of city or town, it is assumed that such divergence remains in 2050. Therefore, the uncertainty of social transformation is examined through the changing food environment. Two possible directions of the changing food environment are projected, i.e., modern supermarkets will become more convenient than modernised wet markets, or modernised wet markets will maintain their relative convenience against modern supermarkets. These two scenarios are further augmented by diet knowledge since improving nutrition knowledge can be an effective tool to enhance diet quality.

Findings confirm the differences in food demand between city and town areas, and these differences are taken as evidence that, at least cross-sectionally, different urbanicity levels imply varied food choice. Population ageing is shown to have a significant negative effect on the expenditure share on grains and a significant positive effect on that of less-commonly-eaten animal products, which is not consistent with findings in the existing literature. Such inconsistency may be due to the model specification where, in this study, the interaction effect between age and dietary knowledge is modelled explicitly whereas in other studies such potential interaction is usually ignored. The inconsistency may also be due to the differently defined food groups. Results in this study highlight the potentially important roles played by relatively cheaper traditional grains and a more varied assortments of animal products in elderly people's at-home diet. Contrary to the extant evidence, supermarket penetration may not increase expenditure share on snacks and drinks which are usually regarded as the culprit for the deterioration of diet quality during nutrition transition in developing countries. On the one hand, this implication needs to be interpreted with caution since the level of supermarket penetration is defined by "relative convenience" in distance in comparison with wet markets which completely ignore the type and scale of any markets; however, on the other hand, this result might indicate that at community level, supermarket penetration may be linked to an overall trend of lifestyle shift which does not necessarily have to be "unhealthy" in terms of its diet component.

In the context of 2050 urban China, projected scenarios with approximated levels of supermarket penetration and population ageing can be augmented by dietary knowledge being increased to its maximum value (that appears among the communities analysed), so as to mitigate the negative impacts of changing food environment on diet. Results from augmented scenarios confirm the positive nutrition impact of diet knowledge improvement on food choice. From the perspective of enhancing the intake of vegetables and fruits and reducing that of oils and sugars, the scenario of increasing the convenience of modernised wet markets relative to that of modern supermarkets in combination with improving nutrition knowledge appears to be the best choice. Besides, this scenario also shows the potential of increasing animal food diversity and decreasing snacks and drinks intake even though such effects tend to be smaller than those from the scenario of increasing the relative convenience of modern supermarkets and dietary knowledge simultaneously. However, the health implications of the substantial positive effect of nutrition knowledge on the expenditure share of grains need further investigation.

7.2 Limitations

Reflections on the limitations of this thesis are from the perspectives of data, variable definition and construction, and model selection.

One of the advantages of the CHNS data is its comprehensive food diary file which documents detailed food items consumed at home for both households and individuals. However, expenditure data on detailed food consumption are available for neither households nor individuals. Instead, only prices of the representative food items consumed at community level are accessible. Over the years 2004, 2006 and 2009, only 44 prices have records in the community level price data. This means that in order to match the price data with the food consumption data, detailed food items are first aggregated to the level which can be roughly approximated by the available price data. Meanwhile, since the price collected are not directly addressing the food entries in China's Food Composition Table, averages of some prices are taken so as to reflect the general price level of a specific defined food group. For example, prices of green vegetables (rape), cabbages and most commonly eaten vegetables which vary across communities are utilised as an approximation of overall vegetable price. The rich heterogeneity in the food consumption information is consequently lost as aggregation is made assuming that a large number of distinct food items share the same price for each community.

Another noted limitation caused by limited price information is the discarding of all food items included in China's Food Composition Table Book 2. From the perspective of potential nutrition and health effects of food choice, exclusion of those most highly-processed food items that are documented in Book 2 would result in significantly underestimating the expenditure share of food group snacks, drinks and condiments. Since the extant literature blames the modern supermarket as a culprit of the increasing intake of "unhealthy" snacks and drinks, the findings of the insignificant impacts of the supermarket revolution on this food group as defined in this thesis might also be caused by the underestimation of the expenditure share on this food group.

The second major limitation is the definition and construction of variables measuring social development factors. The three key aspects of social development discussed are the urbanisation, the ageing population and supermarket penetration. Population ageing is measured by senior proportion which is relatively straightforward. However, the measurement of urbanicity level and supermarket penetration may not be unambiguous.

The measurement of urbanicity levels of community follows a dichotomous method which may risk oversimplifying the differences in real social environment between cities and towns. In effect, in the CHNS communities are classified as urban or rural where the urban site is further classified into an urban neighbourhood or a suburban village and the rural site into a county town or a rural village. The definition of “urban” and “rural” at first level is consistent with the classification adopted by the NBS China. This thesis follows the definition implemented by the CHNS and takes urban neighbourhoods and suburban areas as city while county towns are classified as town, and it is assumed that the urbanicity level in these two areas is distinct in the sense that their varied living environments are used as the measurement of overall urbanicity level. However, as pointed out in the literature, some suburban areas around big cities may still function primarily as agricultural areas with a social environment closer to rural villages (e.g. Van de Poel et al., 2009). Other studies describe the fast suburbanisation of these areas and tend to conclude their roles as functional cities to their nearby large cities (e.g. Wu and Phelps, 2011; Shen and Wu, 2013). Moreover, the rapid townisation process which is considered to be another aspect of urbanisation may further complicate the real social environment changes during fast “urbanising” process (Guan and Rowe, 2016). Literature also studying CHNS has proposed a comprehensive urbanicity index as the measurement of a community’s overall urbanisation level (Jones-Smith and Popkin, 2010). However, this overall index is considered to be too general for the purpose of this thesis focusing on food choice. A more clear-cut as well as well-defined measurement of business facility (excluding supermarkets) density and population density might be more appropriate to capture the key aspect of the urbanising process that may be related to aggregated food choice patterns. Nevertheless, in the attempt to construct those “density” related variables, a relatively significant number of missing values in community area and population variables renders this approach not worthwhile.

