UNDERSTANDING CHANGES IN DIET, PHYSICAL ACTIVITY AND WEIGHT AMONG ADULTS IN CHINA

Shu Wen Ng

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Approved by:

Edward C. Norton

Barry M. Popkin

David K. Guilkey

Harsha Thirumurthy

Shoou-Yih Daniel Lee

ABSTRACT

SHU WEN NG: Understanding Changes in Diet, Physical Activity and Weight among Adults in China
(Under the direction of Edward C. Norton)

China is facing a growing overweight problem in its adult population. This is a worrisome trend given its population size and the potential health care costs associated with nutrition-related non-communicable diseases. This trend has occurred together with changes in China's economic, social and physical environment. Hence, it is important to consider these factors in trying to understand what determined the changes in diet and physical activity, and thus the increases in weight. This dissertation first looks at how various dimensions of urbanization are associated with declines in physical activity. Second, it addresses how price and income changes might have contributed to dietary changes over time. Third, I apply a dynamic panel model to determine the degree to which physical activity and dietary choices affect weight change over time.

I found that physical activity declines are strongly associated with greater availability of higher educational institutions, housing infrastructure, sanitation improvements and economic well-being of the community in which people function. These urbanization factors are associated with four-fifths and two-third of the decline in occupational physical activity for men and women, and 57% and 40% of the decline in total physical activity for men and women, respectively. Looking at food consumption, I found that changes in price elasticities are complex and are food-group and income-specific; income elasticities have fallen for most food-groups; rice has become an inferior good; and that the demand for pork was the most income responsive of these food-groups. I also found that dietary fat intake and declines in physical activities are positively related to weight gain among men, and that 30% of the weight gain was due to declines in physical activity, while 20% was due to higher fat intake. Given the rising overweight and obesity rates in China, these results suggest that policymakers should consider solutions targeting both physical activity and diets, as affected by the built and economic environment.

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This work is done in love, for my parents, Kee-Huek Ng and Yock-Lian Tan, who believed in me every step of the way, from Singapore to North Carolina.

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LIST OF ABBREVIATIONS

2PM	Two-Part Model
2SLS	Two-Stage Least Squares
BIC	Bayesian Information Criterion
BMI	Body Mass Index. Calculated by weight (in kilograms) divided by height (in meters) squared (i.e., BMI = kg/m^2).
CCDC	China Center for Disease Control and Prevention
CDC	Center for Disease Control and Prevention (United States)
CHNS	China Health and Nutrition Survey
cm	Centimeters
CPC	Carolina Population Center
CPI	Consumer Price Index
FE	Fixed Effects
FG	Food-group
GLS	Generalized Least Squares
GNP	Gross National Product
GMM	General Methods of Moments
INFS	Institute of Nutrition and Food Safety (China)
IOTF	International Obesity Task Force
IV	Instrumental Variables
IV-FE	Instrumental Variables with Fixed Effects
kcal	Kilocalorie, equivalent to 1000 calories or about 4.184 kilojoules.
kg	Kilogram = 1,000 grams

km	Kilometer = 1,000 meters
MET	Metabolic Equivalents of Task. A unit of MET is defined as the ratio of a person's working metabolic rate relative to his/her resting (basal) metabolic rate.
MET-hours per week	Metabolic Equivalents of Task x Time (in hours) spent at Task per week
MLE	Maximum Likelihood Estimation
NR-NCDs	Nutrition-related non-communicable diseases
OLS	Ordinary Least Squares
PA	Physical Activity
PSU	Primary Sampling Unit
SLOTH model	A time-budget model incorporating decisions to be active or inactive in the five domains of Sleep, Leisure, Occupation, Transportation and Home activities.
UNC-CH	University of North Carolina at Chapel Hill
WHO	World Health Organization
WTO	World Trade Organization

1. INTRODUCTION

The year is 1980. Lu grabs his steamed bun, says goodbye to his wife and child, and then leaves his modest home at the crack of dawn to bicycle to his farm carrying his sickle, hoe and lunch tin. He spends most of the morning weeding and aerating the ground on which his crops grow. After his lunch of steamed rice with cabbage and sweet potato, Lu continues working the land, fertilizing, watering and harvesting some of his vegetables in the afternoon. Just before the sun sets, he returns home on his bicycle, with his equipment and the day's harvest. Meanwhile, his wife Wang, after having cleared away the dishes from breakfast, carries baby Bao with her to tend to the chickens and pigs behind the house. Into a small wheelbarrow, she puts the freshly laid eggs, the vegetables Lu harvested the day before and her lunch tin. She then ties baby Bao to her back, and heads towards the market that is about 5 kilometers (km) from their home. There she sets up a small stall for selling the vegetables and eggs, while baby Bao plays in a corner with a few of the other women's children. By mid-afternoon, Wang packs up what is left and walks home, picking up a small bag of rice and a few oranges along the way. Once home, Wang soaks, scrubs and hangs the laundry in the backyard, sweeps the floor, and starts cooking dinner, all the while keeping an eye on baby Bao. Dinner consists of steamed rice, stir-fried eggs with chives and eggplant, and oranges. After dinner, Lu walks next door to chat with his neighbors and listen to the day's news on the radio, while Wang mends some clothes by the light of the kerosene lamp, and plays with baby Bao.

Fast-forward 25 years to 2005. Baby Bao is now almost 28 years old, and is now more often referred to as Big Bao, in reference to his size, for he now weighs 72 kilograms (kg) and is 1.6 meters tall. The village he grew up in has changed significantly since when he was just a toddler, and is now classified as a township. His parents Lu and Wang managed to pay for his upper-middle school education in the nearest city about 50 km away by opening up a noodle shop next to the town's new garment factory, which opened in the mid-1990s. Thus, Big Bao was able to attend upper-middle school, though his parents could not afford to send him to the provincial capital to attend college because while Big Bao's grades were good, they were not good enough to earn him a college scholarship. As a result, he worked for a few years helping his parents in their expanded noodle shop after high school, but soon found a better paying job as a bank teller in the city where he went to upper-middle school. Big Bao got married to Lin in 2000, whom he met while in school, and they now have a child of their own, a 4-year old boy named Sheng. They live in a cramped but modestly equipped one-bedroom apartment.

On most days, after a quick breakfast of jam or butter with toast, Big Bao and Lin walk the few blocks from their apartment to the bus stop, where they catch their respective buses to go to work. Big Bao sits at his desk 8-hours a day, assisting customers with their banking needs, except for his lunch break when he and co-workers go to a nearby shop for a quick meal of fried dumplings. Lin, with her upper-middle school education, works in a multinational computer company's assembly plant. After dropping little Sheng off with the other children at her factory's day-care room, she joins her co-workers on the assembly floor where she inspects computer keyboards as they come out of the machine that puts in the tabs. She has lunch with co-workers at the factory's cafeteria, where some of the lunch options include fried rice, steamed buns, ham sandwiches, and soft drinks. At the end of the work day, Big Bao picks up a large packet of fried noodles and half a *jin* (a *jin* is about half a kg) of roasted pork from a food stall on his way home, which the family has for dinner. After dinner, Lin quickly tosses their laundry into the building's shared washing machines and vacuums the living room floor. They spend much of the rest of the evening playing with little Sheng while watching television and snacking on sugar cookies. On most Saturdays, they take the bus and travel the 50 km to visit Big Bao parents, but sometimes Big Bao's parents make the trip instead. On most Sundays, they visit Lin's parents who live in the city. The parents and grandparents all dote on little Sheng, who often gets everything he asks for, especially the snacks and candy he sees advertised on television.

Admittedly, these two scenarios are fictional, and I give these as examples not to romanticize the life of 1980 China, but to highlight some of the lifestyle changes that have occurred for many Chinese. First, daily activities have drastically changed due to changes in occupational types (from manual agricultural labor to work in the manufacturing and service sectors), transportation modes (from walking and bicycling to using motorized vehicles), and access to household technologies (the growing use of washing machines and vacuums) . Second, diets have changed from one high in complex carbohydrates — from grains, fresh vegetables and fruits — to one higher in fat and refined carbohydrates — from processed and pre-made foods. Third, many Chinese now have access to and are able to afford public transportation, food from stalls and restaurants, and are exposed to various forms of media. Lastly, China is now well plugged into the global economy.

These are significant changes that have drastically affected the dietary and physical activity choices of the Chinese, with heavy implications for this population. An imbalance of energy intake and expenditure does not only lead to weight gain, but increases the risk of developing nutrition-related non-communicable diseases (NR-NCDs), such as cardiovascular diseases, type II diabetes, high blood pressure and liver disease. These are chronic and debilitating illnesses that place a large health care burden on society, especially given China's large population. This research focuses on Chinese adults because they are the key players in the continuation of China's growth, and are also the ones who have shown the largest increases in weight and body mass index (BMI). This is not to say that these problems are one of Chinese adults alone. These are problems that will also affect future generations, such as that of little Sheng, if significant changes are not implemented soon.

1.1. Changes in weight and prevalence of overweight among adults in China

Nutritional concerns affect countries at various levels of development. In developed countries such as the United States, over 60% of the adult population is classified as overweight or obese (Flegal, Williamson et al., 2004; Mokdad, Serdula et al., 1999). In developing countries, such as Cameroon and Ethiopia, food insecurities prevail as people struggle to meet their nutritional needs (De Stefano, Hauser et al., 2004; Fezeu, Minkoulou et al., 2006). Meanwhile, emerging economies like Brazil, India and China are witnessing both growing overweight prevalence, as well as the continuation of food insecurity (Caballero, 2005; Monteiro, Conde et al., 2002; Popkin, 2001; Subramanian & Smith, 2006). Genes alone cannot explain the rise in the prevalence of overweight and its associated health problems, because it has happened much too quickly to be explicable in evolutionary terms. Hence, the reasons for the trend must stem from the environment in which people live. China is a particularly interesting country to study because of the rapid pace of its development, and its global importance, in terms of population size, and hence market potential and production capabilities.

Chinese adults are the driving force behind the recent growth in the Chinese economy because they contribute the most to the country's productivity as well as determine the majority of consumption patterns. At the same time, they have had the largest changes in BMI and overweight prevalence and incidence (Ge, Weisell et al., 1994; Popkin, Conde et al., 2006). Data from the China Health and Nutrition Surveys (CHNS) show that between 1991 and 1997 the proportion of adults (20-45 years old) who were overweight or obese (based on the World Health Organizations (WHO) BMI cutoffs of 25 and 30 respectively) rose significantly by 4.8% (Du, Lu et al., 2002). Meanwhile, during the same period, the prevalence of being overweight and obese rose by 0.8% among children (2-9 years old) and 1.7% among adolescents (10-18 years old) (Wang, Monteiro et al., 2002), using the International Obesity Task Force's (IOTF) age and gender specific BMI cutoffs, which correspond to a BMI of 25 at age 25 years (Cole, Bellizzi et al., 2000). In a manuscript on relative increases in overweight between adults and children, Popkin and colleagues (2006) found that not only are the absolute rates of increase in overweight higher among adults in China, the relative rates are also higher among adults. This is a cause for concern because these trends may indirectly affect children and elders and thus have implications for future health-care needs. Children in particular are at risk of establishing dietary and activity habits based on the example of their parents, as found in an analytic cohort study by Wang and colleagues (2002), who studied the predictors of dietary intake patterns from childhood to adolescence under conditions of rapid socioeconomic change. This is certainly troubling, especially given that it is estimated that the cost of overweight and related diseases will be nearly 9% of China's projected gross national product (GNP) by 2025 (Popkin, Kim et al., 2006; Raymond, Leeder et al., 2006).

Biological and epidemiological studies have found that weight gain among adults is mostly gained in the form of fat (rather than muscle mass or fat-free mass). This is especially the case for populations that were previously undernourished or experienced weight fluctuations, either in childhood or adulthood (Dulloo, 2008; Dulloo, Jacquet et al., 2006; Remacle, Bieswal et al., 2004), and that co-currently have lowered their physical activity levels, as is the case in China. Since fat accumulation is well known to be highly associated with morbidity and mortality from cardiovascular diseases, type II diabetes, hypertension, and other NR-NCDs (Folsom, Li et al., 1994; Matsuzawa, Nakamura et al., 1995; Nakamura, Tokunaga et al., 1994; Raymond, Leeder et al., 2006), weight gain is an important outcome.

Among adults in China, the growth in weight for men and women (Figure 1) has been accompanied by declines calorie consumption despite general declines in the relative price of food (Figure 2). This decline in total calorie intake but weight gain over time suggests that an analysis of weight must account not only for food consumption, but also for changes in physical activity level (Paeratakul, Popkin et al., 1998). Physical activity depends on a complex balance between the strenuousness and duration of work, at home and in the market, and on transportation and leisure activities. In addition, the negative price trend for food commodities over time suggests that expansion in the supply of food through agricultural innovation and delivery of food to markets has outpaced increases in demand (Pinstrup-Andersen, 1993; Today's China, 1988). Moreover, increasing globalization means that improvements in goods, services, technology, and know-how in any individual country have effects on all countries of the world (Popkin, 2006) China is an increasingly important player (on both the demand and supply sides) in the world economy.

Figure 1. Weight of adult men and women in China (CHNS 1991–2006)

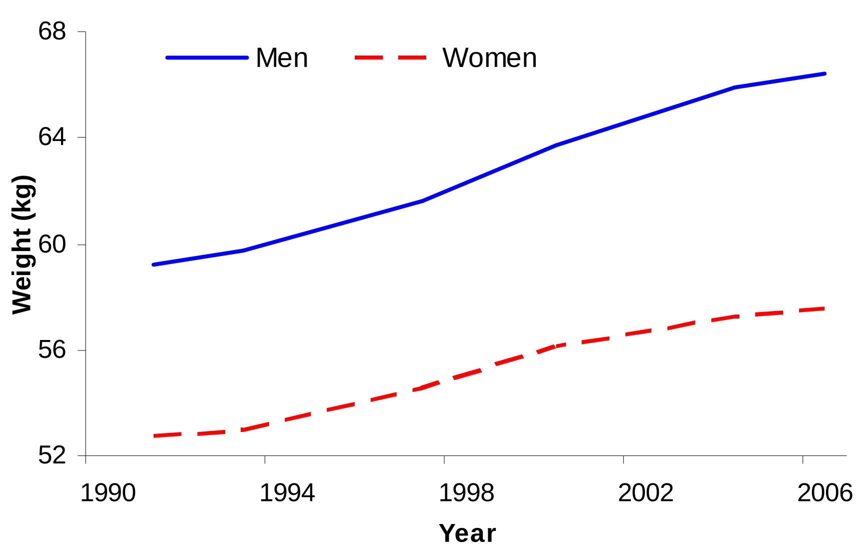
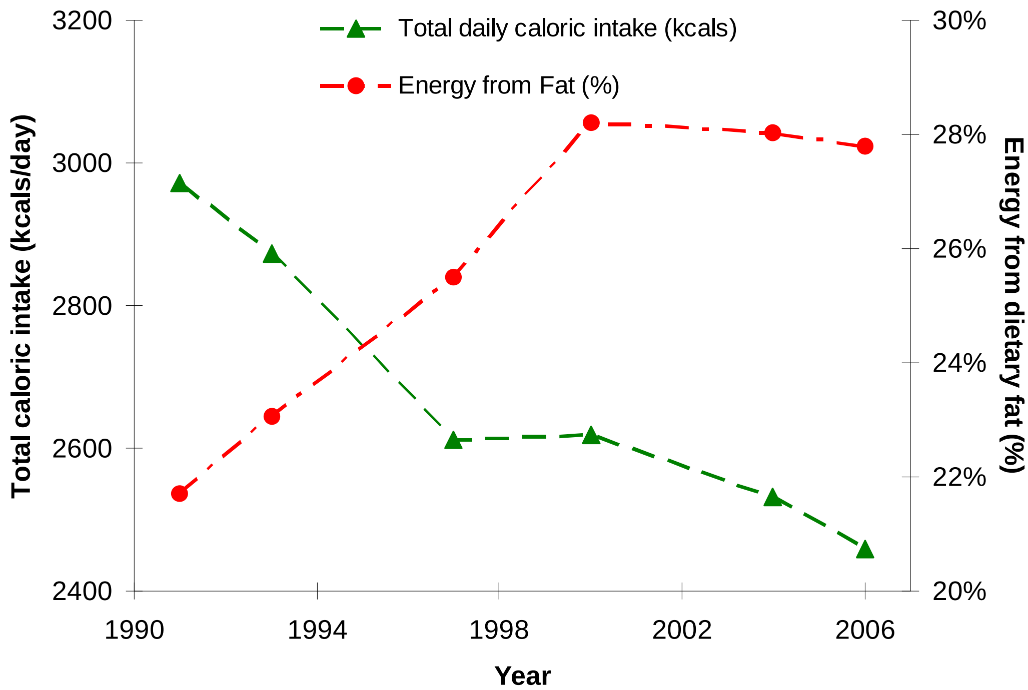


Figure 2. Total caloric and dietary fat intake of adults in China (CHNS 1991–2006)



Therefore, it is not surprising that overweight trends have occurred together with changes in China's economic, social and physical environment. With economic development comes new job opportunities, better wages, greater access to a larger variety of goods, more roads, faster modes of transportation, improved neighborhood facilities, and increased ownership of durable goods and labor-saving technologies. In addition, societal expectations and norms also change towards increased female labor force participation, and changes in division of labor among household members. These can all affect the amount and degree of physical activity individuals perform, as well as their choices of dietary intake. In addition, these are not simply compositional changes, they are structural. For example, it is not just the percentage of the population that is working in the service economy that is important, it is also the types of knowledge or skills people are getting from their jobs that matter.

1.2. Past Empirical Work

In their paper on weight and technological change in the United States, Lakdawalla and Philipson (2005) used the neo-classical framework (see Appendix A for details) to decompose the quantitative implications of the hypothesis that technological change has simultaneously raised the cost of physical activity (by making household and market work more sedentary) and lowered the cost of calories (by making agricultural production more efficient). The authors calculated the weight growth that resulted from changes in the characteristics of the population, and then took the residual secular trend in weight as the effect of technological change. Using variations in the taxation of food (relative to taxation of other goods) across states to identify supply and demand elasticities for weight, they were able to decompose the total effect of technology into the demand and supply components. They found that the neo-classical interpretation of weight gain that relies on changing incentives does surprisingly well in explaining observed trends, without having to resort to psychological, genetic or addictive models. The authors concluded that about 40% of the weight increase over last few decades may be due to expansion in supply of food, potentially through agricultural innovation, and the resulting fall in food prices, while the other 60% may be due to demand factors such as decline in physical activity at both home and work (Lakdawalla, Philipson et al., 2005).

While their paper provides a theoretical and empirical examination of the forces contributing to the long-run weight growth over time, the authors used a number of different data sets in order to piece together a panel dataset for their analyses. While this is a creative and useful approach, it can create potential problems in forming a representative analytic dataset. Moreover, the authors stress the importance of technological advancement on quantity of food, but admittedly did not include considerations of its impact on the quality of food intake, particularly from fat and protein. Lastly, despite providing a breakdown of the impact of technological growth on demand and supply, the authors were unable to distinguish between weight growth due to the diet component and the activity component.