Meanwhile, the “supermarket revolution” is currently defined as the “relative convenience of supermarkets against wet markets”, where “convenience” is defined by the distance to the nearest market for the community. This definition does not capture the variation in the type and scale of any market. Since the supermarket revolution in China starting from large-scale general superstores are gradually diversifying in formats into food supermarkets, community supermarkets and other specialised supermarkets, it is important to examine the type of supermarkets so as to approximate their importance as community food sources (direct information on household food source is not included in the dataset). This is particularly critical since the scenario analysis is projected into 2050, and the format of supermarkets that run in the modern business mode is likely to be even more diversified then than that in the first decade of the twenty-first century. Similarly, it is expected that, in order to be able to survive to the middle of this century, the organisation and management style of wet markets must be upgraded. However, without information on the dataset distinguishing between already "modernised" wet markets and those not yet being upgraded, it may be the information of those that might be soon eliminated by the market that is included in the constructed variable. Therefore, the interpretation of the effects of this variable needs to be made tentatively.

Moreover, the definition of variable dietary knowledge might be vague. The construction of this variable followed the widely practised method of marking consumers' answers to nutrition related true or false questions (e.g. Zhang et al., 2011; Zhang and Chang, 2012). However, it seems that some of the questions in the dietary knowledge survey can be straightforwardly answered by yes or no which reflects the level of knowledge acquisition, whilst others tend to measure attitude rather than hard knowledge. It needs to be noticed that all questions are designed to be measured on a Likert scale, which may be less suitable for recording absolute knowledge levels. On the other hand, however, measuring nutrition and food related opinions and attitudes is more directly related to actual food behaviour than measuring dietary knowledge itself (e.g. Wardle et al., 2000; Gibson et al., 1998; Spronk et al., 2014). To bridge the gap between dietary knowledge or attitude and overt food choosing behaviour, a more comprehensive measurement model could be constructed to further estimate the weights for each aspect of dietary knowledge (that is, a weight assigned to each question). However, the fact that there is a limited number of questions in the dataset may impede the implementation of this method.

Furthermore, the classification of communities according to dietary health as measured by oil and sugar and fruit and vegetable consumption fails to take into account the interactions between the two. Arguably, a unified dietary health index would have been more appropriate.

Finally, the choice of the standard Tobit model rules out the possibility that purchase (decision) function and consumption function can be governed by different data generating mechanisms as in a double hurdle model (Jones, 1989) which describes the decision process and purchase process in a two-step way. However, this is only taken as a minor limitation in practice since in the data analysed there is only 0.30% censoring in total.

7.3 Future research directions

Future research directions could be to investigate in more detail how the unique characteristics of communities may affect food choice in the context of rapid social development, and in particular the emphasis should be put on a more clearly defined and measured set of relevant social development factors. To achieve this goal, ideally, a larger community sample with more variation needs to be surveyed and examined, in particular in terms of their more accurate community business facility information.

Taking into consideration the fast urbanising process happening in China, examining food behaviour of rural village communities and comparing this behaviour with that of city and town area would add more information to the overall picture of changing food patterns during social development in China. Viewing the urbanisation process from the perspective of population migration, tracing the dietary patterns of rural-urban migrants may provide more insights into how overall social environment and food environment may affect food choice.

Considering the potential of dietary knowledge to improve diet quality, constructing a specific measurement model based on the CHNS data to provide a more direct dietary knowledge index could be insightful. It could be expected that a more accurately defined and measured dietary knowledge level would be able to predict actual food choice behaviour more realistically.

Community level analysis provides a broad view of changing food patterns during the transformation of social environment and such an analysis can be enriched by household and individual level analysis. It would be interesting to also classify households and individuals based on their urgent needs in terms of diet improvement and to match them with the corresponding communities. By doing this, the differentiated effects of community level health-related instruments on community members could be identified and detailed.

Finally, since detailed food diary data are collected for both individuals and households, it may be worth making an attempt to overcome the limitations in price and expenditure information within the framework of an economic model.

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Appendix A

Food energy intake and sources

Data in this table are sourced from the China Health and Nutrition Survey of various years.

Table A.01: Trends of energy intake and energy sources from 1990s in China

Energy sourced from macronutrients by region from 1991 to 2009					
	Year	Fat(%)	Protein(%)	CHO(%)	Calorie(Kcal)
Urban	1991	28.7	12.6	58.7	2369.3
	1993	32	13	55	2297.1
	1997	35	12.85	52.15	2435
	2000	35.35	13.1	51.55	2292.3
	2004	33.95	13.35	52.7	2292.6
	2006	38.85	12.7	48.45	2249.1
	2009	36.1	13.7	50.2	2066.6
Suburban	1991	24.4	12	63.6	2573
	1993	26.1	12.3	61.6	2508.8
	1997	29.1	11.8	59.1	2647
	2000	32.9	12.05	55.05	2401.9
	2004	30.65	12.4	56.95	2363.6
	2006	33.55	12.45	54	2370.6
	2009	34.35	13.05	52.6	2189.5
Town	1991	25.4	12.4	62.2	2334.1
	1993	25.4	12.5	62.1	2359.8
	1997	27.85	12.15	60	2348.3
	2000	30.65	12.15	57.2	2347.1
	2004	30.95	12.45	56.6	2291
	2006	32.15	12.3	55.55	2276.4
	2009	32.8	12.45	54.75	2203.9
Rural	1991	18.2	11.4	70.4	2553
	1993	18.5	11.8	69.7	2442.7
	1997	21.75	11.35	66.9	2607.6
	2000	25.7	11.3	63	2464.9
	2004	24.5	11.65	63.85	2418.4
	2006	27.7	11.5	60.8	2496.7
	2009	29.75	11.8	58.45	2336.7
Total	1991	24.175	12.1	63.725	2457.35
	1993	25.5	12.4	62.1	2402.1
	1997	28.425	12.0375	59.5375	2509.475
	2000	31.15	12.15	56.7	2376.55
	2004	30.0125	12.4625	57.525	2341.4
	2006	33.0625	12.2375	54.7	2348.2
	2009	33.25	12.75	54	2199.175

Data source: China Health and Nutrition Survey 1991 to 2009

Appendix B

Consumer price index & Adult equivalent scale coefficients

This appendix documents chained consumer price index (CPI) originally presented in China Provincial Statistical Yearbooks and the converted fixed based index that were used in the data cleaning of this thesis, and adult equivalent scale (AES) coefficients used in the adjustment of per capita per day energy intake. The variable T1 is the province code used in the CHNS.