In the case of China, technological change is a potentially key driver for increased weight among adults. However, unlike a developed country like the United States, China has experienced most of its development during the last 20 years and is still undergoing significant development. Like any country experiencing rapid growth, the process occurs heterogeneously, with certain areas growing more quickly than others. Also, one would expect considerable variation in the process of infrastructure development for communities across a country as large and diverse as China. A number of studies have looked at a broader concept of urbanization and its impact on nutritional change using an index constructed from ten dimensions (Mendez, Du et al., 2003). While the use of an urbanization index can help reflect multidimensional changes in factors that characterize urban living, it does not allow one to identify which of the factors are the main drivers. Using separate measures that are more focused on different dimensions of infrastructure development — for example access to markets, transportation and communication networks, job opportunities, and educational, health and sanitation facilities — can provide greater insight into how important each of these are. Previous work has shown that decisions regarding physical activity and diet have evolved due to changes in the constraints people face. These include changing job opportunities towards more service oriented and less labor intensive jobs (Proper, Cerin et al., 2007); falling activity levels at work, even within the same job due to mechanization, use of computers and various work technology (Bell, Ge et al., 2001; Popkin, 2006); greater motorized transportation and nearer markets (Bell, Ge et al., 2002; Popkin, Paeratakul et al., 1995a; Tudor-Locke, Ainsworth et al., 2007; Tudor-Locke, Ainsworth et al., 2003); and decreasing costs of taking care of one's health due to improved access to health care. In China, community-level development is arguably exogenous to the individual's utility maximization problem, since individuals are not able to directly impact the choice of whether to build a new road into their community, or to specify where local schools will be located.

In addition, the budget constraint is central in the neo-classical model. Therefore, it is important to include real prices and income in any model that seeks to explain the determinants of increased BMI and overweight. Not surprisingly, past studies have found that falling prices and increased food supply (quantity and variety) decreases energy cost (Du, Mroz et al., 2004). Moreover, income level is also a critical dimension to consider beyond just income effects, because a dollar does not mean the same thing to people of varying income or wealth levels. Hence, increases in income lead to movements in diets towards items more dense in energy and fat, or low in fiber. These substitutions could have a detrimental effect on body composition and health, with those in low-income groups experiencing the largest increase in harmful effects (Du, Mroz et al., 2004).

Despite the voluminous discussion in the literature on the economics of obesity and its determinants, none of the previous work has looked at the relationships among these key factors of urbanization, prices, technology ownership and income in a system or as a whole. This is important because it is not clear how the factors relate to each other and how each of these factors contributes to changes in diet, physical activity, and hence weight, BMI and prevalence of overweight among Chinese adults.

1.3. Research Aims

Figure 3. Conceptual framework

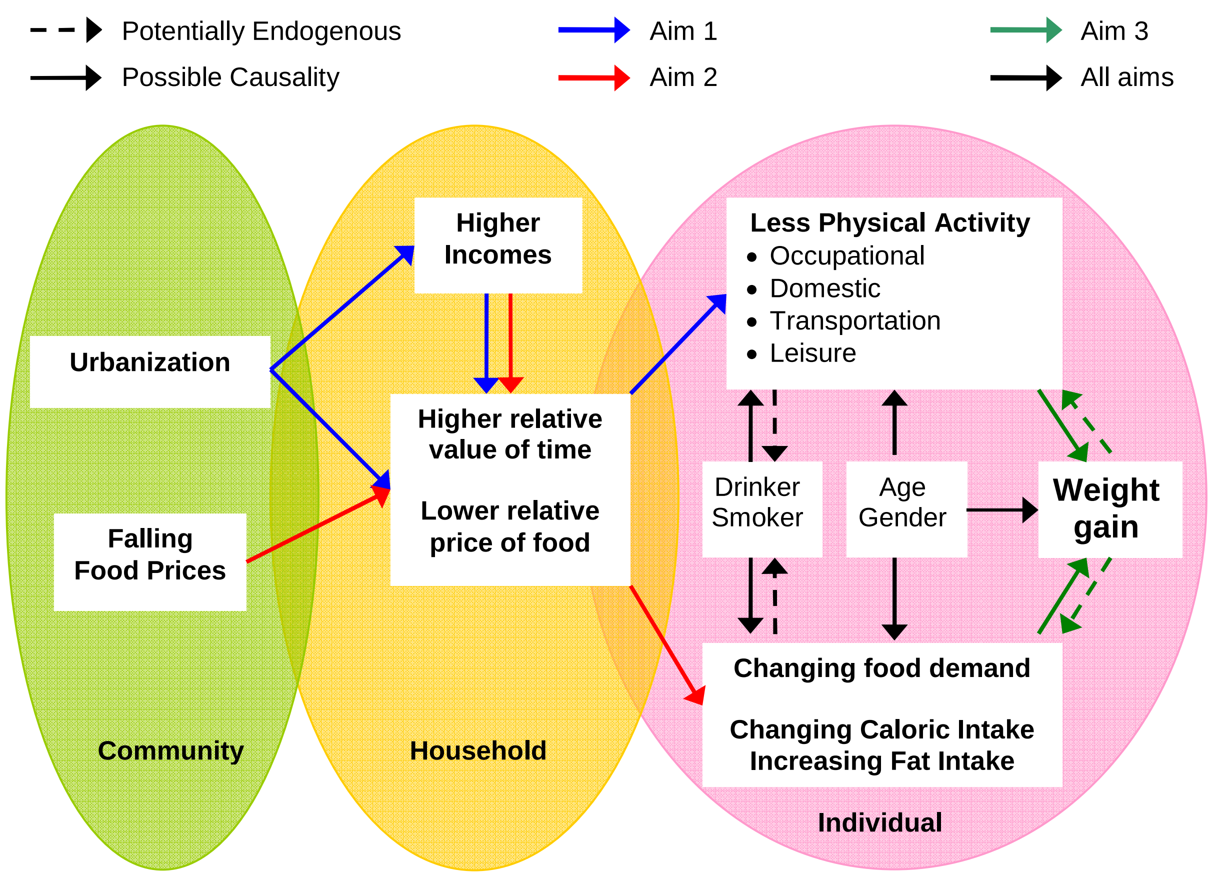


Figure 3 provides a simple schematic framework showing the relationship between the main factors that determine weight gain among Chinese adults. This conceptual model highlights a number of points that relate to the aims this research will address. First, there are multiple layers of influence (the community, the household, and individual) that interact in contributing to changes in weight. Second, it is important to study these processes over time, because that allows determination of the importance of other factors in affecting the observed dietary and physical activity changes. Lastly, there are several endogenous relationships to address when trying to study the determinants of weight gain.

Based on the framework, this research seeks to address the following research aims by testing a number of hypotheses:

Aim 1: What urbanization factors have caused the declines in physical activity among Chinese adults?

H-1: Physical activity levels are negatively associated with urbanization

H-2: Urbanization domains that affect job functions and opportunities will contribute more than other urbanization factors to changes in physical activity levels

H-3: These urbanization domains will be more strongly associated with physical activity levels for men than for women because home activities account for a larger proportion of physical activities for women

Aim 2: How do changes in prices and incomes affect food consumption among Chinese adults?

H-4: Own-price elasticities of demand for most food-groups became more elastic over time

H-5: Income elasticities for the major food-groups have declined over time

H-6: Rice has become an inferior good (i.e. income elasticities for rice have fallen)

Aim 3: How do physical activity, dietary intake and other health behaviors determine weight?

H-7: Caloric intake is positively related with weight gain

H-8: Dietary fat intake is positively related with weight gain

H-9: Declines in physical activities are associated with weight gain

H-10: Physical activity is more strongly associated with weight than diet

The following chapters will address each of these aims and hypotheses using comprehensive longitudinal data from the six most recent waves (1991, 1993, 1997, 2000, 2004 and 2006) of the China Health and Nutrition Survey (CHNS). The CHNS were conducted in nine provinces of China and contain detailed individual-level information on income, diet, health and demography for all members of sampled households, as well as rich data on community-level prices, and public services and facilities. The analytical sample and variables used to answer the research questions will vary, and will be explained in detail in each chapter. General information about the surveys the variables used can be found in Appendix B.

The findings from this research will provide empirical evidence to help researchers and policymakers better understand the main drivers that affect changes in dietary intake, physical activity and weight gain among a large population. These findings can be used to help focus efforts to alleviate China's emerging overweight problem and the health risks associated with it.

2. WHY HAVE PHYSICAL ACTIVITY LEVELS DECLINED AMONG CHINESE ADULTS?

Abstract

Between 1991 and 2006, average weekly physical activity among adults in China fell by 32%. This paper discusses why total and occupational physical activity levels have fallen, and models the association between the rapid decline and various dimensions of exogenous community urbanization. I hypothesize that a) physical activity levels are negatively associated with urbanization; b) urbanization domains that affect job functions and opportunities will contribute most to changes in physical activity levels; and c) these urbanization domains will be more strongly associated for men than for women because home activities account for a larger proportion of physical activity for women. To test these hypotheses, I used longitudinal data from individuals aged 18 to 55 in the 1991–2006 China Health and Nutrition Surveys. I find that physical activity declines were strongly associated with greater availability of higher educational institutions, housing infrastructure, sanitation improvements and the economic well-being of the community in which people function. These urbanization factors predict more than four-fifths of the decline in occupational physical activity over the 1991 to 2006 period for men and nearly two-thirds of the decline for women. They are also associated with 57% of the decline in total physical activity for men and 40% of the decline for women. Intervention strategies to promote physical activity in the workplace, at home, for transit and via exercise should be considered a major health priority in China.

2.1. Introduction

As countries develop, they experience a reduction in mortality and morbidity due to infectious diseases. Concurrently, the prevalence of chronic non-communicable diseases and associated risks has risen rapidly. This has generally been referred to as the epidemiological transition (Omran, 1971). Burden of disease studies have found a marked increase in the proportion of deaths due to non-communicable disease, mainly cardiovascular diseases and cancers (Lopez, Mathers et al., 2006). These diseases are strongly associated with being overweight and obese (Reddy & Katan, 2004) and are now rising in developing countries at a faster rate than that experienced by developed countries (Raymond, Leeder et al., 2006).

This paper focuses on China as a case study. As the most populous country in the world, rising rates of chronic diseases among this population will have striking consequences. The incidence of heart disease among adults in China has risen remarkably quickly over the past several decades (Wu, Yao et al., 2001). Estimates from the 2001 Inter-ASIA survey indicate that 28.2% of the adult Chinese population had hypertension (Gu, Jiang et al., 2003). Additionally, the percentage with diabetes or high cholesterol levels was 5.2% and 32.8%, respectively (Reynolds, Gu et al., 2003). The growing prevalence of such chronic diseases will negatively affect economic productivity and implies that greater financial resources are being spent on health care needs; it is estimated that the cost of overweight and related diseases will be almost 9% of China's gross national product (GNP) by 2025 (Popkin, Kim et al., 2006).

Reasons for the increasing burden of these chronic disease risk factors have not been elucidated, but it has been suggested that urbanization and associated adverse changes in physical activity levels have played a role (Janus, Postiglione et al., 1996; Popkin, 1999). In the context of the United States, one framework for examining this issue is the SLOTH model. This time-budget model incorporates individual decisions to be active or inactive in the five domains of Sleep, Leisure, Occupation, Transportation and Home activities, based on individual, economic and environmental factors (Cawley, 2004; Pratt, Macera et al., 2004; Sturm, 2004).

In the SLOTH model, sleep is considered inactive, but influences activity through time spent sleeping. Occupational activity may become more sedentary due to technological advancements in the work environment, as well as via changing labor opportunities. Physical demands of home activities vary depending on technological advances, such as the availability and growing affordability of microwaves or washing machines. Transportation activities depend heavily on the built environment, accessibility and reliability of public transportation, as well as ownership and use of motorized vehicles. Engagement in leisure activities can be determined by neighborhood design and societal promotion of active participation in sports and exercise as well as technological advances that either lead to sedentary lifestyles or make exercise more attractive.

The SLOTH model suggests that it is important to consider various sources of activities, and that infrastructural development, services and facilities in communities in which people live and work can be significant factors in determining declines in physical activity. Studies in developed countries indicate that neighborhood design affects whether people walk and/or use bicycles as modes of transportation (Oakes, Forsyth et al., 2007; Saelens, Sallis et al., 2003), and influences individuals' choices to exercise (Sallis, Bauman et al., 1998). Perceptions of access and safety for physical activity may also determine physical activity levels for financially disadvantaged populations (Wilson, Kirtland et al., 2004). In addition, occupational opportunities affect the proportion of the workforce employed in sedentary occupations and the use of modern labor-saving technologies at the workplace (Harnack & Schmitz, 2006). In a cross-national analysis of European countries, Rabin et al. (2007) found associations between weight gain and obesogenic environments in the domains of economic, food, urban population, transport, policy.

Since the bulk of this research focuses on developed countries, it is not clear whether these associations may be applicable to developing countries, such as China, where urbanization has occurred more rapidly and may have more immediate effects on physical activity decisions. Studies undertaken in China attribute the rise in overweight and obesity to greater use of motorized transportation (Bell, Ge et al., 2002), use of computers and various work technologies (Bell, Ge et al., 2001; Popkin, 2006), greater access to markets, improved neighborhood facilities (Popkin, Paeratakul et al., 1995b) and urbanization (Caballero, 2001; Monda, Gordon-Larsen et al., 2007). Of these studies, only one looked specifically at physical activity as the outcome of interest. Monda and colleagues (2007) used an urbanization index to examine its effects on the occupational physical activity patterns of Chinese adults using three waves of the China Health and Nutrition Survey (CHNS). They ran simulations that showed that the likelihood of having low occupational activity increased linearly with increasing urbanization, and that the urbanization index explained 54% and 40% of the variance in occupational activity for men and women, respectively.

While these findings provide some insights, consideration of other forms of activities such as in transportation, leisure and domestic chores are also important if one wants to fully understand the shifts in individual activity levels. This is particularly true because of the potential for substitution across various forms of activities, and the changing circumstances of these decisions over time. Moreover, even though the use of a composite urbanization index is an improvement over the classic urban-rural dichotomy that presumes homogeneity in unmeasured aspects of community environments with rural and urban settings (McDade & Adair, 2001), it is still not clear how each of the separate dimensions of urbanization contribute to declining physical activity levels.

Based on the findings from the limited work done in China previously, I hypothesize that a) physical activity levels are negatively associated with urbanization; b) urbanization domains that affect job functions and opportunities will contribute most to changes in physical activity levels; and c) these urbanization domains will be more strongly associated for men than for women because home activities account for a larger proportion of physical activities for women. I will test these hypotheses by using six waves of the longitudinal CHNS as described in the next section.

2.2. Data

This paper uses comprehensive longitudinal data from the six most recent waves (1991, 1993, 1997, 2000, 2004 and 2006) of the CHNS on all adults (18 to 55 years old) interviewed during any of the survey waves. The CHNS was conducted in nine diverse provinces (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong) of China, and contains detailed individual-level information on income, diet, health and demography for all members of sampled households as well as detailed community-level data on infrastructure, public services and facilities. A multistage, random cluster process was used to draw the sample surveyed in each of the provinces. Counties in the nine provinces were stratified by income and a weighted sampling scheme was used to randomly select four counties in each province. Villages and townships (the CHNS definition of communities) within the counties and urban and suburban neighborhoods within the cities were selected randomly into primary sampling units (PSUs). The neighborhoods and villages were defined politically and geographically based on the communist party definitions. The same households were surveyed over time whenever possible and newly formed households were included beginning in 1993. Rural communities had populations ranging from 125 to 14,964 people and urban communities had populations ranging from 167 to 86,733 people. These differences in population across communities were controlled for in the analysis. English language versions of the questionnaires used for the CHNS can be found at the CHNS website (CPC, 2008).

After limiting the sample to those between 18 and 55 years old who were not disabled, pregnant or lactating during a particular wave and had complete data, there were 16,753 male-wave observations and 18,033 female-wave observations for the 1991–2006 analysis, and 11,234 male-wave observations and 12,092 female-wave observations for the 1997–2006 analysis.

2.2.1. Dependent variables

All measures of physical activity were in terms of metabolic equivalent of task (MET)-hours per week to account for both intensity of activities and time spent on activities. A unit of MET is defined as the ratio of a person's working metabolic rate relative to his/her resting (basal) metabolic rate (Sallis, Haskell et al., 1985).

Occupational activity was measured by using self-reported occupation(s) and the average number of hours spent working per week in the last year for up to two market-sector jobs as well as hours worked from home (working on a farm, in a garden or orchard, raising livestock or poultry, fishing, and working on craft or in a home business). Adult respondents were also asked about the activity levels of their occupations, which interviewers categorized into five levels (very light, light, moderate, heavy, and very heavy) based on respondents' job descriptions and the time spent sitting, standing, walking and lifting heavy loads during an average work day. Reported occupations were then cross-tabbed against these occupational activity levels and specific MET values were assigned based on how the majority of respondents reported the activity level of their occupation. Farming, fishing, working in a garden or orchard, and working with livestock were reported as high activity occupations and assigned a MET value of six per hour of work. Four METs per hour worked were assigned to those working as foremen, group leaders, craftsmen, ordinary laborers, loggers, drivers, homemakers or students. Two METs per hour worked were assigned to those working as senior or junior professionals, administrators, executives, managers or office staff, and working as army or police officers. Time spent in each occupation was multiplied by these MET values to get MET-hours per week. For respondents who reported having more than one job, their total occupation MET-hours per week were derived by summing across all occupations. Occupational activity makes up the bulk of activities for both men and women (see Figure 4), and so is used as a dependent variable in the analysis.

Home activity was measured based on four activities: time spent preparing food, buying food, doing laundry, and in childcare. Note that measurements of household chores did not include a number of other key domestic work tasks such as cleaning the house and home maintenance or repairs because these were not included in the survey before 1997. All activities were reported in average hours/week spent in the past year. Time spent in each activity was multiplied by specific MET values based on the Compendium of Physical Activities (Ainsworth, Haskell et al., 2000): 2.3 for buying food, 2.25 for preparing food or cooking, 2.15 for doing laundry, and 2.75 for childcare. Individual MET-hours per week were summed to obtain total home activity energy expenditure. Women expend over three times as many METs on home activities as men (see Table 1). Both men and women have decreased their home activities over time, with women decreasing them from 61.3 in 1991 to 25.3 MET-hours per week in 2006, and men decreasing them from 19.1 to 5.6 MET-hours per week over the same period.

Since 1997, adults have been asked about their participation in leisure physical activities in the past year, and the average time spent per week. They have also been asked about their transportation mode (motorized vehicle, bicycle, or walking) and time spent traveling to and from work or school. Using the Compendium of Physical Activities (Ainsworth, Haskell et al., 2000), METs per hour used for leisure activities were: 4.5 for marital arts, 7.5 for jogging or swimming, five for dancing or aerobics, six for playing basketball, volleyball or soccer, and five for playing tennis, badminton or ping-pong. For transportation activities, METs per hour used were: 1.5 for taking a motorized vehicle, four for bicycling, and three for walking. Time spent in each activity was multiplied by these specific MET intensity values and aggregated to get each individual's leisure and transportation MET-hours per week, respectively. Based on data from 1997 onwards, leisure and transportation were not significant activities for either men or women, but leisure activities do appear to be increasing, while transportation activities are declining slightly (see Table 1). These together with occupational and home activities provide the measure for total activity for the four waves of data from 1997 through 2006. Consequently, the sample used for the total activity analysis is a subset of the sample used in the occupational physical activity analysis, which uses 1991 through 2006 data. Table 1 shows that among Chinese men, physical activities declined significantly with most of the decline occurring due to changes in occupational activities. Among Chinese women, there have been even faster declines due to both occupational and home activities falling over time. Additional descriptive statistics on control variables used in the analyses are also found in Table 1.

Table 1 also shows some descriptive information about the participation rates and time spent in various activities. Over time, the percentage of both men and women in the labor force and the percentage of those that do domestic chores have fallen, as has the time spent doing domestic chores. More striking is the decline in the proportion of adults who averaged more than 30 minutes per day on active transportation (walked or bicycled) or leisure (exercised) from 46% to 51% in 1997 to 28% to 33% in 2006. However, note that due to the longitudinal nature of the data, the sample is aging over time, which may partly explain the decline in physical activities as well as labor force participation.

Figure 4. Change in physical activity levels among Chinese adults (CHNS 1991–2006)

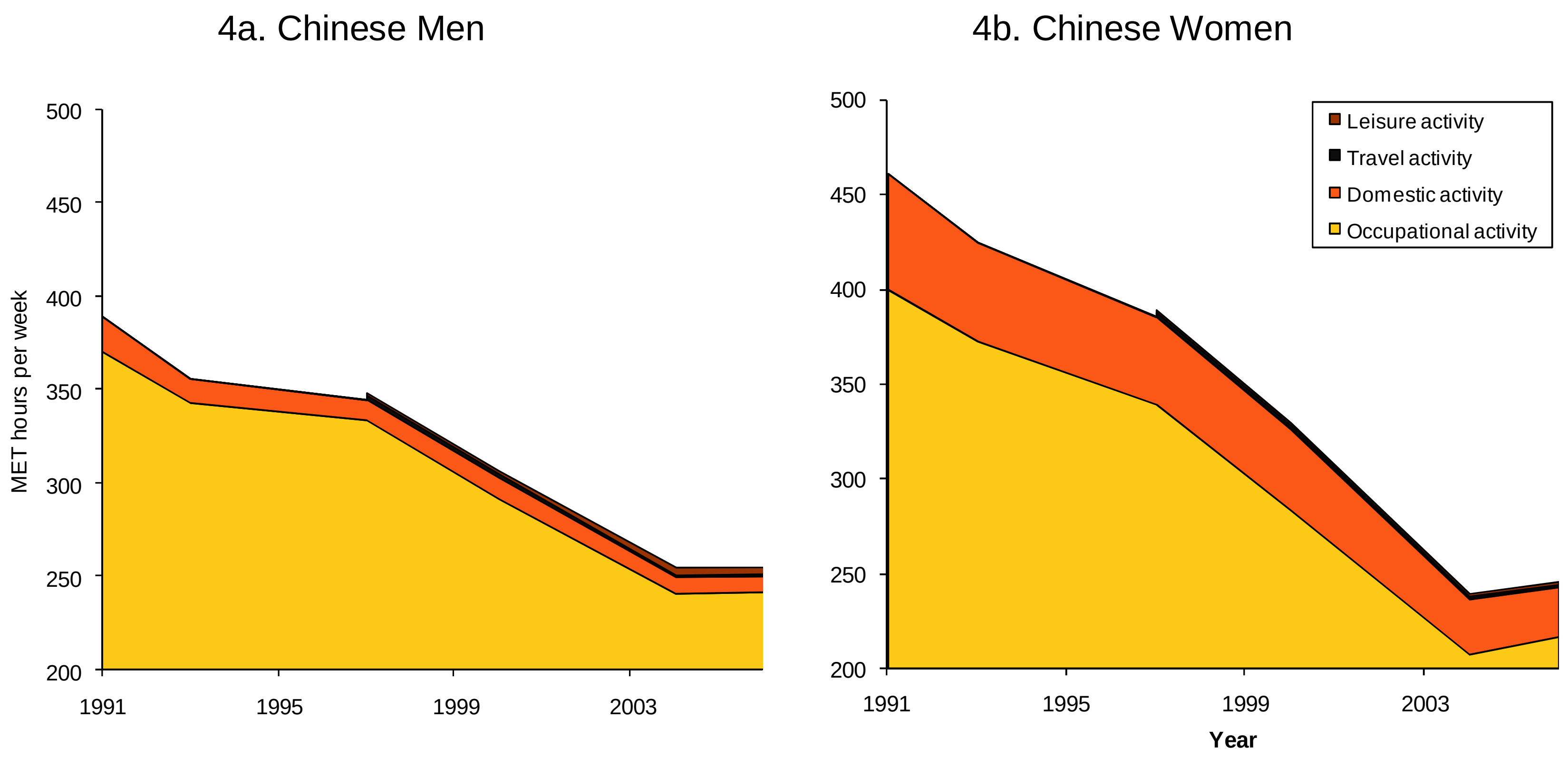


Table 1. Descriptive statistics of individual-level variables for adult Chinese men and women from selected waves of the China Health and Nutrition Surveys

	Men			Women		
	1991	1997	2006	1991	1997	2006
Physical Activity (MET-hrs/week)						
Occupational Activity	370.6 (218.0)	334.4 (214.2)	241.5 (177.5)	399.7 (264.6)	340.1 (242.5)	217.1 (191.8)
Home Activity	19.1 (34.6)	11.7 (31.6)	5.6 (18.3)	61.3 (58.5)	46.8 (56.9)	25.3 (47.7)
Leisure Activity		1.4 (7.6)	3.6 (16.0)		0.6 (4.9)	2.3 (15.0)
Transportation Activity	No data	2.6 (9.7)	1.9 (10.3)	No data	2.5 (11.0)	1.3 (5.0)
Total Activities		350.0 (214.7)	252.7 (176.9)		390.0 (252.0)	246.1 (196.4)
Control Variables						
Age (years)	35.2 (9.9)	36.7 (10.2)	40.4 (9.8)	35.0 (9.9)	37.5 (9.8)	40.9 (9.2)
Married (%)	79.7	78.7	83.9	81.0	84.1	89.4
Living Alone (%)	0.2	0.2	0.3	0.1	0.1	0.3
Predicted real household income (in 2006 yuan)	2227.2 (1447.8)	2546.0 (2361.3)	5242.8 (8046.9)	2240.1 (1595.7)	2550.3 (2264.4)	5075.9 (7785.6)
No education (%)	15.0	9.8	6.5	34.0	27.9	17.8
Completed primary education (%)	62.7	64.5	55.9	50.1	52.9	53.6
Completed secondary education (%)	15.3	17.6	20.6	11.5	12.5	14.4
Completed vocational training (%)	3.2	4.1	9.0	2.5	4.4	7.2
Completed university (%)	3.8	4.0	9.0	1.9	2.4	7.0
Participation in Activities						
In paid or self employment (%)	96.72	94.03	86.81	92.92	88.53	78.16
Did any domestic chores (%)	52.48	45.07	40.83	92.44	90.35	89.36
Time spent on domestic chores (in hrs/wk) §	14.99 (16.11)	10.88 (16.55)	5.77 (10.66)	28.01 (23.03)	22.14 (22.26)	11.86 (19.04)
Exercised for leisure (%) $		15.58	13.15		6.85	8.44
Time spent exercising (in hrs/wk) §		4.84 (5.05)	5.63 (5.81)		4.38 (5.22)	5.81 (7.65)
Bicycled for transportation (%)		34.64	19.26		27.27	17.40
Time spent bicycling (in hrs/wk) §	No data	4.56 (3.15)	4.58 (3.86)	No data	3.80 (3.15)	3.16 (1.47)
Walked for transportation (%)		58.41	38.29		63.38	38.48
Time spent walking (in hrs/wk) §		3.83 (2.15)	3.87 (3.70)		4.35 (3.01)	3.28 (2.18)
Averaged ≥ 30 min/day on transportation or leisure activities (%)¥		50.65	32.72		46.30	28.25
N	2,864	2,949	2,601	3,109	2,963	2,903

Figures in parentheses denote standard deviation. Only reporting data from 1991, 1997 and 2006 because these are the baselines and final wave of interest. § Among those who participated. $ More than 12 times in the past year. ¥ CDC, American College of Sports Medicine, and the WHO recommends ≥ 30 minutes/day for any activity (Haskell, Lee et al., 2007), but here I limit to only transportation and leisure activities for the China adult population due to high labor and domestic activities.

2.2.2. Key independent variables

The main independent variables of interest are time-varying and arguably exogenous dimensions of urbanization of each community. China's household registration (*hukou*) system and the longitudinal nature of the CHNS data ensure that selection into communities and inclusion in the data was as independent of individual or household choices and behavior as possible. The CHNS community-level measures on various dimensions of urbanization have been previously used in papers by Monda et al. (2007), and Zimmer et al. (2007). The ten community-level dimensions of interest in this paper are: population, density, access to markets for household goods, economic wellbeing, transportation, communications, educational institutions, health facilities, sanitation and housing infrastructures. These reflect changes in the various dimensions of infrastructure development over time and reflect the environment in which people function. Each of these dimensions was given a score from zero to ten and was comprised of data collected from local area administrators or official records (see Table 2).

For a country as large and diverse as China, one would expect there to be variation in the urbanization process across communities. Even though overall scores did increase over time, some communities experienced declines in some dimensions, while others saw large improvements. Over time, the infrastructure component scores changed at varying rates (see Table 2).

Table 2. Community level explanatory variables over time (CHNS 1991–2006)

	Community level explanatory variables	Statistics	1991	1997	2006
	Community Infrastructure Scores (each standardized to 0-10 points)				
Population	2, 4, 6, 8 and 10 points assigned based on cut-points of 1000,1500, 2000, 3000 people determined by the distribution of the CHNS data and the standard strategies for classifying areas as urban or rural (United Nations Economic and Social Commission for Asia and the Pacific, 1993)	Mean	6.1	5.8	7.2
		Std. Deviation	2.9	3.0	3.0
		% < 3 points	19.2	23.0	13.8
		3 ≤ % < 6 points	22.3	23.5	13.8
		% ≥ 6 points	58.5	53.5	72.5
Density	2, 4, 6, 8 and 10 points assigned based on cut-points of 250, 5000, 1000 and 2000 persons/km^2 determined by the distribution of the CHNS data and the standard strategies for classifying areas as urban or rural (United Nations Economic and Social Commission for Asia and the Pacific, 1993).	Mean	6.8	6.3	6.6
		Std. Deviation	2.8	3.1	3.0
		% < 3 points	12.8	23.0	18.4
		3 ≤ % < 6 points	17.6	15.5	14.7
		% ≥ 6 points	697	61.5	67.0
Access to markets	Sum of the availability of seven goods (gains, oil, vegetable, meat, fish, beancurd, and fuel) in major shopping areas within each community at each wave, where one point was assigned for each good available within the community and half-a point was assigned for each good available in a neighboring community < 1 km away[‡].	Mean	4.6	5.1	4.9
		Std. Deviation	3.1	3.5	3.9
		% < 3 points	36.2	28.9	37.6
		3 ≤ % < 6 points	26.1	28.3	27.5
		% ≥ 6 points	37.8	42.8	34.9
Transportation infrastructure	Communities were assigned two points each if their leaders reported that the community had mostly paved roads, a bus-stop or train station within their perceived community boundaries and were assigned one point if there was a bus-stop or train station in a neighboring community < 1 km away[‡].	Mean	4.9	5.3	5.8
		Std. Deviation	3.0	2.6	2.6
		% < 3 points	25.5	17.7	11.5
		3 ≤ % < 6 points	32.5	38.0	32.1
		% ≥ 6 points	42.0	44.4	56.4

	Community level explanatory variables	Statistics	1991	1997	2006
Communication infrastructure	Availability of provincial newspaper, a TV station, a radio station, telephone network, postal service, facsimile and telegraph services and a movie theatre. The information on the TV and radio station availability is based on whether ≥ 20% of households in a community reported having a TV or radio.	Mean	6.5	7.5	6.3
		Std. Deviation	2.5	2.4	2.0
		% < 3 points	16.0	9.1	8.3
		3 ≤ % < 6 points	28.7	18.2	44.0
		% ≥ 6 points	55.3	72.7	47.7
Economic Wellbeing	Based on community records or leaders' report of % employment in non-agricultural jobs, % employment fully within the community, and average male wage.	Mean	3.4	4.9	6.7
		Std. Deviation	1.1	2.4	1.9
		% < 3 points	47.9	29.4	0.9
		3 ≤ % < 6 points	52.1	44.9	35.8
		% ≥ 6 points	0.0	25.7	63.3
Educational Institution	Each of the five possible levels of schooling (preschool, elementary, middle, high, and vocational schools) was assigned two points if the school was located within the community. For all institutions except preschools and elementary schools, one point was assigned if the school was not in the community but was < 5 km outside the community[‡].	Mean	6.0	7.0	8.1
		Std. Deviation	2.8	2.7	2.6
		% < 3 points	19.7	8.6	6.9
		3 ≤ % < 6 points	19.7	18.7	9.6
		% ≥ 6 points	60.6	72.7	83.5
Health Facilities	Health facilities available within the community were given 1 point for each village or work unit clinic, 2 points for neighborhood or maternal child health (MCH) clinics, 3 points for town hospital, 4 points for district hospital, 5 points for county, work unit or army hospital, 6 points for private for city hospital, and 7 points for university hospital. Facilities available outside the community but < 10km away[‡] were given half of the listed points.	Mean	6.7	6.8	5.8
		Std. Deviation	2.2	2.3	2.7
		% < 3 points	4.8	8.6	21.1
		3 ≤ % < 6 points	33.5	28.3	26.2
		% ≥ 6 points	61.7	63.1	52.8
Sanitation infrastructure	Based on percentage of households in each community reporting availability of water treatment plant, and each household's overall index of the presence or absence of excreta in the vicinity (based on interviewers' observation).	Mean	5.9	6.7	7.7
		Std. Deviation	4.0	3.7	3.1
		% < 3 points	23.9	16.0	6.4
		3 ≤ % < 6 points	33.0	33.7	33.9
		% ≥ 6 points	43.1	50.3	59.6

Community level explanatory variables		Statistics	1991	1997	2006
Housing infrastructure	Based on percentage of households in each community reporting use of natural gas, piped water, indoor toilets and electric lighting, and on community-level reports on the availability and reliability of electricity (hours/day).	Mean	3.6	5.5	7.3
		Std. Deviation	2.7	2.9	2.2
		% < 3 points	55.3	30.5	4.6
		3 ≤ % < 6 points	28.2	25.1	28.0
		% ≥ 6 points	16.5	44.4	67.4
	Community Consumer Price Index (100 = 2006 urban Liaoning)	Mean	41.9	84.1	90.3
		Std. Deviation	3.6	10.0	9.7
		% < 40	42.0	0.0	0.0
		40 ≤ % < 80	58.0	42.3	14.7
		% ≥ 80	0.0	57.8	85.3
Number of communities			188	187	218

Only reporting data from 1991, 1997 and 2006 because these are the baselines and final wave of interest.

Questionnaires used in the CHNS can be found at the survey's website (CPC, 2008).

‡ For items involving distances, these were relative to the center of the community, determined by latitudes and longitudes on official maps.

2.3. Empirical framework

The empirical model uses a longitudinal random effects model with year,*t*, nested within individuals,*i*, and communities, *c*. Analyses for men and women were run separately due to the differing activity trends of the two genders. The model can be written as:

$$PA_{tic} = \lambda + Z_{tc}\bullet\gamma + P_{tc}\bullet\zeta + \pi\bullet T_{tic} + X_{ti}\bullet\alpha + \mu_{ti} + \varepsilon_{tic}, \quad (1)$$

where PA_{tic} denotes individual activity level (occupational or total), λ represents the overall mean base year activity level; Z_{tc} represent the time-varying community-level urbanization dimensions; the coefficient γ represent the vector of change in activity given a unit change in the different urbanization dimensions; P_{tc} represents the time-varying community consumer price index (CPI); the coefficient ζ represents the vector of change in activity given a one percent change in prices; the coefficient π represents change in activity between the base year and specific years, T; X_{ti} is a vector of individual- and household-level characteristics such as age, education attainment, marital status, living situation and predicted real per capita household income; the vector of coefficients α represents the change in activity given a one unit change in these characteristics; μ_{ti} is the time-varying individual error; and ε_{tic} is the random effect error term.

For the model on total physical activity, inclusion of occupational physical activity as an explanatory variable poses statistical problems due to multi-collinearity between total and occupational physical activity. Including an indicator variable for occupational change is not ideal either because what I am trying to estimate should not be conditional on changes on occupational choice. In addition, it is not clear if those who changed jobs did so from more physically active jobs to less active ones or vice versa. It also does not capture changes in physical activity within the same type of occupation (investigation into this reveals that significant declines in occupational physical activity occurred even among those who remained in the same job codes). Thus, I used the same specification for both occupational and total physical activity.

The coefficients of interest are those of the ten urbanization dimensions, denoted by γ (results are in Table 3). I did not test each community dimension in separate models because while they might be correlated with each other, they were not collinear and needed to be studied jointly to allow us to test the multiple dimensions of urbanization.

The first hypothesis is that these coefficients will be negative, and jointly statistically significant. In order to get an idea of the contribution of the various community measures to declines in physical activity, I derive the marginal effect of each of the community measures and multiply those by the change in each measure between the base year and 2006. Then, I calculate the proportion of that figure that explains the total decline in physical activity over the same period (results are in Table 4). Based on the second hypothesis, I would expect that the contribution of the dimensions of economic wellbeing, transportation and educational institutions would account for most of the decline in physical activity levels, especially for occupational physical activity. If the third hypothesis is correct, I would expect the calculated contribution of the urbanization dimensions to be larger for men than for women.

I first start with a model that includes only time, to see how variation in physical activity is allocated across the levels. Evidence of between-person and between-community variation justifies including individual- and community-level predictors. Next, cross-level interactions are tested to evaluate whether the effects of community-level characteristics on physical activity levels and dietary intake differ over time. These interaction terms are included in the final models only if they improve the model fit significantly. I correct for heteroskedasticity by clustering at the outer-most (community) level. This approach allows for inclusion of two potential sources of heterogeneity, which captures both individual-specific unobserved factors, and unobserved community-specific unobserved factors that affect physical activity levels over time, and is equivalent to a multi-level model (Angeles, Guilkey et al., 2002).

2.4. Results

2.4.1. Basic results

Results from the estimations show that urbanization is negatively associated with both occupational and total physical activity levels for both adult men and women in China. They also show that community economic wellbeing, availability of educational institutions, improved sanitation and housing infrastructures are the factors most strongly associated with declines in occupational and total physical activity levels, for both men (Table 3, columns 1 and 2) and women (Table 3, columns 3 and 4).

For men, a one point increase in the education facility score decreases physical activity by almost 13 MET-hours per week; a one point increase in housing or sanitation scores decreases physical activity by between eight and ten MET-hours per week; and a one point increase in the community's economic wellbeing score decreases physical activity by six to seven MET-hours per week. For women, the marginal effect of these component scores on physical activity declines was more pronounced. A one point increase in the education facility score decreases physical activity by 16 to 17 MET-hours per week; a one point increase in housing infrastructure scores has a greater impact than for men; a one point increase in sanitation scores decreases physical activity six to ten MET-hours/week; and a one point increase in the community's economic wellbeing score decreases physical activity by nine MET-hours per week.

Access to markets (a measure on the availability and distance of various types of household goods) is also significantly associated with declines in both occupational activity and total activity for men and women, but appears to be slightly more strongly predictive of total activity. This seems possible since shopping for food or other items involves both home and transportation activity. Health facility services is significantly associated with declines in occupational activity for both men and women, but is not associated with declines in total activity. The other four components do not appear to be strongly associated with physical activity levels at all. It is somewhat surprising that transportation infrastructure is not significantly associated with physical activity levels, but this finding is possible because transportation activity constituted a small proportion of total physical activity in this population.

Model specifications that include interactions between year dummies and the community level variables result in very similar results, and do not improve the model fit significantly.