CPI and computed CPI by province urban/rural

wave	T1 (Province code)	CPI urban_general	CPI urban general_2004base	CPI urban_food	CPI urban food_2004base	CPI rural_general	CPI rural general_2004base	CPI rural_food	CPI rural food_2004base
2004	21	102.8	100.0	108.1	100.0	106.3	100.0	111.9	100.0
2005	21	100.8	100.8	101.9	101.9	104.0	104.0	101.7	101.7
2006	21	101.1	101.9	102.5	104.4	101.6	105.7	102.0	103.7
2007	21	104.6	106.6	111.9	116.9	107.0	113.1	116.5	120.9
2008	21	104.4	111.3	112.3	131.3	105.5	119.3	112.3	135.7
2009	21	100.0	111.3	125.5	164.7	100.3	119.7	133.0	180.5
2004	23	103.5	100.0	107.7	100.0	105.2	100.0	113.9	100.0
2005	23	100.8	100.8	99.7	99.7	102.3	102.3	101.4	101.4
2006	23	101.8	102.6	102.9	102.6	102.4	104.8	103.4	104.8
2007	23	105.4	108.2	113.5	116.4	105.4	110.4	114.5	120.1
2008	23	105.0	113.6	110.9	129.1	107.2	118.4	115.2	138.3
2009	23	99.8	113.4	101.3	130.8	101.2	119.8	100.8	139.4
2004	32	103.7	100.0	110.2	100.0	104.6	100.0	110.2	100.0
2005	32	102.0	102.0	103.6	103.6	102.4	102.4	104.5	104.5
2006	32	101.6	103.6	102.7	106.4	101.7	104.1	102.6	107.2
2007	32	104.1	107.9	110.7	117.8	104.8	109.1	112.5	120.6
2008	32	105.2	113.5	113.5	133.7	105.6	115.3	112.0	135.1
2009	32	99.6	113.1	101.1	135.2	99.5	114.7	100.7	136.0
2004	41	105.4	100.0	114.1	100.0	105.4	100.0	112.4	100.0
2005	41	102.1	102.1	104.0	104.0	102.1	102.1	102.4	102.4
2006	41	101.2	103.3	101.9	106.0	101.5	103.6	101.3	103.7
2007	41	105.4	108.9	114.2	121.0	105.5	109.3	115.9	120.3
2008	41	106.5	116.0	116.2	140.6	107.9	118.0	116.5	140.1
2009	41	98.8	114.6	101.9	143.3	100.4	118.5	100.3	140.5
2004	43	104.1	100.0	110.2	100.0	105.7	100.0	114.0	100.0
2005	43	102.1	102.1	104.0	104.0	102.8	102.8	100.9	100.9
2006	43	101.6	103.7	101.8	105.9	101.2	104.0	100.7	101.6
2007	43	105.2	109.1	113.0	119.6	106.9	111.2	116.0	117.9
2008	43	105.8	115.5	115.0	137.6	107.4	119.4	116.2	137.0
2009	43	99.7	115.1	100.7	138.5	99.6	119.0	99.4	136.1
2004	45	104.1	100.0	111.7	100.0	104.9	100.0	113.0	100.0
2005	45	103.0	103.0	103.1	103.1	101.6	101.6	102.2	102.2
2006	45	101.6	104.7	102.4	105.6	100.9	102.5	101.2	103.4
2007	45	105.6	110.5	113.3	119.6	106.8	109.5	115.3	119.3
2008	45	107.6	119.0	119.5	142.9	108.5	118.8	121.0	144.3
2009	45	99.2	118.0	98.8	141.2	97.5	115.8	97.1	140.1

Continued

wave	T1 (Province code)	CPI urban_general	CPI urban general_2004base	CPI urban_food	CPI urban food_2004base	CPI rural_general	CPI rural general_2004base	CPI rural_food	CPI rural food_2004base
2004	52	103.5	100.0	111.0	100.0	105.3	100.0	116.6	100.0
2005	52	100.6	100.6	101.1	101.1	102.1	102.1	101.7	101.7
2006	52	101.6	102.2	104.0	105.1	102.0	104.1	102.2	103.9
2007	52	105.9	108.2	116.1	122.1	107.4	111.8	118.2	122.9
2008	52	107.0	115.8	117.0	142.8	108.8	121.7	118.1	145.1
2009	52	98.6	114.2	98.9	141.3	99.0	120.5	97.6	141.6
2004	37	102.8	100.0	108.4	100.0	104.6	100.0	110.0	100.0
2005	37	101.1	101.1	102.2	102.2	102.4	102.4	103.5	103.5
2006	37	101.0	102.1	102.3	104.6	101.0	103.4	101.9	105.5
2007	37	103.8	106.0	112.3	117.4	105.3	108.9	115.5	121.8
2008	37	104.7	111.0	112.8	132.4	106.2	115.7	113.3	138.0
2009	37	99.9	110.9	101.7	134.7	100.1	115.8	100.5	138.7
2004	42	104.5	100.0	110.3	100.0	105.8	100.0	111.3	100.0
2005	42	102.7	102.7	104.9	104.9	103.3	103.3	102.9	102.9
2006	42	101.5	104.2	102.2	107.2	101.9	105.3	101.8	104.8
2007	42	104.7	109.1	112.4	120.5	105.1	110.7	112.9	118.3
2008	42	105.7	115.4	114.2	137.6	107.4	118.9	116.5	137.8
2009	42	99.3	114.6	100.4	138.2	100.0	118.9	100.6	138.6