Table 3. Longitudinal regression coefficients and robust standard errors of community components on physical activity among adult Chinese men and women

Community Infrastructure Components	Men: Occupational Activity 1991–2006	Men: Total Activities 1997–2006	Women: Occupational Activity 1991–2006	Women: Total Activities 1997–2006
Population	-0.37	-1.25	2.61	0.43
	(1.30)	(1.50)	(1.73)	(1.90)
Density	**-3.24 ***	-0.88	-2.87	-0.01
	(1.39)	(1.48)	(1.80)	(1.86)
Access to markets	**-1.88 ***	**-2.72 ***	**-3.06 ****	**-3.12 ***
	(0.92)	(1.09)	(1.15)	(1.37)
Transportation Infrastructure	-1.06	-0.17	-2.03	-3.19
	(1.29)	(1.52)	(1.43)	(1.70)
Communications Infrastructure	-1.85	-0.42	**-4.21 ***	-1.41
	(1.51)	(1.64)	(2.11)	(2.41)
Economy	**-7.08 ****	**-6.39 ****	**-9.22 ****	**-8.84 ****
	(1.46)	(1.54)	(1.59)	(1.79)
Educational Institution	**-12.97 ****	**-12.91 ****	**-17.00 ****	**-16.22 ****
	(1.80)	(2.19)	(2.39)	(2.85)
Health Facilities	**-2.93 ***	-2.15	**-3.50 ***	-3.64
	(1.46)	(1.70)	(1.72)	(1.95)
Sanitation Infrastructure	**-9.13 ****	**-8.43 ****	**-9.82 ****	**-6.12 ****
	(1.22)	(1.44)	(1.59)	(1.93)
Housing Infrastructure	**-9.15 ****	**-10.18 ****	**-10.54 ****	**-12.49 ****
	(1.82)	(2.61)	(2.16)	(3.18)
Statistics for regression models				
# of observations	16,753	11,234	18,033	12,092
# of unique individuals	6,740	5,450	7,188	5,669
# of communities	235	225	235	225
Wald	2545.71 **	1608.64 **	2283.50 **	1241.87 **
Degrees of freedom	27	25	27	25
σ_u (Std error of random error)	82.71	77.63	89.81	90.69
σ_e (Std error of residual)	136.39	137.65	151.32	152.41

** denotes significance at the 1% level; * denotes significance at 5% level.

Controlling for year dummies, age, age-squared, age-cubed, individual educational attainment, marital status, living situation, predicted household income tercile and community-level CPI.

2.4.2. Main contributing factors

Next, I calculated the contribution of these community-level factors to declines in physical activity by multiplying the change in each measure between the base year and 2006 (Table 4, column 1), by each urbanization dimension's marginal effects (Table 4, column 2) and then attributing the proportion of that figure to the decline in occupational activity (129.1 MET-hours per week for men and 182.6 MET-hours per week for women) and total physical activity (97.3 MET-hour per week for men and 143.9 MET-hours per week for women) over the same period (Table 4, column 4).

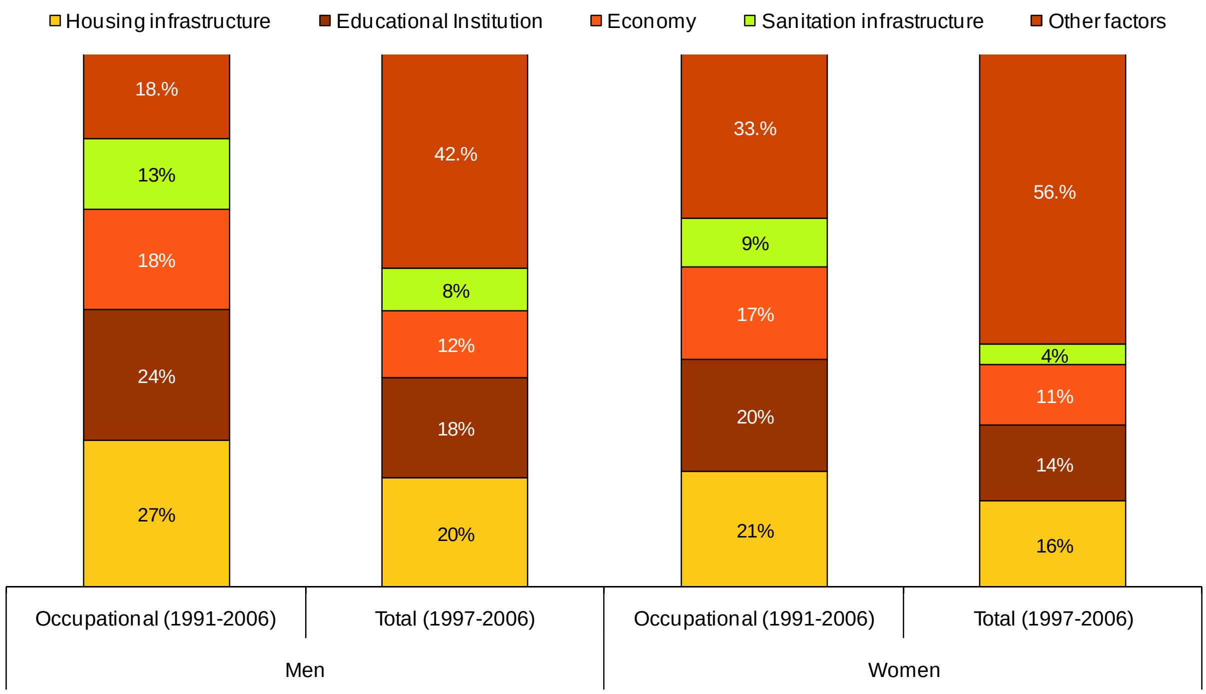
The ten community-level urbanization dimensions are associated with 80.5% of the decline in occupational activity from 1991 to 2006 and 57.2% of the decline in total activity from 1997 to 2006 (see Table 4) for men. These dimensions do not appear to be as strongly associated with the decline among women: the ten community-level urbanization dimensions are associated with 64.4% of the decline in occupational activity from 1991 to 2006 and 40.2% of the decline in total activity from 1997 to 2006 (see Table 4). This is because females had more rapid declines in physical activity than men, due to declines in both occupational and home activities. These results are consistent for both occupational and total physical activity for both men and women; in all cases, most of the physical activity decline is strongly related to housing, education, economy and sanitation changes.

Table 4. Contribution of key community components in explaining physical activity decline among adult Chinese men and women

		(1)	(2)	(3)	(4)	(5)	
	Occupational Physical Activity (1991–2006)	Change (1991–2006)	Coef.	Change * Coef.	% contribution of explained change	% contribution change in PA Mean	Bootstrapped 95% CI
Men	Housing Infrastructure	3.79	-9.15	-34.66	33.27%	26.79%	(22.18, 85.40)
	Educational Institution	2.36	-12.97	-30.61	29.39%	23.66%	(20.97, 26.35)
	Economy	3.36	-7.08	-23.78	22.82%	18.38%	(14.67, 22.09)
	Sanitation Infrastructure	1.80	-9.13	-16.44	15.78%	12.71%	(11.24, 14.18)
	Other components			1.32	-1.26%	-1.02%	
	Total			-104.17	100.00%	80.52%	(75.63, 85.40)
Women	Housing Infrastructure	3.65	-10.54	-38.49	32.72%	21.05%	(17.60, 24.50)
	Educational Institution	2.19	-17.00	-37.17	31.60%	20.37%	(18.37, 22.37)
	Economy	3.34	-9.22	-30.79	26.18%	16.85%	(14.23, 19.48)
	Sanitation Infrastructure	1.67	-9.82	-16.37	13.91%	8.97%	(7.89, 10.05)
	Other components			5.19	-4.41%	-2.84%	
	Total			-117.66	100.00%	64.39%	(60.66, 68.12)
	Total Physical Activity (1997–2006)	Change (1997–2006)	Coef.	Change * Coef.	% contribution of explained change	% contribution of change in PA Mean	Bootstrapped 95% CI
Men	Housing Infrastructure	1.89	-10.18	-19.24	34.71%	19.85%	(15.55, 24.16)
	Educational Institution	1.38	-12.91	-17.81	32.14%	18.38%	(15.61, 21.15)
	Economy	1.82	-6.39	-11.63	20.98%	12.00%	(9.18, 14.82)
	Sanitation Infrastructure	0.90	-8.43	-7.59	13.69%	7.83%	(6.56, 0.10)
	Other components			0.85	-1.53%	-0.87%	
	Total			-55.41	100.00%	57.19%	(51.78, 62.60)
Women	Housing Infrastructure	1.79	-12.49	-22.36	38.91%	15.64%	(12.55, 18.72)
	Educational Institution	1.21	-16.22	-19.63	34.25%	13.73%	(11.86, 15.59)
	Economy	1.80	-8.84	-15.91	27.69%	11.12%	(9.24, 13.00)
	Sanitation Infrastructure	0.86	-6.12	-5.26	9.14%	3.68%	(2.77, 4.59)
	Other components			5.74	-9.98%	-4.01%	
	Total			-57.45	100.00%	40.16%	(36.21, 44.12)

Bootstrapped confidence interval derived from 1000 replications.

Figure 5. Contribution of community infrastructure components in explaining physical activity decline among Chinese adults



Why are these four factors so important? There are a number of possible explanations relating to time allocation decisions towards human capital investments and changing job markets. The housing measure is based on having piped water and reliable electricity access into homes. As this access improves, people can reduce energy and time spent obtaining water and fuel. Meanwhile, better sanitation services result in fewer and less severe illnesses. Both improved housing and sanitation may allow individuals to put more time into human capital investments such as education and health, and income-generating activities.

The educational institution score is a measure of investment in educational infrastructures in the community. Having access to schools (from primary level to higher educational institutions) can help enhance the skills of the community's workforce, attract more capital and less labor intensive types of enterprises and result in higher marginal rate of return for work. These effects can be seen in the fact that communities with higher educational institutions also have higher economy scores. The changing job opportunities and declining physical labor needs of these jobs have been cited as important reasons for activity declines.

When interpreting these results, one should bear in mind that the estimated contribution of each of these factors is taken *ceteris paribus* (holding all else constant). In reality, however, the community components are not independent of each other or of urbanization in general. For example, higher educational institutions tend to be in areas where they are sufficient populations to attend them. These are often more urbanized communities with denser population bases. Therefore, despite being able to calculate the stand alone effect of each of these community components, it is also not clear if each of these components has specific seperable results from urbanization in general, or whether the various community components affect physical activity in convergent or divergent ways.

2.5. Discussion

This paper found that urbanization as measured by a collection of dimensions is associated with a significant proportion of the decline in physical activities, particularly occupational physical activities, among Chinese adults. Improved housing infrastructures, better access to educational institutions, higher economic opportunities and improved sanitation services are the key community-level factors that explain this decline. These findings suggest that improvements in community infrastructures and services may have affected the environments in which the Chinese live, the choices available to them, and consequently the choices they make.

2.5.1. Is urbanization bad?

While the results may suggest that improvements in community infrastructure and services are significantly associated with declines in physical activity, it does not mean that urbanization is necessarily detrimental. Declines in occupational activity are signs of shifts in the job market toward less labor intensive occupations. Descriptive statistics show that leisure activity is gradually on the rise in China among both men and women, which might help attenuate the effects of declines in physical activity at work and in the home. While this is promising, active leisure activity levels are clearly not rising fast enough to make up for the declines in occupational and home activities. In fact, only 13.2% of Chinese men and 8.4% of Chinese women engaged in any exercise in 2006 (see Table

1), and among those who participated in leisure activities, the percentage of their total activity due to leisure was less than 5%.

Declines in physical activities are not necessarily negative per se, because they may reflect more efficient allocation of energy. However, they can be a problem when declines in caloric intake are not moving at equally rapid rates, since caloric imbalance will lead to higher body mass index, and more importantly the development of many chronic diseases such as type II diabetes, high blood pressure, and cardiovascular disease (Popkin, 2007). Furthermore, lack of physical activity poses major risks for cancer and a range of metabolic diseases (National Institutes of Health, 1995; World Cancer Research Fund-American Institute for Cancer Research, 2007). These diseases will create new health and financial challenges for developing countries such as China.

2.5.2. Policy implications

In the United States and Europe, physical activity has been considered the ‘best buy’ in public health (CDC, 2000; De Backer & De Bacquer, 2004; Morris, 1994) , which may be the case in a developing country like China as well.

In China, declines in physical activity have occurred mostly at work, therefore intervention strategies to increase physical activity levels at the workplace are one possible strategy. Examples include encouraging stair use in buildings by placing signs near stairways and escalators, or by making stairways more centrally located and escalator use less convenient. To increase physical activity in other domains, active leisure and transportation activities such as walking and bicycling can be promoted by designing built environments that are safe and conducive for such transit or exercise modes (Forsyth, Hearst et al., 2008; Nagel, Carlson et al., 2008). It is also possible that parking can be made less accessible to promote walking, or improved access to public transit can help promote walking (Rodriguez, Aytur et al., 2008) or bicycling — a diminishing activity in urban and rural China. Pricing policies in the form of higher taxes on automobiles, lower entry fees to parks and government run health facilities can also help promote physical activity. Moreover, disincentives for automobile ownership can discourage motorized transportation and help reduce air pollution and provide more pleasant environments for outdoor exercise. These policies can be province- or community-specific depending on geographical, cultural and socio-economic circumstances.

Local governments should take advantage of current transformations in infrastructural changes to incorporate such considerations into town or city planning, land-use development decisions, and provision of services. In the long-run, increased physical activities will not only be beneficial for individual health, they also have the potential to decrease both private and public health care expenditures.

2.5.3. Limitations and future directions

While this paper has provided insights into the association between community-level infrastructure and service and their relationship with occupational and total physical activity levels over time, there are a number of limitations with this analysis.

First, modeling the relationships between environment and physical activity choices is difficult because the direction of the relationship is unclear. It is possible that individuals' decisions and preferences about where to live and work (such as individual preference for big cities) help determine both physical activity levels as well as living environments. For example, if people tend to move to more urbanized areas with better occupational prospects and no longer want to engage in labor intensive occupations, then the coefficients will overestimate the effects of urbanization as determinants of behaviors. However, this endogeneity problem is somewhat less problematic in the context of China where the household registration (*hukou*) system limits mobility and determines access to public services and subsidies. Nonetheless, there is still significant rural-urban migration.

Second, there are some data limitations that may compromise the findings. For example, the use of MET-hours per week to quantify energy expenditure does not take into account individual differences that may alter the energy cost of movements. Nonetheless, this approach is the best available way to systematically apply average energy cost estimates in self-reported measures (Matthews, 2002), and has been shown to be valid at least in the area of occupational activity (Ainsworth, Richardson et al., 1999). Moreover, I included multiple sources of occupational and domestic activity to allow a more complete assessment of physical activity; this may be especially important for women in developing countries because of their multiple responsibilities (Short, Chen et al., 2002). I investigated the possible gender, age and geographical differentials by conducting separate analyses for men and women, controlling for age and community-level factors. One way to validate the physical activity measures that were used is through studies that investigate the link between physical activity levels and outcomes such as weight and chronic diseases. Other published studies (Bell, Ge et al., 2001; Monda, Adair et al., 2007; Monda & Popkin, 2005) have used the CHNS physical activity data for these purposes. Moreover, the model specifications might still be problematic because the random effects model assumes that the errors are orthogonal to all explanatory variables. If this is not the case, the estimated coefficients may be biased, even though the standard errors are smaller.

This paper only looks at one of main drivers of why health indicators have deteriorated among Chinese adults. Ultimately, two components determine weight and BMI, which are major determinants of numerous health risks: physical activity and diet. Future work will include estimating a dynamic panel model that incorporates the community-, household- and individual-level factors and relate them to changes in weight or BMI over time. Such a model will address both the problem of endogeneity and the fact that weight and BMI are stock variables that depends on prior weight or BMI, dietary intake and activity levels. Due to possible endogeneity issues, the analysis did not account for ownership of technological assets (motorized vehicles, washing machines, etc.), which are factors that might provide further insights and deserve attention in future work. Future work should also be considered regarding joint decisions about time and energy allocation among household members, instead of just considering individuals alone.

3. THE EFFECT OF CHANGES IN PRICES AND INCOME ON FOOD CONSUMPTION AMONG CHINESE ADULTS

Abstract

China has seen marked economic changes and shifts in the structure of food consumption in the last two decades. Measuring the relative effects of these factors on diet change has been challenging due to the lack of longitudinal data on individual consumption, and time- and spatially-varying prices at the community-level. This paper looks at some of the main drivers of the dietary change by estimating the own-, cross-price and income elasticities for six key food-groups and how they vary over time and income levels. This paper uses the 1991–2006 waves of the longitudinal China Health and Nutrition Survey (CHNS). I found that changes in price elasticities are complex and are food-group and income specific; income elasticities have fallen for most food-groups; rice has become an inferior good; and that the demand for pork was the most income responsive of these food-groups. China's membership into the World Trade Organization (WTO) will mean continued price changes experienced by the Chinese. This paper provides some sense of the way shifts in food prices may affect Chinese food demand.

3.1. Introduction

Globally, there has been marked shift in the composition of people's diets, with consumption of animal source and energy dense foods increasing significantly since the 1970s (Delgado, 1999). It is generally agreed that this global change in consumption is related to the general declines in global prices of edible oils, grains, feed, livestock, and milk. Given that global food prices (with the exception of maize/corn) are projected to continue falling, it is predicted that there will be continued increases in the consumption of such foods worldwide, but particularly in developing countries (Delgado, 1999; Delgado, Rosegrant et al., 2001).

China in particular has had some of the largest rate of increase in meat and milk consumption in the last two decades. The traditional Chinese diets that were high in fiber, cereals, and grains are now predominantly compose of animal source foods (eggs, poultry, pork and milk), are higher in fat, and more energy dense (Hu, Reardon et al., 2004; Popkin & Du, 2003). These dietary changes have been found to be strongly associated with development of cardiovascular diseases, hypertension, type II diabetes, non-alcoholic steato-hepatitis of the liver, and certain cancers (Chen, Zhao et al., 2008; Wang, Mi et al., 2007). China now has some of the highest growth rates in the prevalence of these nutrition related non-communicable diseases (NR-NCDs) (Popkin, Wolney et al., 2006; Raymond, Leeder et al., 2006; Yang, Kong et al., 2008).

Most researchers agree that changes in dietary patterns in China have been largely due to the rapid income growth, shifts in relative prices, and structural shifts in demand (Haddad, 2003). This has led some economists and policymakers to contend that if economic factors are indeed drivers of diet change, it may be possible to alter the economic environment to discourage consumption of less healthy foods, while encouraging the consumption of more healthy foods (Frazao & Allshouse, 2003; Jacobson & Brownell, 2000). To do so would require an understanding of how consumers respond to such economic factors. However, estimating the effects of price changes and income changes on diet has been challenging due to the lack of longitudinal individual-level consumption measures and good time- and spatially-varying price data.

The majority of the literature on the effects of economic factors on food demand in China has been done so with the primary purpose of guiding policymakers in understanding the global and country-specific food markets for trade and agricultural planning. Therefore, most of these efforts have estimated price and expenditure elasticities using cross-sectional household aggregate data by modeling household expenditures and budgeting on food versus other needs (clothing, education, housing, for example). When the data are available, researchers have been able to model food budgeting into various broad categories of food. These typically use Deaton & Muellbeuer's Almost Ideal Demand model (Deaton & Muellbauer, 1980), the Rotterdam model (Theil, 1965, 1975) that considers total demand systems, and some variation or functional form of these (Fan, Wailes et al., 1995; Gao, Wailes et al., 1996; Gould & Villarreal, 2006; Jiang & Davis, 2007).

However, there are a number of problems with the estimates from these past studies. First, the estimates vary significantly depending on functional form and type of model. In particular, the use of aggregate data lowers the likelihood of getting reliable estimates of structural price and income coefficients (Blundell, Pashardes et al., 1993). Second, using aggregate expenditure on broad commodities (food, housing, education or clothing) does not allow for accurate estimation of substitutions among foods. This is especially true when important nutritional effects occur, such as in the substitution of high fat pork for lean pork, or the substitution of flour for rice. In these cases, the level of commodity detail needed to reproduce accurately the impact of relative price changes is more important than the econometric approach (Timmer & Alderman, 1979). Third, the lack of food-specific price data also means that often, past estimates have been calculated using the unit value (ratio of expenditures to quantity purchased of a board budget category) as price (Gale & Huang, 2007). Fourth, the use of cross-section data is unable to resolve possible endogeneity problems because it does not allow sources of structural change, such as changes in the built environmental or food markets, to be implicitly included into the model (Capps & Schmitz, 1991). Fifth, most of these studies have not tried to estimate different elasticities for different income levels. Therefore, while these past estimations from household expenditure and average price data can be useful for macro-level planning purposes, it provides little insight into individual-level consumption responses and hence potential health outcomes (Haddad, 2003).

Although a general rise in income or decline in food prices are usually associated with a rise in caloric intake, this is not the case in China. Instead, there is a shift in the source of calories from various macronutrients and food-groups, and so there is a need to understand the associations among prices, income on the consumption of macronutrients and foods. There have been only a handful of studies using dietary intake data done in China. These past studies suggest that food prices and income changes are possible mechanisms for shifting people's dietary choices (Guo, Mroz et al., 2000; Guo, Popkin et al., 1999; Ng, Zhai et al., 2008). Work done by Guo and others (2000; 1999) used the earliest three waves of the China Health and Nutrition Surveys (CHNS), conducted in 1989, 1991 and 1993, which covered a period when the Chinese food economy was not freely priced and traded. It was not until late-1992 that price controls and subsidies were fully lifted across the country. Consequently, while the price and income estimates by Guo and colleagues are informative, they are no longer reflective of the current food economy in China, in terms of both prices and income. Their results from the early economic reform period in China found that increasing pork, eggs, and edible oil prices could lower fat intake, but only increasing pork prices were associated with reduction in protein intake (Guo, Popkin et al., 1999). Also, the income elasticities of dietary fat and higher fat foods (pork, eggs, and oil) became more elastic over time; low fat, high fiber foods became less important in the Chinese diet, especially among adults in high income households (Guo, Mroz et al., 2000). Ng and colleagues (2008) looked specifically at edible oils, and the effects of manipulating edible plant oil prices based on 1991 to 2000 data. They found that increasing edible plant oil price can result in a decreasing consumption of edible plant oils, an even more drastic decrease in non-plant oils, and that the poor were more price sensitive with regards to plant oils and dietary fat consumption.

This paper provides new evidence on how consumers respond to changing prices and income by estimating the own-, cross-price and income elasticities for a number of key food-groups (rice, wheat flour, plant oils, pork, eggs, and vegetables) using more recent measures of individuals' consumption to better reflect of the realities of the food economy in China. It also looks at how these elasticities vary by household income over a period of rapid economic change by using longitudinal models that account for time interactions with prices and income. This paper also seeks to improve earlier price and income estimates by controlling for contextual variables that vary both geographically and temporally, and by using the appropriate estimation models based on the distribution of consumption for each food-group.

I expect that own-price elasticities to be negative, while income elasticities are positive for these six food items. I also hypothesize that since the early 1990s, own price elasticities for most food-groups have increased as varieties of substitutes within food-groups increase. In addition, income elasticities should have fallen for most food-groups over time — in particular, I expect rice to have become an inferior good because of the availability of substitutes that are perceived to be of higher status or quality (e.g., flour, bread). Lastly, I expect income elasticities to have flattened out across income levels for most food-groups as people gain easier access to these foods.

3.2. Data

In order to test the hypotheses, there is a need for longitudinal individual-level consumption and demographic data, information on household income, as well as contextual information about the communities where people live. Fortunately, all of these are available in the China Health and Nutrition Surveys (CHNS), which was designed to study how the socio-economic transformation of Chinese communities affects the health and nutritional behaviors and status of their populations.

This analysis used six waves of data collected in 1991, 1993, 1997, 2000, 2004 and 2006, involving nine provinces that varied in demography, geography, economic development, public resources, and health indicators. A multistage, random cluster process was used to draw the sample surveyed in each of the provinces. Counties in the nine provinces were stratified by income and a weighted sampling scheme was used to randomly select four counties in each province. Villages and townships within counties, and urban and suburban neighborhoods within cities, were selected randomly. The same households were surveyed during each wave as best possible to allow for a longitudinal study (for further information see: http://www.cpc.unc.edu/projects/china and Appendix B).

The analysis is limited to adults, between 18 and 55 years old, who were not disabled, pregnant or lactating during each survey wave for whom complete variables were available. The final case analysis included 35,064 person-wave observations from a sample of 13,969 individuals over the 15-year period (1991 to 2006).

3.2.1. Dependent variables

The dietary outcomes of interest are based on food-groups because of the interest in determining how price changes of these foods affect food consumption (rather than just total caloric intake) over time among people in different income groups. This paper uses measurements of the intake of six food-groups in kilocalories (kcal): rice, wheat flour, plant oils (e.g., soybean oil, rapeseed oil, and peanut oil), pork, eggs, and vegetables as dependent variables.

Detailed food consumption data were collected for households and individuals on three consecutive days with the start day randomly allocated from Monday to Sunday. Household food consumption was determined by measuring the change in the weight of the household food inventory at the beginning and the end of each day for all three days. All processed foods, purchases, home production, and processed snack foods at the initiation of the survey were weighed and recorded. Preparation waste was estimated when weighing was not possible. The number of household members and visitors at each meal was recorded. Individual dietary intake was surveyed for all adults based on daily, self-reported, 24-hour recalls on all food consumed away-from-home and at-home. More than 99% of the sample was available for all three days of data collection.

The collection of both household and individual dietary intake allowed for quality checks. Where significant discrepancies were found, the household or the individual in question were revisited, and again asked about their food consumption in order to resolve these discrepancies. Nutrient intakes were calculated by matching the consumption data with the 1991 and the 2002 China Food Composition Tables (FCTs) for the appropriate waves (i.e., the 1991 FCT was used for the 1991 to 2000 waves, and the 2002 FCT was used for the 2004 and 2006 waves) (Institute of Nutrition and Food Hygiene, 1991, 2002). The FCTs provided a comprehensive list of the macronutrient content of food items available in the Chinese market.

There were significant changes in the types of foods people ate from 1991 to 2006 (Table 5). The proportion of adults who ate any eggs rose by over 25%, and 14.3% more people consumed any plant oils. Among those who ate eggs or plant oils, they also ate significantly more on average per day. Nearly 11% more adults consumed any flour in 2006 compared to in 1991, but daily calories from flour fell significantly, as did daily calories from rice. About 11% more adults ate any pork, mainly due to an increase in the proportion that ate any fatty pork. Vegetables were the only food-group that consistently was highly consumed in terms of any consumption, although the amount consumed fell over time. Here, we can see at least descriptively, the greater availability of types of foods (in terms of food-groups) for people, but a shift in dietary intake away from rice, flour, and somewhat from vegetables towards eggs, pork, oils. It is important to note that any consumption was based on three-day consumption data, so these are a snap-shot, not a completely representative measure of the annual consumption pattern, in which seasonality and special occasions can play a part (e.g., during the Lunar New Year celebrations, pork, poultry and fish might be more likely to be consumed). Nonetheless, the measurements of amounts consumed can be representative given the sampling procedure applied.

3.2.2. Independent variables

Community price surveys conducted on a set of sample stores and markets were used to provide price data. Variations in food prices across communities are due to both supply and demand side factors. On the supply side, agricultural production, transportation, marketing and distribution costs, imports of specific foods, and availability of substitutes and complements can affect prices across communities. On the demand side, preferences or food fads may vary by communities. In addition, there are also variations in inflation, measured by the Consumer Price Indices (CPI) across communities, depending on the province and urbanicity. It is possible that prices and income might be linked, particularly in rural areas where residents may be net producers. Also, rising incomes might result in changing aggregate demand, which can affect prices. On the other hand, most price changes in China are driven by supply factors and economic decisions made at the provincial level by price commissions and other macroeconomic trade agreements. As a whole, prices are determined in aggregate by a number of demand and supply forces that are beyond the control of individuals, so it is assumed that the community-level prices are exogenous.

Table 5. Descriptive statistics on consumption among Chinese adults (CHNS 1991–2006)

	All years			1991			2006		
	Consumed Any (%)	Amount consumed |consumed (kcal/day)	Amount consumed (kcal/day)	Consumed Any (%)	Amount consumed |consumed (kcal/day)	Amount consumed (kcal/day)	Consumed Any (%)	Amount consumed |consumed (kcal/day)	Amount consumed (kcal/day)
Rice	87.50	1101.70 (641.63)	964.02 (702.12)	85.41	1381.48 (725.59)	1179.91 (829.17)	87.94	896.05 (533.73)	787.95 (579.38)
Wheat Flour	73.96	700.35 (675.62)	517.95 (657.31)	68.56	898.44 (833.67)	616.01 (806.53)	79.36	557.35 (522.90)	442.32 (517.56)
Plant Oil	82.02	325.91 (332.47)	267.33 (326.08)	73.12	284.24 (232.85)	207.84 (235.64)	87.46	335.78 (249.37)	293.69 (258.37)
All Pork	69.12	299.73 (239.34)	207.17 (242.42)	65.04	305.54 (244.93)	198.73 (245.45)	76.64	299.20 (240.63)	229.29 (245.77)
Fatty Pork	63.12	306.51 (238.95)	193.46 (240.64)	59.65	313.18 (246.26)	186.81 (244.50)	70.15	305.17 (241.15)	214.08 (245.55)
Lean Pork	11.55	85.83 68.63	9.92 (36.01)	11.14	84.00 (75.47)	9.35 (36.49)	11.97	82.87 (65.93)	9.92 (35.26)
Eggs	48.03	60.53 (55.37)	29.07 (48.86)	35.02	52.55 (50.30)	18.40 (38.92)	60.68	64.21 (63.53)	38.96 (58.59)
Vegetables	98.55	39.99 (28.10)	39.40 (28.30)	98.03	42.43 (28.73)	41.59 (29.05)	98.91	36.80 (26.51)	36.40 (26.64)
Tofu	48.00	83.46 (83.36)	40.06 (71.23)	42.27	87.50 (90.49)	36.99 (73.00)	49.36	84.38 (81.34)	41.66 (71.03)
Chicken	13.19	97.50 (109.68)	12.86 (51.71)	8.15	127.17 (171.70)	10.36 (60.06)	15.32	78.39 (76.87)	12.01 (41.25)
N	35,064		35,064	5,990		5,990	5,504		5,504

Figures in parenthesis are standard deviations

Community prices for a representative basket of goods were primarily from free markets, and were collected from visits to stores in the communities surveyed. Free market prices were collected in a systematic manner from the most central market in each community. Over time, the variance in the selection and quality of each food-group has grown, which makes identifying the appropriate representative food item for a food-group difficult. As a default, surveyors were instructed to take the price of the cheapest food item by volume for each food-group sold in each community. In some of the earlier waves of the CHNS, when the studied goods were not sold in the free market, state store prices were used. Price records published by the State Statistical Bureau (SSB) of China that provided the provincial averages were used if the other two sources did not contain the information.

In the surveys, household income was reported as a continuous variable (in *yuan*). The total household income came from a very detailed income protocol that collected income for each activity. This included all cash and non-cash income components (e.g., state-subsidized housing) and excluded food subsidies that existed before 2001. In addition, household income is adjusted for deflation before taking the logarithm of it for use in the analysis to allow for both the non-linearity in the effect of income and to allow for income elasticity interpretations.

Price and income variables were deflated by year- and province-specific CPI developed for urban and rural areas by the China SSB (SSB, 1992, 1994, 1998, 2001, 2005, 2007), using the 2006 urban Liaoning as the baseline. The use of real deflated values in the analyses removed the effect of inflation and allowed the analysis to focus on the effect of an increase in real prices and real incomes.

Individual characteristics controlled in the models were age, gender, and education. Age was a continuous variable; highest educational attainment and gender were dichotomous variables. I also included year dummies to account for the possibly of time trends, and use these as interactions as discussed later. Other control variables included were: household size; a continuous measure of urbanization based on ten dimensions of urban development previously used in papers by Monda and colleagues (2007) and Zimmer (2007); and region of residence (South, Central or North) in order to control for major food preference differences.

3.3. Methods

3.3.1. Estimation Models

The models used for estimating the relationships between prices, income and consumption over time will depend primarily on the consumption distribution for each of the specific food-groups. There are some food-groups that are consumed by almost everyone and can have close to a normal distribution. In such cases, a straightforward Generalized Least Squares (GLS) approach with appropriate corrections for the standard errors due to clustering, would be perfectly acceptable.

However, most food consumption distribution is often skewed due to two factors: high proportion of non-consumers; and among consumers, a non-normal distribution. For such food-groups, there are a number of possible ways to deal with these two issues. The latter non-normal distribution problem can be fixed by using a log-transformation or an appropriate Box-Cox transformation on the consumption measure, so as to minimize the skewness of the distribution. The former non-consumption problem can be dealt with using a two-part model (Haines, Guilkey et al., 1988). The two-part model, as its name suggests considers the consumption decision in two parts. The first part is whether or not to consume, and the second part is how much to consume given that a particularly food is consumed. Two-part models are useful in predicting actual outcomes based on observed data, such that a zero does not represent missing data but is interpreted as a corner solution in consumer optimization.

Looking at the consumption distributions is an important first step in informing what models might be appropriate (available upon request). The figures along with the descriptive statistics from Table 1 suggest that the following models should be tried for these food-groups: Vegetable consumption should be estimated with a longitudinal GLS model, but the consumption of all other food-groups should be estimated with a two-part model (the first part is a probit model, and the second part is a longitudinal GLS model). All estimations were clustered at the community level, which is the highest level (the levels being individual, household and community) to correct for the error correlations (Angeles, Guilkey et al., 2002).

3.3.2. Specifications

The estimation uses log-log models for two reasons. First, I am interested in elasticity estimates, and log-log models would allow for straightforward interpretations. Second, in conducting a Box-Cox test (Box & Cox, 1964; Davidson & MacKinnon, 1985), it was found that for all food-groups except for rice, non-zero caloric consumption should be logged (results available upon request).

In the specifications, all models included year dummies (*year*), logged real household income (ln *inc*), logged real price of the food-group consumed (ln *op*), logged real price of other foods (ln *cp*), consumer price index (*cpi*), urbanization index (*urb*), region dummies (*region*), age (*age*), gender (*male*), education (*educ*), household size (*hhsize*) as control variables. I also included logged own price and year interactions, logged real household income and year interactions, and a three-way interaction of logged own price, logged real household income and year for all the food-groups. The specifications were kept the same for the GLS and for both parts of the two-part model:

(2) *Dependent variable = (probit or logged kcal)*

$$\begin{aligned}&\gamma_0 + \gamma_{year}\, year + \gamma_{\ln op} \ln op + \gamma_{\ln cp} \ln cp + \gamma_{\ln inc} \ln inc \\ &+ \gamma_{year \cdot \ln op}(year \cdot \ln op) + \gamma_{year \cdot \ln inc}(year \cdot \ln inc) \\ &+ \gamma_{year \cdot \ln op \cdot \ln inc}(year \cdot \ln op \cdot \ln inc) + \gamma_{cpi}\, cpi + \gamma_{urb}\, urb + \gamma_{region}\, region \\ &+ \gamma_{age}\, age + \gamma_{male}\, male + \gamma_{educ}\, educ + \gamma_{hhsize}\, hhsize + error\end{aligned}$$

For all the food-groups except for pork, the lowest price in the community for rice, wheat flour, plant oil, pork, eggs, vegetables, tofu, and chicken was used. Pork is the staple source of meat for the Chinese and is considered such an important food source that the Chinese government even has a strategic pork reserve, which was established in the late 1990s and includes both frozen stocks and access to pig farms. In addition, there has been a general trend of higher meat consumption over time. For these reason, it is important to look at pork prices in more detail. Therefore, for pork, I applied the two-part model, but used a slightly different specification that included both fat and lean pork prices as key explanatory variables. The caloric consumption for all pork, fatty pork, and lean pork was also investigated using this specification.

3.3.3. Deriving elasticities

The main estimates of interest were the marginal effects of logged own prices, logged prices of other food items, and logged real household income. The marginal effects would be the estimated coefficients when there are no interaction terms in the specification. However, because there are interaction terms included in all the estimations, there is need to calculated the relevant marginal effects.

For the GLS, the use of the log-log models allows for a straightforward interpretation — the marginal effects of own prices, other prices and income are the own-price, cross-price and income elasticities, respectively. This was the case for vegetables.

However, for the two-part models used for the other food-groups, the deriving elasticities was more complicated due to the need to take into account the non-consumers. Recall that the first part of the model predicts the probability of consuming a particular type of food:

(3) $$\Pr(Y > 0 \mid X) = \Phi(X'\hat{\alpha}),$$

where Y_{it} represents caloric consumption of a food, Φ represents the standard normal cumulative distribution function (i.e., probit), X represents the vector of explanatory variables, and $\hat{\alpha}$ denotes the vector of marginal effects from the probit estimation.

The second part of the model predicts logged caloric consumption of a food conditional on non-zero caloric consumption:

(4) $$E(\ln Y \mid Y > 0, X) = X'\hat{\beta},$$

where $\hat{\beta}$ denotes the vector of marginal effects from the GLS estimation.

To obtain the unconditional predicted logged consumption, the probability of consumption from the first part is multiplied by the expected logged caloric consumption from the second part of the model:

(5) $$E(\ln Y \mid X) = \Pr(Y > 0 \mid X) \cdot E(\ln Y \mid Y > 0, X) = \Phi(X'\hat{\alpha}) \cdot (X'\hat{\beta})$$

The marginal effect of a logged explanatory variable, ln x (e.g., logged own price, logged other prices or logged income), on the unconditional predicted consumption will be the derivative of $E(\ln Y \mid X)$ with respect to the explanatory variable, ln x:

(6) $$\frac{\partial E(\ln Y \mid X)}{\partial \ln x} = \Phi(X'\hat{\alpha}) \cdot \hat{\beta}_{\ln x} + [\hat{\alpha}_{\ln x} \cdot \varphi(X'\hat{\alpha})] \cdot (X'\hat{\beta}),$$

where φ represents the normal probability density function, $\hat{\alpha}_{\ln x}$ denotes the marginal effect of ln *x* in the first part, and $\hat{\beta}_{\ln x}$ denote the marginal effect of ln *x* in the second part. Hence, for the empirical model, the elasticities are calculated the following way:

(7) Own price elasticity, η^{op}
$$\begin{aligned} &= \frac{\partial E(\ln Y \mid X)}{\partial \ln op} \\ &= [\Phi(X'\hat{\alpha}) \cdot (\hat{\beta}_{\ln op} + \hat{\beta}_{year \cdot \ln op} year + \hat{\beta}_{year \cdot \ln op \cdot \ln inc} year \cdot \ln inc)] \\ &+ [(\hat{\alpha}_{\ln op} + \hat{\alpha}_{year \cdot \ln op} year + \hat{\alpha}_{year \cdot \ln op \cdot \ln inc} year \cdot \ln inc) \cdot \varphi(X'\hat{\alpha}) \cdot (X'\hat{\beta})]; \end{aligned}$$

(8) Income elasticity, η^{inc}
$$\begin{aligned} &= \frac{\partial E(\ln Y \mid X)}{\partial \ln inc} \\ &= [\Phi(X'\hat{\alpha}) \cdot (\hat{\beta}_{\ln inc} + \hat{\beta}_{year \cdot \ln inc} year + \hat{\beta}_{year \cdot \ln op \cdot \ln inc} year \cdot \ln op)] \\ &+ [(\hat{\alpha}_{\ln inc} + \hat{\alpha}_{year \cdot \ln inc} year + \hat{\alpha}_{year \cdot \ln op \cdot \ln inc} year \cdot \ln op) \cdot \varphi(X'\hat{\alpha}) \cdot (X'\hat{\beta})]; \end{aligned}$$

(9) Cross-price elasticity, η^{cp}
$$\begin{aligned} &= \frac{\partial E(\ln Y \mid X)}{\partial \ln cp} \\ &= [\Phi(X'\hat{\alpha}) \cdot (\hat{\beta}_{\ln cp})] + [(\hat{\alpha}_{\ln cp}) \cdot \varphi(X'\hat{\alpha}) \cdot (X'\hat{\beta})]. \end{aligned}$$

These were used to determine the own-price, income and cross-price elasticities for the all the food-groups except for vegetables. Marginal estimates and elasticities were all bootstrapped with 1000 replications (Davison & Hinkley, 1997).