References: China Statistical Yearbooks by province from various years

Adult male equivalent coefficient based on EER

age and age group		male			female		
lower	upper	PAL I	PAL II	PAL III	PAL I	PAL II	PAL III
0	0		0.22			0.19	
0.5	0.5		0.22			0.19	
1	1		0.40			0.36	
2	2		0.49			0.44	
3	3		0.56			0.53	
4	4		0.58			0.56	
5	5		0.62			0.58	
6	6	0.62	0.71	0.80	0.56	0.64	0.73
7	7	0.67	0.76	0.84	0.60	0.69	0.78
8	8	0.73	0.82	0.93	0.64	0.76	0.84
9	9	0.78	0.89	1.00	0.69	0.80	0.89
10	10	0.80	0.91	1.02	0.73	0.84	0.96
11	14	0.91	1.04	1.16	0.80	0.91	1.02
14	18	1.11	1.27	1.42	0.89	1.02	1.13
18	50	**1.00**	1.16	1.33	0.80	0.93	1.07
50	65	0.93	1.09	1.24	0.78	0.91	1.04
65	80	0.91	1.04	1.19	0.76	0.87	0.99
80		0.84	0.98	1.12	0.67	0.78	0.89

PAL: Physical Activity Level (I: light; II: middle; III: high)

EER: Estimated Energy Requirement

Reference: Chinese Nutrition Association (2013) *Chinese Dietary Reference Intakes (DRIs)* , China Light Industry Press: Beijing.

Appendix C

Overweight and obesity criteria for the Chinese population

This table documents the overweight and obesity criteria defined in BMI, which were adopted by this study. These criteria were especially developed among the Chinese population (Li et al., 2010). Criteria for male and female adults (aged 18 and over) are identical.

Table C.01: Overweight and obesity criteria by age: cut-off points of BMI

	Boy		Girl	
Age	Overweight	Obese	Overweight	Obese
2	17.5	18.9	17.5	18.9
3	16.8	18.1	16.9	18.3
4	16.5	17.8	16.7	18.1
5	16.5	17.9	16.6	18.2
6	16.8	18.4	16.7	18.4
7	17.2	19.2	16.9	18.8
8	17.8	20.1	17.3	19.5
9	18.5	21.1	17.9	20.4
10	19.3	22.2	18.7	21.5
11	20.1	23.2	19.6	22.7
12	20.8	24.2	20.5	23.9
13	21.5	25.1	21.4	25
14	22.1	25.8	22.2	25.9
15	22.7	26.5	22.8	26.7
16	23.2	27	23.3	27.2
17	23.6	27.5	23.7	27.6
18	24	28	24	28

Source: Li et al. (2010)

Appendix D

Standard deviations of the estimated variables

This Appendix documents estimated standard deviations of the quantities of interest.

Table D.01: Estimated coefficients in the LAIDS: Standard deviation

	Estimated coefficients (standard deviation) in the equation of					
Explanatory variables	Grains	Commonly-eaten meats	Less-commonly-eaten meats	Vegetables and fruits	Oils and sugars	Snacks, drinks and condiments
Constant	0.2950	0.3643	0.4708	0.2938	0.2854	0.5869
ln(p-grain)	0.0145	0.0110	0.0099	0.0092	0.0085	0.0067
ln(p-common meat)	0.0110	0.0146	0.0114	0.0092	0.0092	0.0075
ln(p-less common meat)	0.0099	0.0114	0.0178	0.0095	0.0092	0.0107
ln(p-veg and fruit)	0.0092	0.0092	0.0095	0.0106	0.0071	0.0068
ln(p-oils and sugars)	0.0085	0.0092	0.0092	0.0071	0.0099	0.0064
ln(p-snacks and drinks)	0.0067	0.0075	0.0107	0.0068	0.0064	0.0126
ln(expend/P)	0.0178	0.0211	0.0300	0.0180	0.0175	0.0326
Income L2	0.0117	0.0145	0.0188	0.0118	0.0114	0.0235
Income L3	0.0142	0.0171	0.0224	0.0138	0.0137	0.0281
Senior >= 65 (%)	1.8539	2.3096	2.9587	1.8666	1.8239	3.7241
Dietary knowledge (DK)	0.0072	0.0089	0.0115	0.0072	0.0070	0.0143
Relative conv. Spmkt vs. wet mkt	0.0031	0.0038	0.0050	0.0031	0.0031	0.0062
Town	0.0104	0.0128	0.0167	0.0105	0.0102	0.0210
DK*(Senior >= 65)	0.0449	0.0560	0.0717	0.0453	0.0442	0.0903
2006	0.0170	0.0205	0.0233	0.0155	0.0157	0.0266
2009	0.0149	0.0193	0.0215	0.0142	0.0140	0.0243

Source: estimated results based on data from CHNS 2004, 2006 and 2009

Table D.02: Uncompensated price and expenditure elasticity matrix: Estimated standard deviation

	Price of						**Expenditure**
Food group	Grains	Commonly-eaten meats	Less-commonly-eaten meats	Vegetables and fruits	Oils and sugars	Snacks, drinks and condiments	
Grains	0.1255	0.1040	0.0879	0.0863	0.0750	0.0659	0.1545
Commonly-eaten meats	0.0458	0.0649	0.0490	0.0422	0.0394	0.0360	0.0883
Less-commonly-eaten meats	0.0373	0.0487	0.0612	0.0387	0.0335	0.0421	0.1047
Vegetables and fruits	0.0576	0.0628	0.0600	0.0692	0.0444	0.0467	0.1109
Oils and sugars	0.1218	0.1453	0.1341	0.1084	0.1412	0.0998	0.2467
Snacks, drinks and condiments	0.0573	0.0827	0.1033	0.0663	0.0537	0.1143	0.2592

Source: Estimated results based on data from CHNS 2004, 2006 and 2009

Appendix E

Trace plots from the MCMC estimation

12000 iterations were run and the first 2000 draws were treated as from the burn-in period and were discarded. Hence, 10000 iterations were used to draw the trace plots. Trace plots of the simulated distributions of the coefficients only contain those of the first five food groups. The subscripts of "beta" mark its position in the coefficient matrix. For example, "$beta_{312}$" denotes the coefficient of the twelfth variable in the third demand equation. Similarly, the subscript of sigma note the position of the elements in the variance-covariance matrix. For example, "$sigma_{45}$" denotes the covariance between the fourth and the fifth equation in the variance-covariance matrix.

Figure E.01: MCMC trace plots: Beta (part 1)

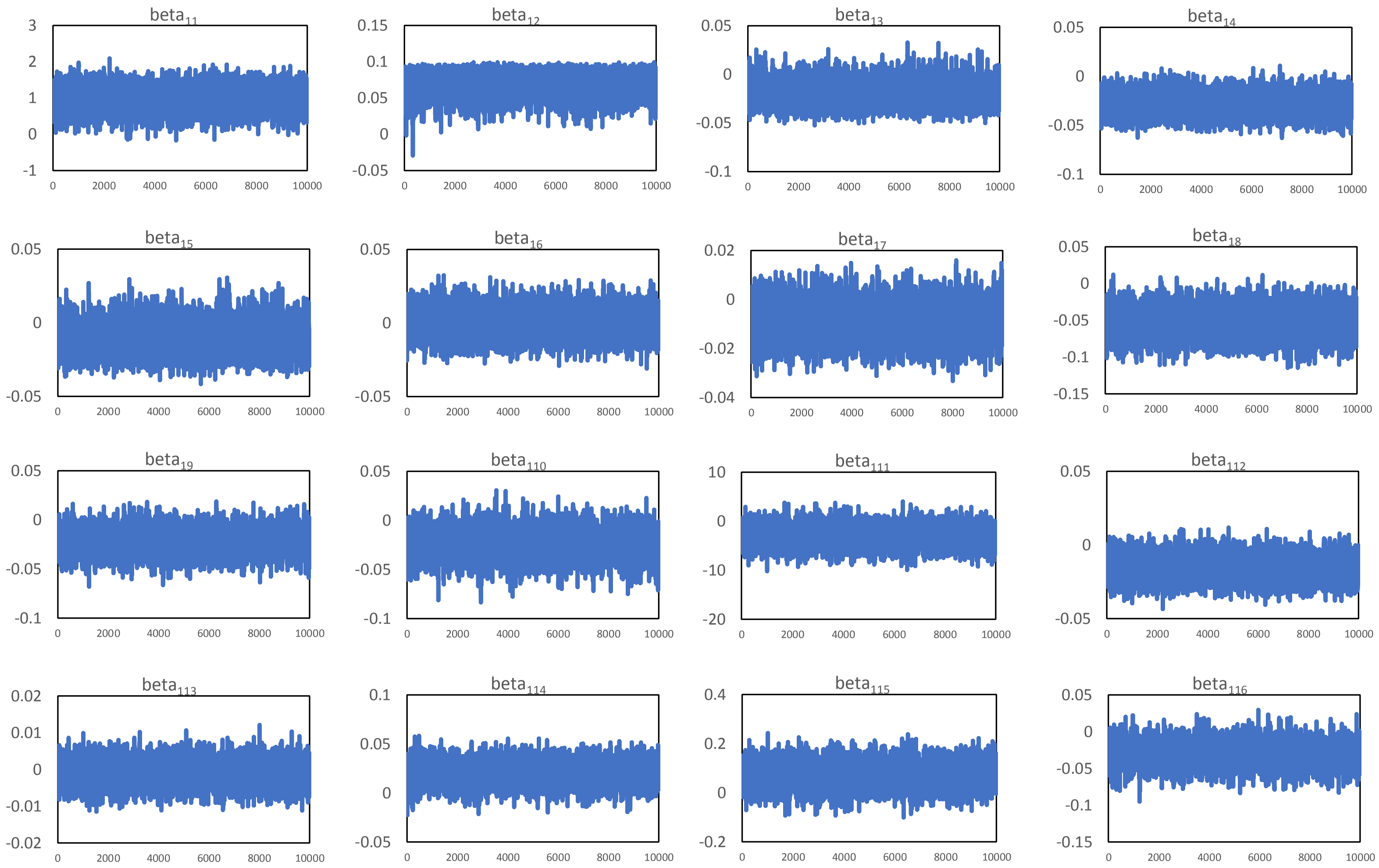

Figure E.02: MCMC trace plots: Beta (part 2)