3.3.4. Interpreting elasticities

Own-price elasticity of demand is defined as the percentage change in quantity demanded that occurs in response to a percentage change in price. This should be negative, except for in the case of Giffen goods (a lack of substitutes causes the income effect to dominate) or Veblen goods (demand rises as the price rises because its quantity demanded is a direct function of its price).

Income elasticities of demand is the percentage change in quantity demanded that occurs in response to a percentage change in income. Income elasticities of demand that are negative are considered to be inferior goods, such that a rise in income will lead to a fall in the quantity demanded and may lead to changes to more luxurious substitutes. Income elasticities that are positive are normal goods, of which income elasticities that are less than 1 are considered necessary goods and income elasticities that are greater than 1 are considered luxury goods. Income elasticities around zero suggest that the good is a “sticky” good, because a change in income is not associated with a change in the quantity demanded.

Cross-price elasticity of demand is the percentage change in quantity demanded for the first good that occurs in response to a percentage change in the price of a second good. Substitutes (e.g., coffee and tea) will have positive cross-price elasticities; complements (e.g., coffee and milk) will have negative cross-price elasticities, and independent goods will have cross-price elasticities of demand of essentially zero.

3.4. Results

3.4.1. Own price elasticities

As mentioned earlier, I used the two-part model for all the food-groups except for vegetables, where the single-equation GLS model was applied. The own-price elasticities for rice, flour and eggs are all negative and statistically significant. The own-price elasticities for oil and vegetables were negative but insignificant (Table 6).

It is possible that that there is substitution within types of pork in response to price changes. Thus, two pork prices (lean pork price and fatty pork price) were include as explanatory variables. The results (Table 6 and Table 7) show that when the real price of fatty pork increases by 1%, calories from all pork decreases by almost 2% points (but this is not statistically significant). Meanwhile, if the real price of lean pork increases by 1%, calories from total pork consumption increase by 1.4% points (statistically significant at the 5% level). This finding lends some support to the argument that substitution from lean pork to fatty pork occurs when lean pork prices increase, and because fatty pork will have more calories per gram as lean pork (each gram of protein has 4 kcal of energy, while each gram of fat has 9 kcal of energy), subsequently any substitution of fatty for lean pork is linked with added calories from pork.

Table 6. Own price elasticities from longitudinal GLS and two-part model estimations for six food-groups in China (CHNS 1991–2006)

% point change in kcal consumed		Marginal effect of 1% increase in real price		
		P(any)	ln(kcal |any)	ln(kcal)
Two-Part Model	**Rice**	**-2.116 ****	**-0.701 ****	**-2.29 ****
		(0.303)	(0.103)	(0.629)
	Wheat Flour	**-0.965 ****	**-0.915 ****	**-1.854 ***
		(0.133)	(0.089)	(0.943)
	Plant Oil	0.113	0.011	-0.155
		(0.207)	(0.062)	(0.699)
	All Pork ‡	**0.735 ****	**-0.309 ***	-1.969
	(Fatty pork prices)	(0.145)	(0.137)	(1.355)
	All Pork ‡	-0.091	**0.317 ****	**1.407 ***
	(Lean pork prices)	(0.127)	(0.027)	(0.891)
	Eggs	**-0.669 ****	-0.214	**-0.991 ****
		(0.061)	(0.135)	(0.119)
GLS	**Vegetables**	N/A		-0.013
				(0.033)

All estimates are marginal effects for each step and for the joint or unconditional estimates.
Controlling for year dummies, logged real household income, logged real food prices, consumer price index, urbanization index, region, age, gender, education, household size.
‡ denotes inclusion of two pork prices (fatty and lean pork prices) in the specification.
Figures in parentheses are bootstrapped standard errors based on 1000 replications
** denote significance at the 1% level; * denote significance at the 5% level

Table 7. All pork, Lean pork and Fatty pork price elasticities

% point change in kcal consumed	Marginal effect of 1% increase in real price	
	Fatty Pork	Lean Pork
All Pork	-1.969	**1.407 ***
	(1.355)	(0.891)
Lean Pork	-1.248	0.367
	(0.739)	(0.561)
Fatty Pork	-1.374	**1.681 ***
	(1.386)	(0.920)
Fatty pork, organs and pork products	-1.015	**1.456 ***
	(1.331)	(0.857)

All estimates are marginal effects for each step and for the joint or unconditional estimates.
Controlling for year dummies, logged real household income, logged real food prices, consumer price index, urbanization index, region, age, gender, education, household size.
Figures in parentheses are bootstrapped standard errors based on 1000 replications.
** denote significance at the 1% level; * denote significance at the 5% level

I also broke down the consumption of pork into calories from lean pork sources, fatty pork sources and the sum of fatty pork sources, organs and pork products (Table 7). It appears that a 1% increase in the price of lean pork is associated with a 1.7% point increase in the caloric consumption of fatty pork, consistent with the above reasoning. However, there does not appear to be a statistically significant decline in the caloric consumption of lean pork. Lastly, the post-estimation covariances between the estimators for price of fatty and lean pork were negative in all cases.

These findings suggest that there are subtleties in people's responses to price changes that even data that allows differentiation between fatty and lean pork is unable to capture. Also note that the interpretation of these results assumes *ceteris paribus*. In reality, if the price of fatty pork increase, the price of lean pork will likely also increase — in fact, the correlation coefficient between the real price of fatty and lean pork was in the range of 0.52 to 0.71 between 1991 and 2006.

Beyond just estimating price elasticities, it is useful to understand how these price elasticities vary by income by predicting own-price elasticities under different income levels in 1991 versus 2006 for rice and pork. For these figures, the dotted lines are the 95% confidence intervals based on bootstrapped standard errors from 1000 repetitions. For rice (Figure 6), the demand curve rotated counter-clockwise during the 15-year span, with own-price elasticities becoming smaller for the wealthier, while being more negative for the poor (i.e., the poor are becoming increasingly price responsive, while the rich are becoming less price responsive).

As for price elasticities by income for all pork with respect to fatty and lean pork prices, fatty pork price elasticities (Figure 7) in 1991 were insignificantly different from zero. However, this declined as income rose, suggesting that at lower income levels, the income effect dominated, and that there is a lack of substitutes for pork, which explain the positive price elasticities. Among the richer households, fatty pork demand became more elastic as income rose. By 2006, pork had positive responses to increases in fatty pork prices, albeit insignificantly for most income levels except for the middle income group. Again, it may be that there is a lack of substitutes for pork.

Lean pork price elasticities (Figure 8) in 1991 followed a different trend. As income rose, lean pork demand became less price elastic, but became positive for the higher income households. The trend appears to have shifted down over time, as the lean pork price elasticities remained negative for most income levels in 2006, becoming less elastic as income increased.

Figure 6. Relationship between a 1% increase in real price of rice on % change in kcal consumption of rice in 1991 and 2006 across income levels

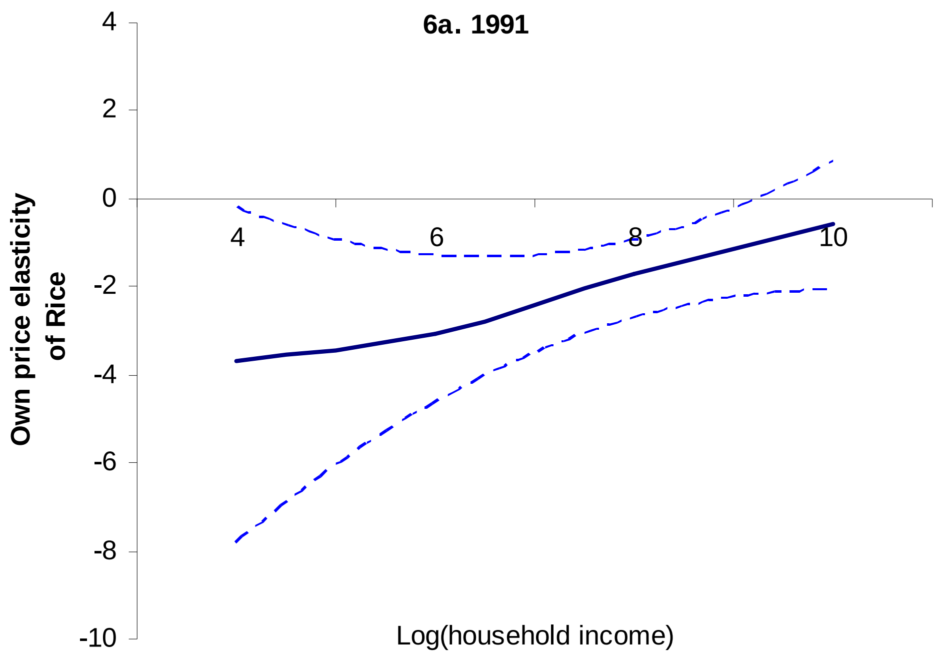


Figure 7. Relationship between a 1% increase in real price of fatty pork on % change in kcal consumption of all pork in 1991 and 2006 across income levels

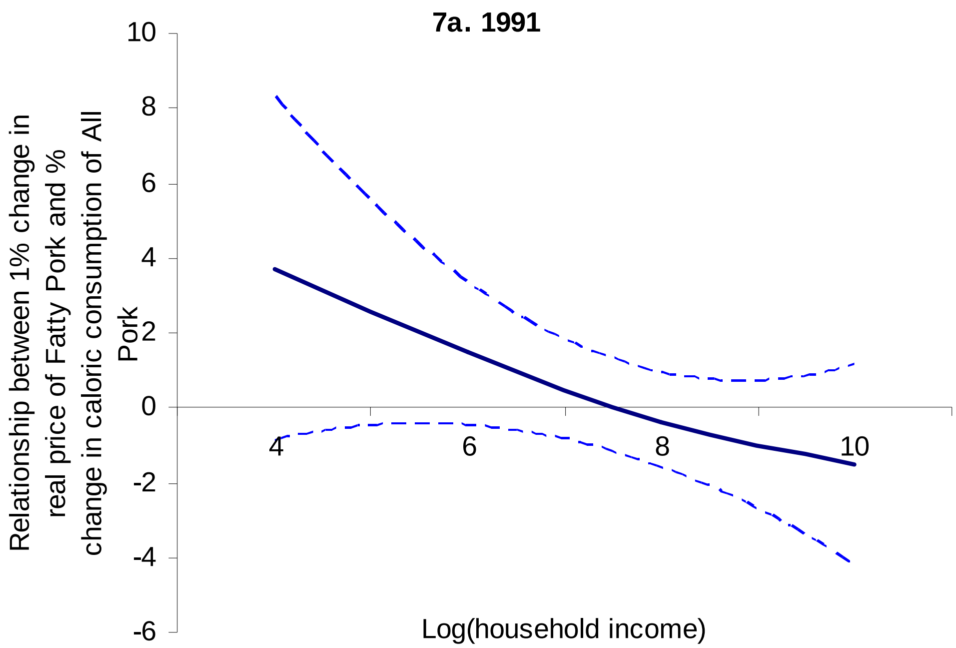
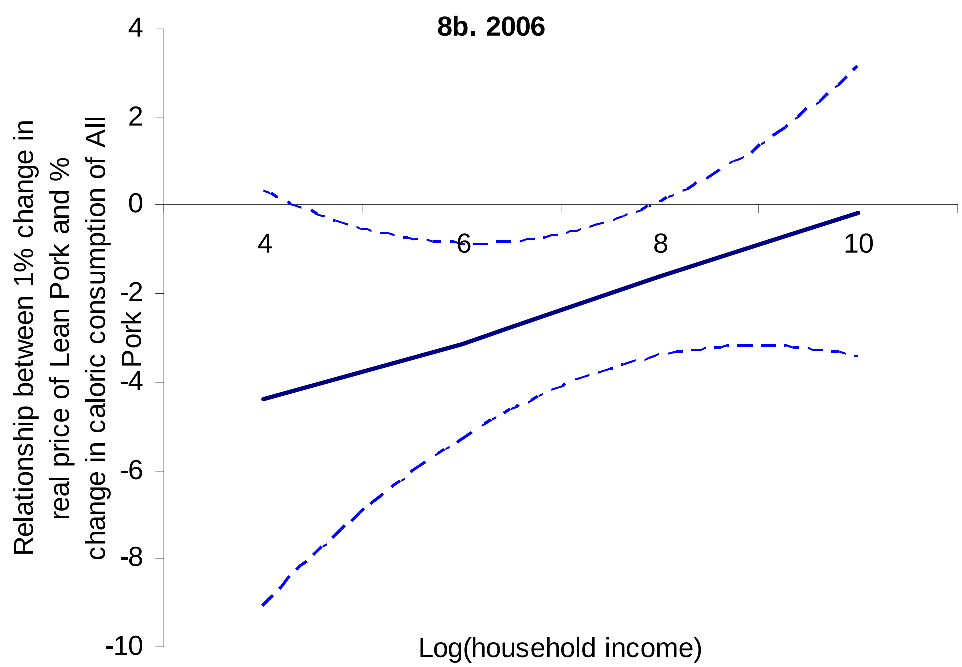


Figure 8. Relationship between a 1% increase in real price of lean pork on % change in kcal consumption of all pork in 1991 and 2006 across income levels



Similar predictions were done for the other food-groups, but are not presented graphically. To summarize, the own price elasticity for flour moved from being strongly negative (around -2) in 1991 to around -1.5 by 2006 across all income levels. Eggs had relatively inelastic demand in 1991, with elasticity rising as household income increase, but had leveled out for all income at around -1 by 2006. The own price elasticities for plant oils were not significant in 1991 or 2006, but moved from being negative to positive, which suggest that plant oils has possibly shifted from being relatively inelastic to a Giffen good across all income levels. Finally, the own price elasticities for vegetables were also not significantly different from zero and appeared perfectly inelastic across all income levels. This non-significant finding may be due to the fact that the types of vegetables are heterogenous across time (due to seasonality) and space (due to regional differences).

Therefore, it appears that own price elasticities did not necessarily increase, or change uniformly across income groups. While changes in own-price elasticities did not vary much by income levels for foods such as wheat flour, plant oils and vegetables, they changed over time differently by income levels for rice and lean pork foods — the better-off adults in generally were not price sensitive, but the poorer ones were. It is possible that increase in varieties of substitutes within rice and lean pork products affected the poor the most.

3.4.2. Income elasticities

Results from using the longitudinal GLS and two-part models are shown in Table 8. Only the income elasticity estimates for pork and eggs were statistically significant. It appears that on average, rice, wheat flour, plant oils and vegetables are sticky goods, such that a marginal change in income would not affect people's caloric consumption of these food-groups. Of these food-groups, pork appears to be the most income responsive ($\eta^{inc,\ pork} = 0.5$), suggesting that of these food-groups, the consumption of pork will grow the fastest as real income rises in China.

As with own-price elasticities, it is useful to understand how income elasticities change as income changes, by predicting income elasticities under different income levels in 1991 compared to 2006. Rice (Figure 9) was a necessary good (albeit less so for higher income adults) in 1991. However, by 2006, rice has become an inferior good across all income levels, but particularly for the rich. In 1991, pork (Figure 10) was a necessary good, being less necessary for higher income households. By 2006, the income elasticity for pork had fallen across all income levels with no obvious variation by income group.

The income elasticity for eggs in 1991 was somewhat curious. While positive across all income levels, it rose as income increased from lower to middle incomes and then declined slightly from middle to higher income households. By 2006 however, income elasticities were virtually equal across all income levels at around 0.1 (Figure 11). Similar predictions were done for the other food-groups. Flour and plant oils were both "sticky" goods, with income elasticities not significantly different from zero across all income levels. The income elasticities for vegetables were not significantly different from zero across all income levels for both 1991 and 2006, but the elasticities were generally higher in 1991 than in 2006.

The income elasticity estimates appear to support the hypotheses that income elasticities have fallen for most food-groups over time, with rice becoming an inferior good, and that they have flattened out across income levels for most food-groups as people gain easier access to these foods.

Table 8. Income elasticities from longitudinal GLS and two-part model estimations for six food-groups in China (CHNS 1991–2006)

% change in calories consumed		**Marginal Effect of 1% increase in real price**		
		P(any)	ln(kcal |any)	ln(kcal)
Two-Part model	**Rice**	**0.116 *** (0.059)	0.002 (0.020)	0.422 (0.284)
	Wheat Flour	-0.023 (0.041)	**-0.065 **** (0.019)	-0.075 (0.057)
	Plant Oil	0.021 (0.036)	**0.048 **** (0.013)	0.049 (0.020)
	All Pork ‡	**0.207 **** (0.020)	**0.077 **** (0.013)	**0.501 **** (0.239)
	Eggs	**0.155 **** (0.021)	**0.027 *** (0.017)	**0.356 **** (0.123)
GLS	**Vegetables**	N/A		0.025 (0.018)

All estimates are marginal effects for each step and for the joint or unconditional estimates.
Controlling for year dummies, logged real household income, logged real food prices, consumer price index, urbanization index, region, age, gender, education, household size.
‡ denotes inclusion of two pork prices (fatty and lean pork prices) in the specification.
Figures in parentheses are bootstrapped standard errors based on 1000 replications
** denote significance at the 1% level; * denote significance at the 5% level.