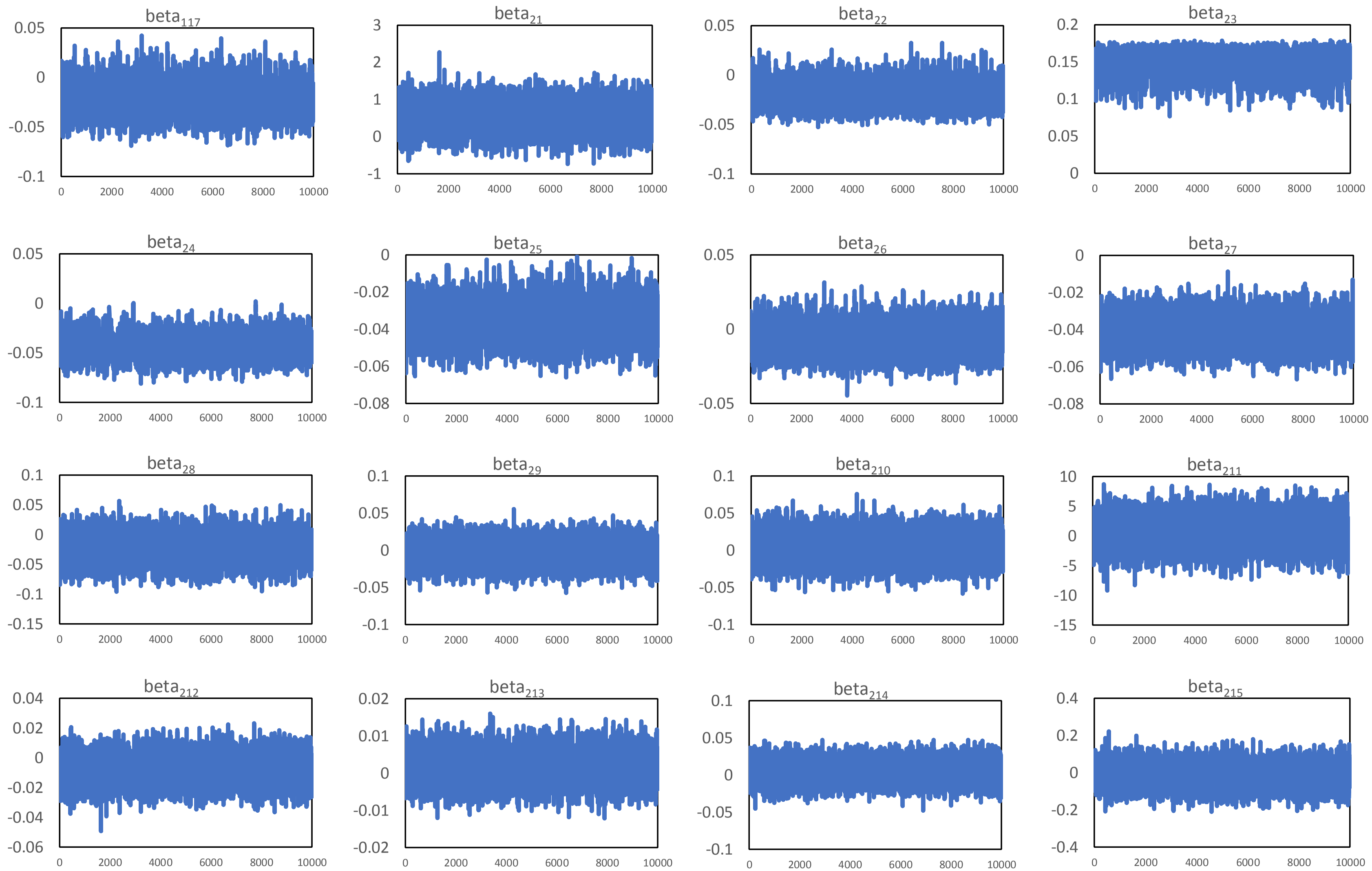

Figure E.03: MCMC trace plots: Beta (part 3)