Figure 9. Relationship between a 1% increase in real household income on % change in kcal consumption of rice in 1991 and 2006 across income levels

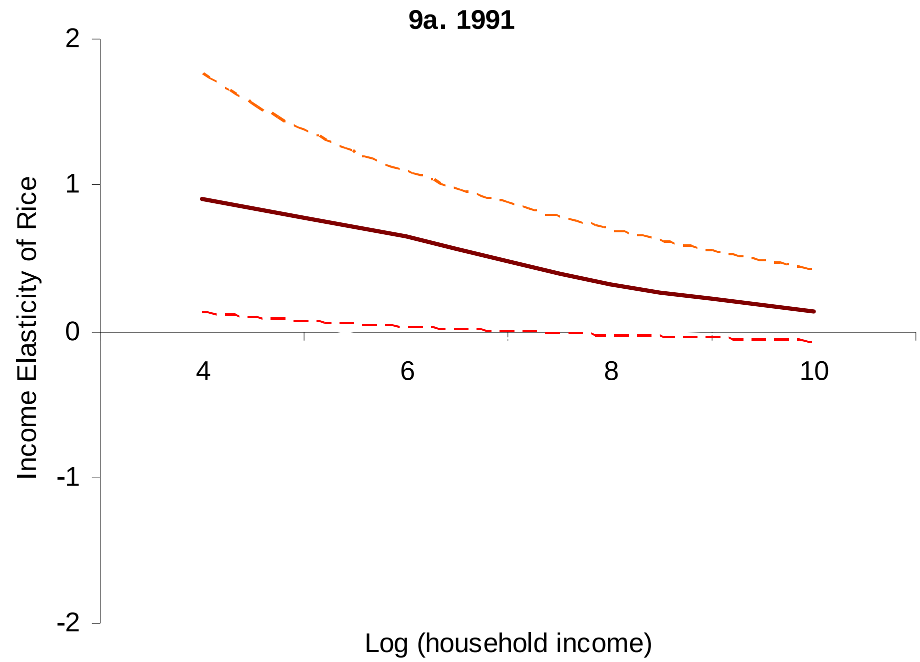
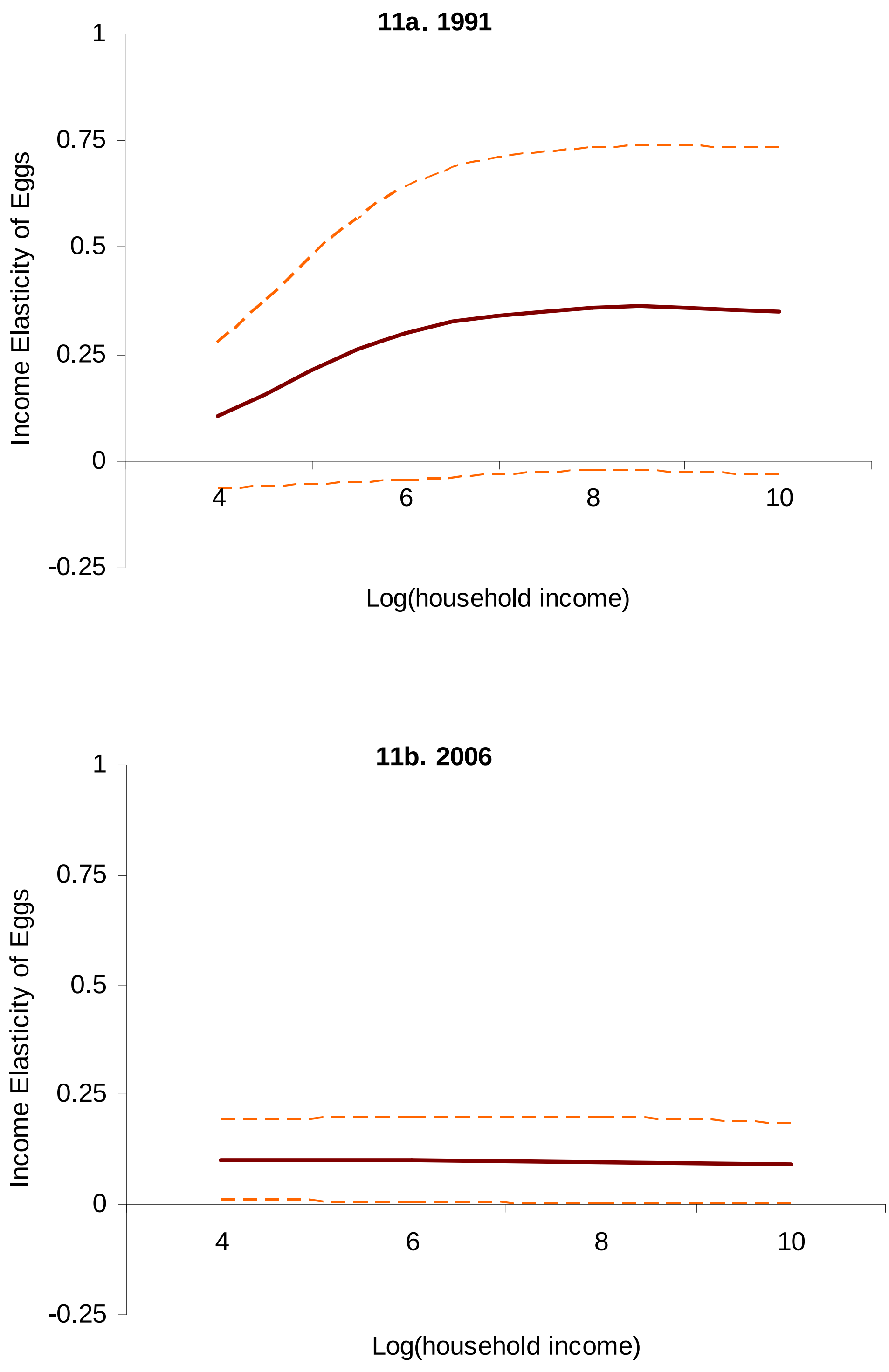


Figure 10. Relationship between a 1% increase in real household income on % change in kcal consumption of all pork in 1991 and 2006 across income levels

Figure 11. Relationship between a 1% increase in real household income on % change in kcal consumption of eggs in 1991 and 2006 across income levels



3.4.3. Cross-price elasticities

Much of Chinese cooking involves combining foods from various food-groups into mixed dishes. For example, some common dishes are scrambled eggs with tomatoes; pork and vegetable or mushroom dumplings; pan-fried Chinese pancakes with chives; and steamed glutinous rice packs with vegetables and pork or chicken.

Across China, there are significant seasonal and regional differences in food preferences, availability, and cooking styles. Therefore it is difficult to properly determine how changes in the price of one food-group may affect the quantity demanded of another food-group, *ceteris paribus*. Here, I provide a broad sense of the pattern across China by using the same specification across the food-groups to allow for ease of interpretation and understanding.

The findings suggest that as the price of rice increases, Chinese adults consume less pork and vegetables, but more wheat flour (Table 9). Meanwhile, as the price of wheat flour increases, they consume more calories from rice, pork and vegetables. The findings between these two grains suggest that wheat flour is an important substitute for rice (likely in the form of wheat flour-based noodles and increasingly, breads and pastries) and vice-versa. Also it is clear that rice, pork and vegetables are complements.

Also, as the price of eggs increase, calories from rice and pork increases, but calories from wheat flour and plant oil fall, suggesting that rice and pork provide substitutive calories for eggs. An increase in plant oil prices is associated with more calories from flour, but less from rice, a finding consistent with Ng (2008). Meanwhile, as vegetables become more expensive, Chinese adults consume more rice, plant oils and eggs, but less flour. Change in the price of tofu did not appear to have any real affect on calories consumed from these food-groups, except for flour. Not surprisingly, chicken and pork are substitutes, and because the price of chicken and eggs are interlinked, increases in chicken prices likely reflect increases in eggs prices, which explain the negative cross-price elasticity (Table 9).

Table 9. Own and Cross price elasticities for six food-groups in China (CHNS 1991–2006)

% point change in calories consumed	1% increase in real price of								
	Rice	Wheat Flour	Plant Oil	Fatty Pork	Lean Pork	Eggs	Vegetables	Tofu	Chicken
Rice	**-2.29 ****	**2.355 ****	**-1.565 ****	0.381	N/A	**1.014 ****	**0.368 ****	0.225	**1.064 ****
	(0.629)	(0.312)	(0.309)	(0.263)		(0.199)	(0.087)	(0.142)	(0.167)
Wheat Flour	**0.903 ****	**-1.854 ***	**1.252 ****	**-1.398 ****	N/A	**-0.57 ****	**-0.522 ****	**-0.417 ****	**-1.792 ****
	(0.288)	(0.943)	(0.309)	(0.422)		(0.226)	(0.104)	(0.159)	(0.203)
Plant Oil	0.124	-0.296	-0.155	**0.968 ****	N/A	**-1.655 ****	**0.219 ***	-0.202	-0.248
	(0.274)	(0.210)	(0.699)	(0.332)		(0.219)	(0.101)	(0.144)	(0.157)
All Pork ‡	**-0.507 ****	**0.83 ****	0.312	-1.969	1.407	**0.72 ****	**0.119 ***	0.126	**0.508 ****
	(0.188)	(0.159)	(0.314)	(1.355)	(0.891) *	(0.145)	(0.064)	(0.112)	(0.110)
Eggs	0.134	-0.008	0.172	-0.109	N/A	**-0.991 ****	**0.159 ****	-0.019	**-0.269 ****
	(0.164)	(0.120)	(0.143)	(0.182)		(0.119)	(0.054)	(0.077)	(0.091)
Vegetables	**-0.473 ****	**0.27 ****	-0.042	**0.593 ****	N/A	0.078	0.06	-0.034	0.018
	(0.069)	(0.056)	(0.080)	(0.080)		(0.050)	(0.077)	(0.036)	(0.047)

All estimates are marginal effects for each step and for the joint or unconditional estimates.
‡ denotes inclusion of two pork prices (fatty and lean pork prices) in the specification.
Figures in parentheses are bootstrapped standard errors based on 1000 replications
** denote significance at the 1% level; * denote significance at the 5% level

3.5. Discussion

3.5.1. Comparing to past estimates

Compared to Guo and others' own-price elasticity results from using the CHNS (Guo, Popkin et al., 1999), the estimates here are much higher, particularly for rice and wheat flour. This could be a result of the different time periods used in the analyses (1989 to 1993 versus 1991 to 2006), with the different results reflect changing demand over time, as well as larger within food-group substitution in the later years as people gain access to growing options for substitutes. Meanwhile, compared to plant oil price estimates from Ng and others (2008) (-0.11), the estimates are slightly higher here (-0.38), again possibly due to the addition of two more waves of data, and the greater elasticity of demand over time (due to a larger variety of oils available).

Own price elasticity estimates from household expenditure data in general have lower own-price elasticities for rice and flour, as most of these estimates are below -1 (Huang & David, 1993; Wu, Li et al., 1995). However, the estimates for eggs (-0.99) fell within the range of past estimates from -0.47 to -1.15 (Gao, Wailes et al., 1996; Gould, 2002; Wu, Li et al., 1995; Yen, Fang et al., 2004). While the estimate for oil here (-0.38) was slightly lower compared to the -0.55 estimate from Yen and others (2004). There appeared to be a wide range of estimates for vegetables from studies using household expenditure data, which ranged from -0.008 to -1.375 (Gould, 2002; Pudney & Wang, 1991), with the estimate here being on the very low end. Household expenditure data is unable to distinguish between lean and fatty pork consumption and prices and so there are no immediate comparisons for the pork estimates here.

The income elasticities estimated here appear to be comparable to those from past studies. Note however, that past studies had a relatively wide range of estimates as well, and other than the Guo study (Guo, Mroz et al., 2000), no other paper have looked at income elasticities using individual-level consumption data. Compared to estimates from household expenditure data, the income elasticity estimate for rice (0.42) is within the range reported by Huang and David (1993) who reported 0.43 and Wu et al. (1995) who had an estimated income elasticity of 0.37 for rice. The estimate for pork (0.501) also fell between the ranges from other studies 0.03 to 0.923 (Gale & Huang, 2007; Pudney & Wang, 1991; Sullivan, Roningen et al., 1992; Webb, Webbs et al., 1992; Wu, Li et al., 1995). Similarly, the estimated income elasticity for eggs (0.356) was also within the range from other studies (-0.03 to 1.044) (Gale & Huang, 2007; Pudney & Wang, 1991; Sullivan, Roningen et al., 1992; Webb, Webbs et al., 1992; Wu, Li et al., 1995).

3.5.2. Conclusions

In order to understand the potential effect of pricing policies and income changes as it relates to nutrition, it is critical to use individual consumption data along with community-specific prices and urbanicity people are exposed to. I investigate the effects of real prices and income on dietary intake, while controlling for individual characteristics and the economic and built environment in which people live, using longitudinal consumption data from the 1991 to 2006 (six waves) of the CHNS. The empirical approach varied depending on the food-group, and corrected for both the non-consumers and the skewness of the distribution among consumers.

The price elasticities were all negative with the exception of pork, which might be due to substitution away from lean pork towards fatty pork. It also should be noted that while food prices were officially free of government control since early-1993, the Chinese government still has a hand in affecting pork prices due to the importance of pork in the Chinese diet, by managing pork supplies in China via its pork reserve (Bradsher, 2007). The price elasticities for oils and vegetables were negative, but were not statistically significant. These non-significant findings may be due to the fact that the types of vegetables and oils are heterogenous due to regional variations and seasons. While changes in own-price elasticities did not vary much by income levels for foods such as flour, plant oils and vegetables, they changed over time differently by income levels for rice and lean pork foods — the better-off adults in generally were not price sensitive, but the poorer ones were.

For all food-groups, the income elasticities were higher in 1991 than in 2006. In addition, the relatively high income elasticity for pork suggests that the consumption from pork will grow the fastest as real income levels rise in China. The results from rice shows that it moved from being a necessary good in 1991 to an inferior good in 2006. Wheat flour, plant oils and vegetables were all "sticky" goods (i.e., change in income had no effect on caloric consumption of these foods). Also, income elasticities flattened out across income levels for most food-groups as people gained easier access to these foods. Prices can have an affect on dietary intake in China as substitution occurs among and increasingly even within food-groups. Moreover, seasonal, regional differences in food preferences, availability, and cooking styles can mean varying types of substitutions and complementary of food products both temporally and geographically. The cross-price estimates only provide a broad sense of the pattern across China. I find that overall, wheat flour and rice are important substitutes for each other; rice, pork and vegetables are complements; rice and pork are substitutive calories for eggs; plant oils are complements for rice.

Not all of the estimates were statistically significant, highlighting how challenging it can be to predict the relationships among food commodities (even with detailed consumption and price data, and a large sample size). Food consumption represents a class of commodities that is difficult to influence in a predictable manner. First, it is difficult to identify the offending food item because there are many characteristics to any one food item that can make it both desirable and undesirable. Second, there can be a wide spectrum of substitutes and range of quality for any one food item. Third, there is a need to understand the food culture in terms of how foods are used together and prepared.

This is not to say that pricing policies will not work as potential means of which to help the population make healthier food choices. A number of studies in developed countries have discussed the use of both taxes to discourage the consumption of foods considered unhealthy and subsidies to encourage the consumption of foods considered to be healthier (Caraher & Cowburn, 2005; Cash, Sunding et al., 2005; French, 2003). Such strategies may face opposition from both consumers and the food industry (who might find ways around their products being categorized as unhealthy), particularly in developed nations (Elston, Stanton et al., 2007). In China, such concerns may be alleviated given the political structure, so that taxing fatty pork, animal source products that have high fat content, and oils, while subsidizing lean pork and low-fat animal source products, along with public nutrition education campaigns might be feasible. The estimated elasticities here suggest that these policies may discourage the consumption of fatty pork and plant oils without adversely burdening the poor.

Nonetheless, there is a need to have detailed understanding of the food preferences and combinations, and how they vary seasonally and geographically. It is crucial (particularly in the context of rapidly developing places, and for a country like China with its membership in the WTO) to continue considering both real prices and income as they change over time to understand if demand have shifted and how they have shifted over time and across income. The wide range of estimates and the different estimates depending on the time period studied and the types of data used suggest that there is a need for continued collection of information regarding individual-level consumption, incomes and representative price data given where people live. There is also a need for more nuanced studies of the effects of price changes for more specific types of foods rather than broad food-groups, especially as new food items enter and spread in the Chinese market.

4. THE EFFECTS OF PHYSICAL ACTIVITY AND DIETARY INTAKE ON WEIGHT GAIN AMONG CHINESE MEN

Abstract

To date, economic analysis on weight can only speculate on the differential effects of diet and physical activity. This paper considers the neo-classical economics of obesity model and uses time and spatially varying macro-level urbanization and price measures as instruments to correct for the endogenous and auto-correlated choices of diet, physical activity, smoking and drinking on weight. This paper applies a dynamic panel system GMM estimation model on longitudinal (1991–2006) data from China and found that among adult men in China, 30% of weight gain was due to declines in physical activity, while 20% was due to higher fat intake.

4.1. Introduction

In the last decade or so, economists have tried to understand the economics of weight gain, obesity (or overweight), and have come up with a few theoretical models to do so. One of the main approaches is the neo-classical model (Lakdawalla & Philipson, 2006; Rashad & Grossman, 2004). This model is based on the idea of maximizing utility under a set of changing constraints due to changes in relative prices of goods, income, and time allocation. As such, most of the empirical work tends to look at variation in supply, demand, and prices of food or energy, income, state laws or the opportunity cost of time (Cawley, 2004; Chou, Grossman et al., 2004; Drewnowski & Darmon, 2005; Kuchler, Tegene et al., 2004; Lakdawalla, Philipson et al., 2005; Schroeter, Lusk et al., 2008; Sturm, 2004). Moreover, most of the studies have been done in the context of developed countries, particularly the United States, often using aggregate level data, or are not truly longitudinal (e.g., Lakdawalla and colleagues used a number of different data sets in order to piece together a panel dataset for their analyses). These do not allow for a proper empirical examination of the forces contributing to the long-run weight gain over time. Hence, it is unclear from the current literature what factors are the most important causes.

This paper looks at weight gain because biological and epidemiological studies have found that weight gain is mostly gained in the form of fat (rather than muscle mass or fat-free mass) among adults. This is particularly the case for populations that were previously undernourished or experienced weight fluctuations, either in childhood or adulthood (Dulloo, 2008; Dulloo, Jacquet et al., 2006; Remacle, Bieswal et al., 2004), and that co-currently have lowered their physical activity levels, as is the case in China (Ng, Norton et al., 2009). Since fat accumulation is highly associated with morbidity and mortality from cardiovascular diseases, type II diabetes, hypertension, and other nutrition-related non-communicable diseases (Folsom, Li et al., 1994; Matsuzawa, Nakamura et al., 1995; Nakamura, Tokunaga et al., 1994; Raymond, Leeder et al., 2006), weight gain is an important outcome.

At first glance, modeling an individual’s weight change appears straightforward: define the number of calories consumed and expended, and determine the resulting trends in weight gain.

However, the layers of complexity in the relationships among physical activity, diet, and weight change are lost in a simplistic formulation of weight change (Moore, 2000).

For one, despite a consistent relationship between low physical activity, high caloric intake and weight in cross-sectional studies, there might be endogeniety — it is possible that lower physical activity and increased sedentary behaviors among those who are heavy may be the consequence of being heavy (social stigma, excluded from sports, etc.). Similarly, it is possible that people consume more (as a coping mechanism) in reaction to being marginalized. Moreover, diet and activity combined can interact to affect weight (Astrup, 1999). Therefore, there is a need to untangle the possible reverse causalities and confounding often discussed in the diet, physical activity and weight relationships. Past studies typically only look at the relationships between physical activity and weight, and diet and weight separately, without considering the endogenous decisions of contemporaneous and lagged diet and physical activities on weight, and the serial correlations of these decisions over time (Klesges, Klesges et al., 1992). This is problematic because if endogeneity does exist but is not corrected for, the result will be inconsistent parameter estimates. Meanwhile, if the correlation of weight over time is not controlled for, then the effect of past weight will tend to be over-estimated.

Second, even if one is able to properly address reverse causality and confounding, there might also be a different effect of diet on weight depending on the type of food consumed, since calories from fat versus calories from carbohydrates or proteins might affect weight change differently (Miller, Lindeman et al., 1990; Tryon, 1987). For example, it has been found that people with low physical activity levels but high fat intake have slower metabolisms, which results in greater weight gain (Bray & Popkin, 1998), particularly for people in developing countries who might have experienced undernutrition during prenatal and postnatal growth (Frisancho, 2003; James & Ralph, 1999).

This paper handles these complexities and determines the directions and relative importance of the diet, physical activity, and health behavior with regards to weight gain among adult men over a period of rapid economic growth in China by employing two strategies. First, I use the neo-classical model and explicitly include time and spatially varying macro-level factors such as urbanization and prices to be used as valid instruments to correct for the endogenous micro-level choices of diet, physical activity and other health behaviors to affect weight change over time. Second, I apply a dynamic panel system generalized methods of moments (GMM) model estimation model, which allows current weight to depend on prior weight and endogenous decisions about physical activity, diet and health behaviors. This estimation approach also uses statistical methods that control for the simultaneity problem and for temporal autocorrelation.

The dynamic panel model is estimated using a GMM estimator developed by (Blundell & Bond, 1998) that exploits a large set of moment conditions and combines in a system, the regression-in-differences with the regression-in-levels. I provide a comparison of these results to those derived from usual reduced form, instrumental variable (IV) and instrumental variables with fixed effects (IV-FE) models to show how the failure to correct for simultaneity bias and autocorrelation can affect the findings.

To my knowledge, a dynamic panel analysis of these decisions that controls for endogeneity and autocorrelation in weight, diet, physical activity and health behaviors has not yet been done due to the requirement of rich longitudinal data with at least two waves of data and large sample sizes. Fortunately, the longitudinal China Health and Nutrition Surveys (CHNS) has up to six waves of detailed individual-level data on anthropometrics, dietary consumption, energy expenditure, as well as time varying community measures of urbanization and prices that can be used as instrumental variables for potentially endogenous variables.

China is an interesting country in which to carry out the research because its growing epidemic of overweight and obesity, risk markers for a large number of chronic diseases, will have severe consequences on its economic productivity and will become a significant healthcare burden. Currently, it is estimated that the cost of overweight and related diseases will be almost 9% of China's gross national product (GNP) by 2025 (Popkin, Kim et al., 2006). In addition, the paper focuses on Chinese men in this study for two main reasons. First, men and women have very different biological processes and social or economic roles that can influence their weight gain rather diversely. In terms of biological processes, prior studies have found that men and women expend energy at different rates (Ferraro, Lillioja et al., 1992; Kennedy, Gettys et al., 1997) and gain weight differently (Lovejoy

& Sainsbury, 2009; Westerterp & Goran, 1997). Socio-economic roles mean that women often have the triple burden of work, children and domestic chores, which have competing effect on diet and physical activity choices and limit the variance observed in data. Second, there is better variance in the data for men because men are more likely to own technology like motorized vehicles as well as experience occupational change than women.