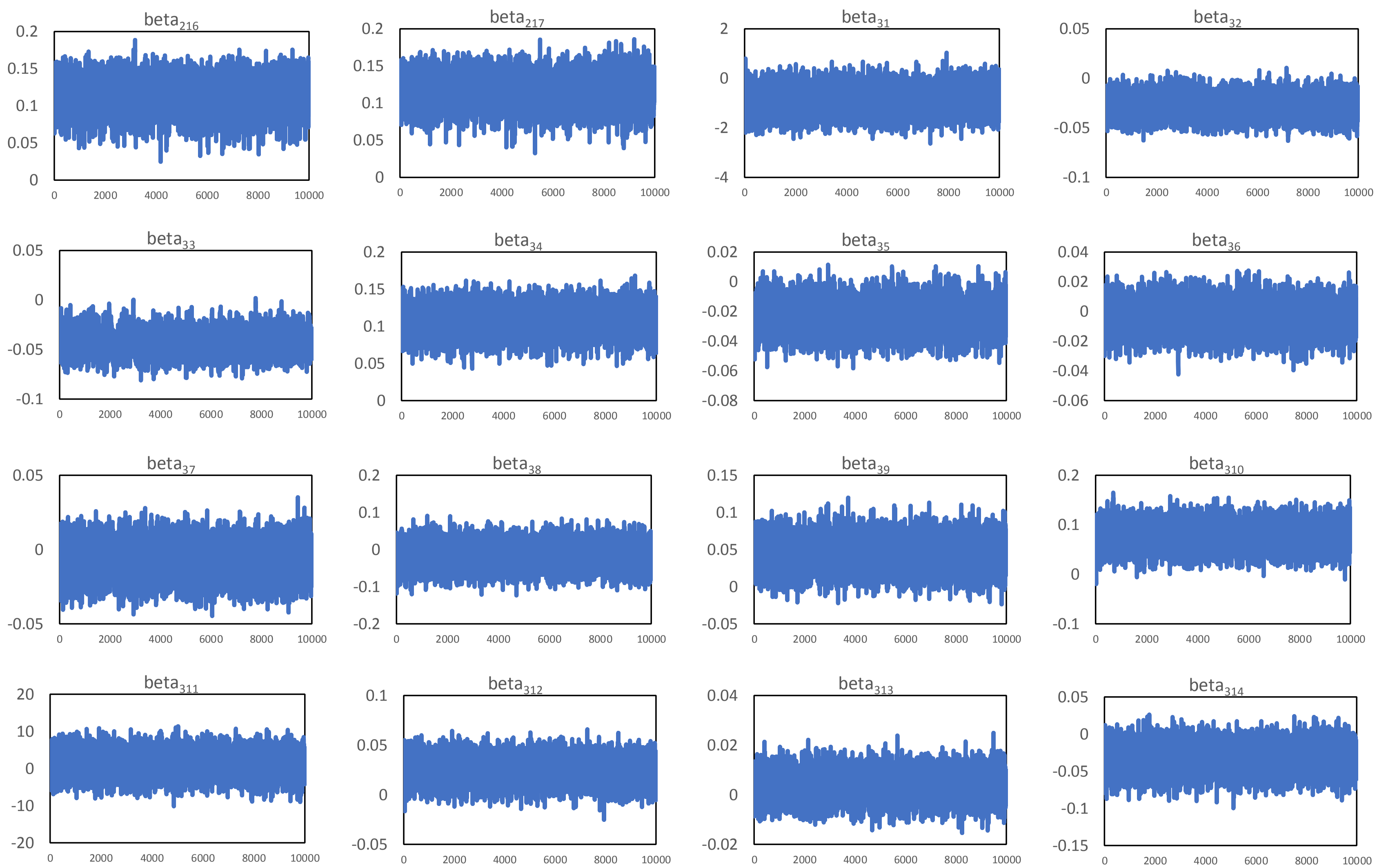

Figure E.04: MCMC trace plots: Beta (part 4)

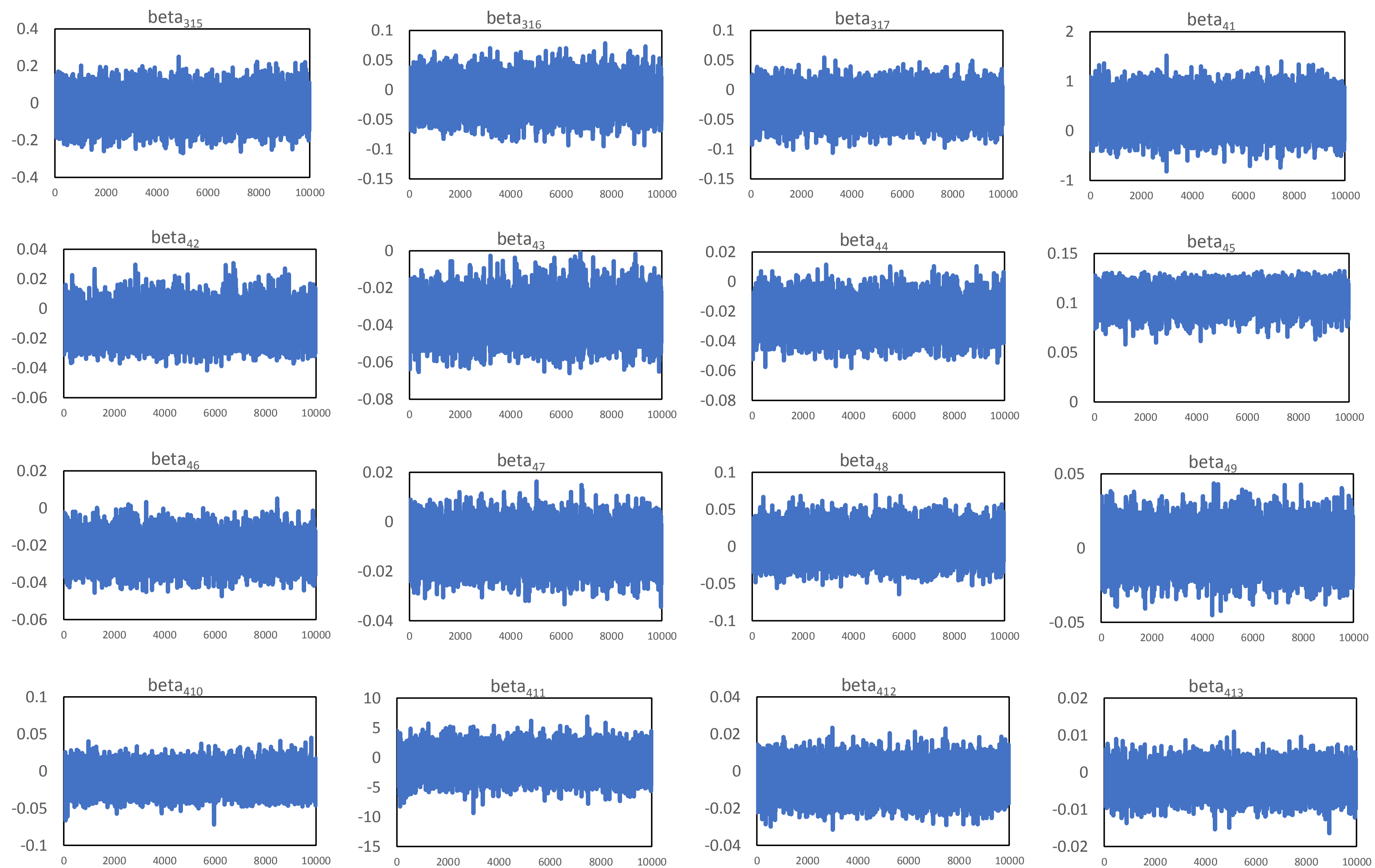

Figure E.05: MCMC trace plots: Beta (part 5)

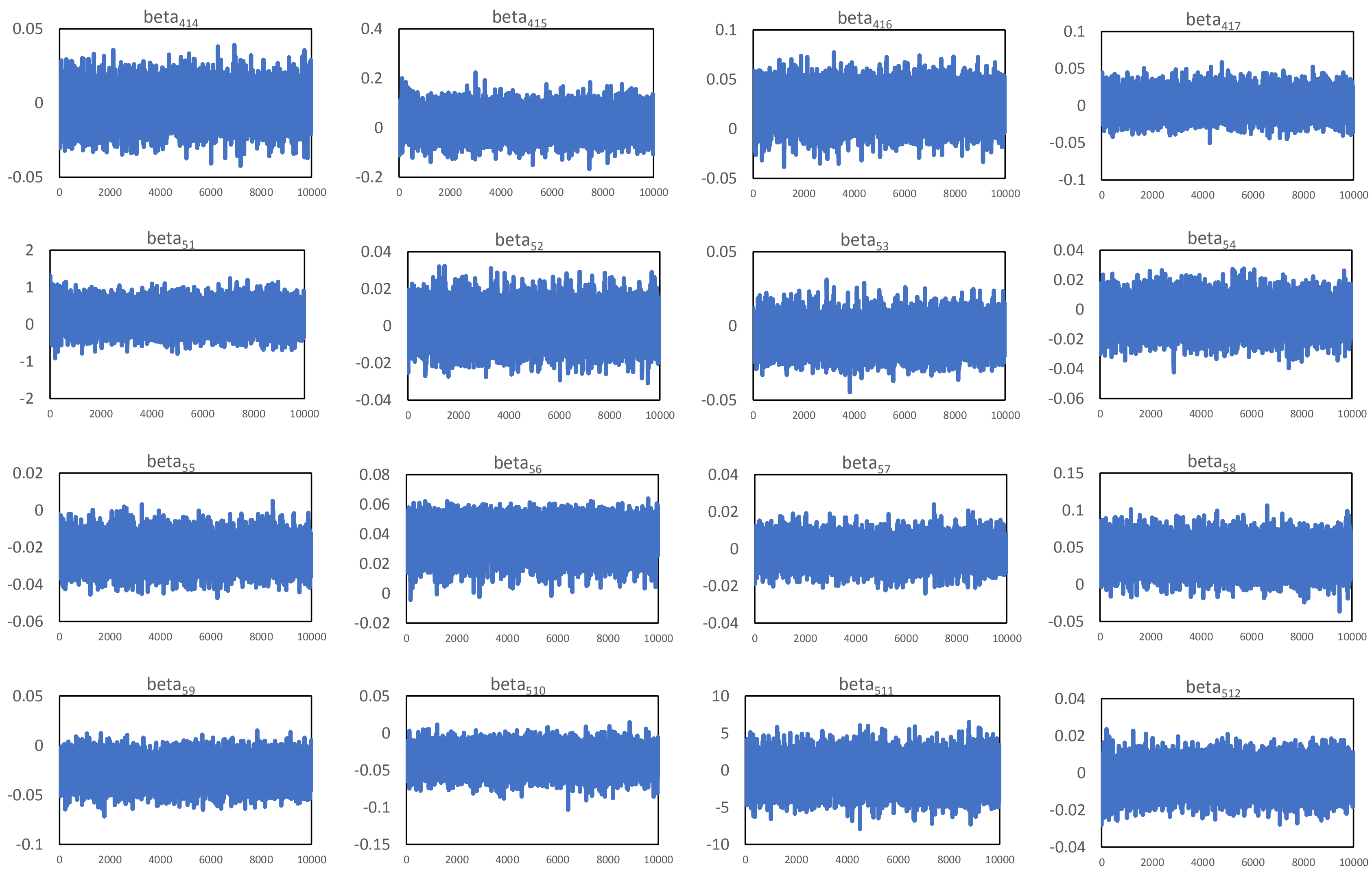

Figure E.06: MCMC trace plots: Beta (part 6)

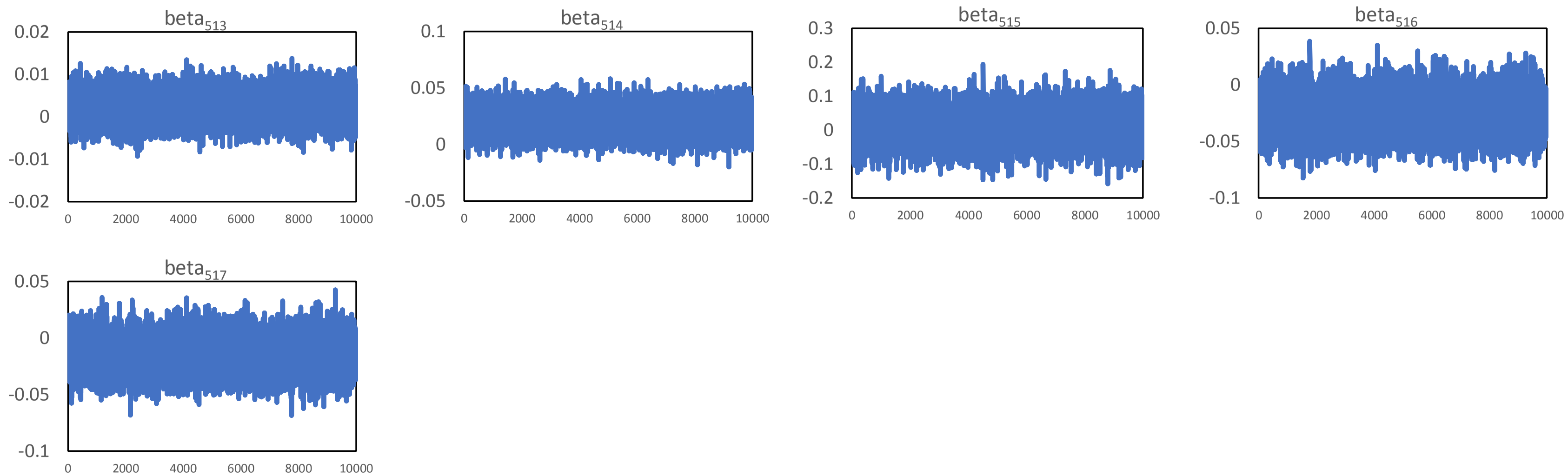

Figure E.07: MCMC trace plots: variance-covariance matrix