This paper is organized as follows. Section 4.2 will provide an overview of the theoretical framework behind the economics of weight change. Section 4.3 discusses the empirical modeling approaches that will be used and tested. Information about the CHNS, the analytic sample and the variables used are provided in Section 4.4, along with specification tests for the instrumental variables. The results are presented in Section 4.5 and a discussion of the findings, contributions and limitations are in Section 4.6

4.2. Neo-classical model of the dynamics and determinants of weight change

This paper uses the standard neo-classical model on the economics of obesity (Cawley, 2004; Chou, Grossman et al., 2004; Drewnowski & Darmon, 2005; Lakdawalla, Philipson et al., 2005; Rashad & Grossman, 2004). It is useful to understanding the theory behind the model as it helps provide guidance on instruments and what factors might be endogenous in affecting weight gain.

4.2.1. Dynamics of weight change

I follow Lakdawalla et al. (2005), where an individual's utility in current period, *t*, depends on food consumption, *F*, other consumption, *C*, and current weight, *W*. We can write this as $U_t (F_t, C_t, W_t)$, where *U* rises in food consumption and other consumption, but is only monotonically increasing in weight if current weight is less than ideal weight, $\ddot{W}$, otherwise *U* declines in *W*. To summarize, the partial derivations of utility with respect to each argument are: $U_F \geq 0$; $U_C \geq 0$; $U_W \geq 0$ if $W \leq \ddot{W}$; and $U_W < 0$ if $W > \ddot{W}$.

In reality, food intake is multi-dimensional, comprising of calories, the nutritional content of foods eaten, and the types of foods eaten. For simplicity, in this modeling section I only consider food intake as a scalar. We will assume that food consumption and other consumption are not substitutes in the sense that $U_{FC} \geq 0$. We also assume that there is no direct utility from activity, *A*. Instead, *A* is a determinant of weight and affects utility indirectly through its effect on weight. This is because it not clear if this effect is positive or negative since U_A could be > 0 for people who enjoy exercise, and < 0 for people who do not.

Let's consider an individual who manages weight according to a dynamic problem where his weight, *W* is the state variable. Weight is a capital stock that depreciates over time (where δ can be thought of as basal metabolism, because holding food intake and activity constant, there is some metabolic cost of living to the next period), and can be accumulated by food consumption, *F*, or decreased by activity, *A*. Moreover, an individuals' activity level depends on how developed a place he or she lives and works is, *D*, such that $A_t = A(D_t)$. Thus, an individual's weight at time *t*, depends on prior period's weight, food consumption and activity level:

(10) $$W_t = (1-\delta)W_{t-1} + g(F_{t-1}, A(D_{t-1})),$$

where $\delta < 1$ and *g* is continuous, concave, increasing in food consumption and decreasing in activity level ($g_F \geq 0$ and $g_A \leq 0$).

Here we see that an individual makes choices on F_{t-1} and A_{t-1} simultaneously. In addition, F_{t-1} and A_{t-1} affects W_t, and also is strongly related to F_t and A_t. Hence F_t and A_t will be correlated to W_t both via W_{t-1} and through F_{t-1} and A_{t-1}. This suggests that it is important to control for the simultaneity bias from diet and physical activities choices on weight, and the serial correlations of these decisions over time.

Moreover, individuals are subject to a budget constraint at each time period: $p_F F + p_c C \leq I$, where p_F and p_c are the prices of food and other consumption goods respectively. Standardizing by p_c, the budget constraint can be written as:

(11) $$C \leq I - p_F F$$

Calculations of the comparative statics show that these will yield a steady-state in food consumption, activity and weight as long as the marginal utility of food is falling in weight (see Appendix A for complete calculations and details on the dynamics of weight change), The optimality condition will be:

(12) $$v'\{W + g[F_t, A(D_t)]\} = (p_F U_C - U_F)/g_F ,$$

which is that the marginal benefit of weight in the future equals the marginal cost of spending on weight change.

4.2.2. Steady State Determinants of Weight

The steady state choices of weight, food consumption and physical activity can be determined by income, I, food prices, p_F, and urbanization, D, such that $W^*(I, p_F, D), F^*(I, p_F, D), A^*(I, p_F, D)$. If these factors are exogenous to weight, diet and physical activity, and vary spatially and over time, then they would make ideal instruments for use in correcting for the simultaneity bias and autocorrelation found in estimating weight dynamics.

Increases in income will initially raise weight, but at high levels of income, further increases could actually lower weight such that $U_{WC} > 0$ for the underweight but $U_{WC} < 0$ for the overweight (i.e., W_I^* can have an inverted U-shape). This is because an increase in income lowers the marginal cost of spending on weight gain (food consumption), and also affects the marginal value of weight, v'. Income can also affect one's activity level, such that A is a function of job characteristics which are also reflected in earned income. This is like a substitution effect (i.e., the quantity of activity changes but the individual derives the same level of utility). Hence, the total effect of income on weight includes the direct income effect along with effect of earned income on activity levels, $dW^*/dI = W_I^* + W_A A_I (p_F, D, I)$. We assume that $W_A < 0$ since holding all else constant, increasing activity levels should lead to decreasing weight. For a developing country with a large rural population, such as in China, those who are poorer generally work in areas that require greater physical activity. Thus, we also assume that A_I <0. This means the total effect of income on weight will be positive when an individual is underweight, or when an individual is overweight and the negative direct effect of income on weight is less than the indirect effect of activity level on weight. The total effect of income on weight will only be negative when an individual is overweight and the negative direct effect of income on weight is greater than the indirect effect of activity level on weight.

Increasing the price of food, p_F, raises the marginal cost of spending on food, but the marginal benefit of weight tomorrow remains the same. An increase in the price of food decreases the marginal “joy of eating”, so food consumption decreases, so that $F_{pF}^*(p_F, D, I) < 0$. The decrease in food consumption will have a negative effect on weight, so that $W_{pF}^*(p_F, D, I) < 0$. Hence, prices are important determinants of weight change and are exogenous factors that need to be included in any structural modeling of weight change.

Community level urbanization, *D* is exogenous to individual choice assuming that people who move to other communities do not do so based primarily on these community-level characteristics. It can certainly affect prices of food, other consumption goods, and income, such that increased development will lower prices and raise incomes. Hence it can be thought of as an argument for p_F, and *I*. Using chain rule, the effect of urbanization on food consumption and activity levels are $F_D^* > 0$ and $A_D^* < 0$. The effect of urbanization on weight will depend on the relationships between income, prices and weight (see Appendix A for details). The direction of these effects should not be surprising. Urbanization would certainly lower physical activity at work due to shifts in labor market needs and job functions, access to technologies that aid work and domestic activities, and availability of motorized transportation, for example. Also, one would expect urbanization at the community level to reduce food prices such as through lowering transportation costs, and lessening the time costs involved in purchasing food.

4.3. Empirical modeling

The dynamic empirical model that relates weight to its own lagged value along with lagged diet and lagged physical activity takes the following form:

$$W_{it} = \alpha W_{i,t-1} + \beta F_{i,t-1} + \gamma A_{i,t-1} + \theta HB_{i,t-1} + \pi X_{it} + \eta_i + \mu_{it} \,, \qquad (13)$$

where W_{it} denotes weight in the current wave *t* for individual *i*; $W_{i,t-1}$ denotes weight in the prior wave for individual *i*; $F_{i,t-1}$ denote lagged values of two dietary consumption variables: total caloric intake and energy from dietary fat; $A_{i,t-1}$ denote lagged total physical activities; $HB_{i,t-1}$ denote lagged smoking and drinking status; X_{it} denotes other control variables such as age, marital status, educational attainment, predicted household income and time dummies; α, β, γ, θ and π denote the vectors of coefficients for the explanatory respective variables; η_i denotes unobserved time-invariant individual characteristics, and μ_{it} denotes a time varying disturbance term.

It is expected that β_{kcal} *and* β_{efat} (the coefficients for lagged caloric intake and lagged energy from dietary fat) would be positively related to W_{it}, and γ (the coefficient for lagged physical activity) would be negatively related to W_{it}. If β_{kcal}, β_{efat} and γ are found to be statistically significant, then I can determine the contribution of caloric intake, dietary fat intake and physical activity in determining weight gain and from that tell whether diet or physical activity are more important in affecting weight gain. To determine the type of estimation method to use, it is important to discuss the assumptions made about:

1) The correlation between explanatory variables and η_i.;
2) Autocorrelation: correlation in the time varying error terms over time (e.g., corr($\mu_{i,t-1}$, μ_{it}));
3) The type of correlation between the explanatory variables and μ_{it} , μ_{it-1} or μ_{it+1}.

It is clear from the dynamic form of the stochastic model that at a minimum lagged weight will be correlated with η_i, the time invariant error term. It is also highly likely that there will be overlap in the set of unobserved fixed characteristics of the individuals that affect weight, diet, physical activity, smoking and drinking, which will cause correlation between η_i and these variables as well. It is well known that first differencing will drop η_i along all time invariant observed variables from the model:

$$\Delta W_{it} = \alpha \Delta W_{i,t-1} + \beta \Delta F_{i,t-1} + \gamma \Delta A_{i,t-1} + \theta \Delta HB_{i,t-1} + \pi \Delta X_{it} + \Delta \mu_{it} . \quad (14)$$

A frequently made assumption is that the time varying error is not correlated with the explanatory variables, which means that in differenced form diet, physical activity, smoking, and drinking will be uncorrelated with the error term in equation (14). However, it will still be the case that differenced weight will be correlated with the differenced error term. However, $W_{i,t-2}$ will be not and can be used as an instrument.

This instrumental variables estimation in differences tends to yield imprecise parameter estimates if α is large (Alonso-Borrego & Arellano, 1999; Blundell & Bond, 1998). An alternative (Blundell & Bond, 1998) is to estimate the model in levels with $\Delta W_{i,t-2}$ used as an instrument for $W_{i,t-1}$ in equation (13). This method, of course, must assume that there is no correlation between the other explanatory variables and either the time invariant or time varying error term. A more efficient method estimator, (Blundell & Bond, 1998) would jointly estimate equations (13) and (14) using a system GMM approach.

As already noted, it is highly likely that there will be correlation between diet, physical activity, smoking, and drinking and the time invariant error and so instruments are needed for these variables in addition to lagged weight in equation (13). It is also possible that there will be correlation between these variables and the time varying error term, meaning that instruments may be needed for these variables even in differenced form in equation (14). Autocorrelation in the time varying error could also invalidate $W_{i,t-2}$ as an instrument in equation (14).

It is clear that separate instrument sets must be specified for equations (13) and (14) in the system GMM approach and I discuss these sets further below. Cameron and Trivedi (2005) provide a discussion of the large set of instruments that are potentially available in dynamic panel models and a series of papers provide information on efficient estimation strategies for these models (Arellano & Bond, 1998; Blundell & Bond, 2000; Blundell, Bond et al., 2000; Bond, 2002). Fortunately, the data set includes lagged measures of various dimensions of urbanizations and real price of consumption items that can be used to help provide identification, which will be discussed later.

I estimate robust standard errors using the two-step version of the Arellano-Bond system estimator (the one-step version uses a weighted matrix that does not depend on estimated parameters, while the two-step estimator may result in efficiency gains, but the asymptotical distribution approximations may be less reliable due to the dependence of the two-step weighted matrix on estimated parameters) with a finite-sample correction (Windmeijer, 2005) using the *xtabond2* procedure in Stata (Roodman, 2003). I also perform two specification tests. First, I test for the presence of second-order autocorrelation in the differenced equation. Note that first-order autocorrelation in the differenced equation is expected and does not signify an improper model specification. Second, I test for the exogeneity of the instruments using Sargan-Hansen's *J*-test, which is robust to heteroskedasticity and autocorrelation, and is asymptotically distributed as χ^2 in the number of restrictions.

This dynamic panel approach has been used in financial/investment (Carstensen & Toubal, 2004; Horioka & Wan, 2006), environmental economics (Arbués, Barberán et al., 2004), healthcare organization modeling (Brown, Coffman et al., 2006; Mark, Harless et al., 2004) and in untangling the health-wealth relationship (Michaud & van Soest, 2008),where autocorrelation and endogeneity are of potential concern. For the empirical question of weight over time, the system GMM dynamic panel approach is ideal. This is the first paper to my knowledge to use it because it requires at least two consecutive waves of panel data (depending on the exact specification) and a large number of observations in each wave. There are six waves of 4,180 unique men, or 1,380 to 2,010 observations per wave. The results are also straightforward to interpret (in the same manner as with usual regression results), where a one-unit increase in the explanatory variable causes a coefficient unit change in weight.

Finally, I compare the two-step system GMM estimator to simple estimators to see how the results differ. First, I estimate a random effects model that does not control for the correlation between the explanatory variables and the disturbance terms. Let's refer to this method as exogenous regressor model — the results of this estimation should be badly biased for the reasons laid out above. Second, I apply an instrumental variables (IV) estimator to equation (13). Third, I use an instrumental variables estimator with fixed effects (IV-FE) without $W_{i,t-1}$ in the model to control for both endogeneity and individual unobservable factors, which is one way of estimating equation (14). It is expected that these two IV and IV-FE estimators to provide consistent parameter estimates but these estimators should be less efficient than the two-step system GMM estimator.

4.4. Data

This paper used comprehensive longitudinal data from the six most recent waves (1991, 1993, 1997, 2000, 2004 and 2006) of the China Health and Nutrition Survey (CHNS) on all adults (18 to 55 years old) interviewed during any of the survey waves. The CHNS were conducted in nine diverse provinces (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong) of China, and contains detailed individual-level information on income, diet, health and demography for all members of sampled households as well as detailed community-level data on infrastructure, public services and facilities. A multistage, random cluster process was used to draw the sample surveyed in each of the provinces. Counties in the nine provinces were stratified by income and a weighted sampling scheme was used to randomly select four counties in each province. Villages and townships within the counties and urban and suburban neighborhoods within the cities were selected randomly into primary sampling units (PSUs). The same households were surveyed over time as best possible and newly formed households began to be surveyed in 1993.

After the data is limited to men between 18 and 55 years old and who were not disabled during a particular wave there were 16,883 person-wave observations made up by 10,935 men.

Of these, only 4,180 men had at least two consecutive waves of data, making up 8,645 observations (Table 10). There is concern as to the loss of many observations over time due to this criterion. Some of the loss of observations was due to the fact that those whose first survey was conducted in 2006 were not included in the analytic sample (850 observations made up of 643 men). In addition, Liaoning province was dropped from the survey and replaced by Heilongjiang province in 1997 (Heilongjiang was kept in henceforth) due to flooding in Liaoning that year. This meant that observations from adult men in Liaoning who were first collected in 1993 would not have made it to the analytic sample due to the missing data for 1997. Also, the 1991 and 1993 Heilongjiang sample did not exist.

Beyond these factors, there was also loss to follow up. To ensure that attrition was not systematic, I ran a Heckman selection model (Heckman, 1979) on the individual-level data. This two-stage estimation was based on whether an individual had two or more consecutive waves of data using observed exogenous characteristics (community urbanization measures, prices, province, time, age, marital status, education attainment and predicted household income) in their first wave, and the last observed weight of individuals using exogenous characteristics from the last observed wave among those with two or more consecutive waves of data.

Results from the first step of the Heckman selection model suggests that the men who are younger, single, from Guangxi province (in the South), and who are from communities that generally scored lower on the various urbanization measures in their first wave are more likely to be dropped from the analytic sample. However, the Wald test of independence in the errors between these two stages produced a χ^2-statistic of 1.63, meaning that the null that there is no correlation between the errors of these two equations cannot be rejected (i.e., selection is not a problem). I also ran a Hausman specification test (Hausman, 1978) between the coefficients from the second equation and from basic OLS and found that the null hypothesis that the difference in coefficients are not systematic cannot be rejected ($\chi^2(35) = 1.43$).

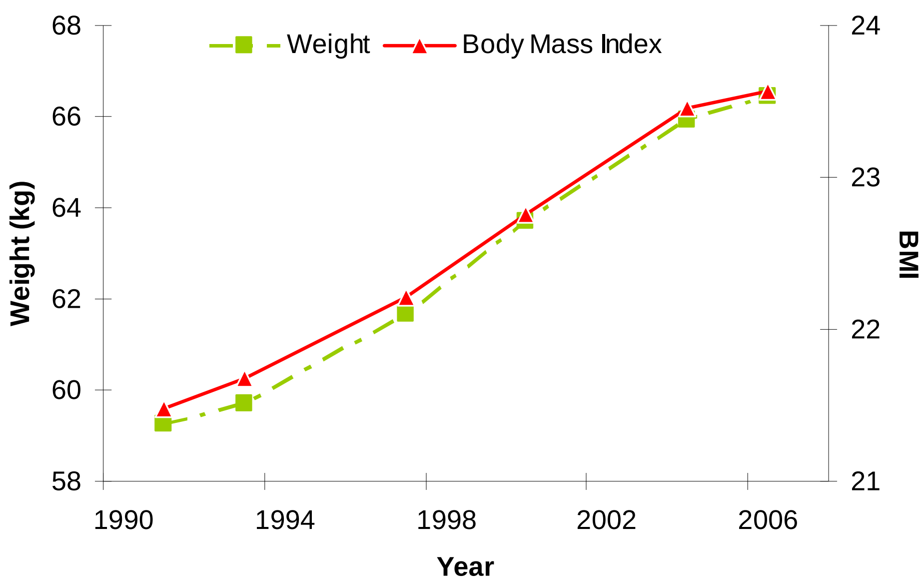
Table 10. Sample size of men (CHNS 1991–2006)

Consecutive waves	Unit of observation	Wave 1991	1993	1997	2000	2004	2006	Total
T ≥ 2	Individuals		1,138	542	779	728	993	4,180
	Person-wave		2,014	1,381	1,756	1,743	1,751	8,645
T =1	Individuals	2,398	558	1,280	984	892	643	6,755
	Person-wave	2,873	654	1,487	1,314	1,060	850	8,238
Total	Individuals	2,398	1,696	1,822	1,763	1,620	1,636	10,935
	Person-wave	2,873	2,668	2,868	3,070	2,803	2,601	16,883

4.4.1. Dependent Variables

Anthropometric data was collected by trained health workers during a comprehensive physical exam at a local clinic or at the respondent's home. Figure 12 shows that from 1991 to 2006, both weight and body mass index (BMI= weight in kg/(height in m)^2) rose significantly among adult men in China. In this analysis, I used weight as the dependent variable (but control for height) because of the fact that weight gain among adults is mostly in the form of fat (Dulloo, Jacquet et al., 2006) as mentioned earlier. It is also easier to interpret the results in terms of weight, and because height does not change much within an adult (18 to 55 year old) population. As a check, I will also run the two-step system GMM with height as an endogenous variable.

Figure 12. Weight and Body Mass Index of adult men in China (CHNS 1991–2006)



4.4.2. Key Explanatory Variables

The key explanatory variables were lagged total physical activities, total caloric intake, the proportion of energy from fat, smoking and drinking status.

Total physical activity was based on self- reported information on activity levels and times spent for up to two occupations (see Appendix B for details), and time spent on four types of domestic activities (buying food, preparing food, doing laundry and childcare). These were combined with specific metabolic equivalent of task (MET) values based on the Compendium of Physical Activities (Ainsworth, Haskell et al., 2000) to derive MET-hours per week to account for both intensity of activities and time spent on activities. A unit of MET, is defined as the ratio of a person's working metabolic rate relative to his/her resting (basal) metabolic rate. There is additional information about leisure activities and travel activities, which was only available in the last four waves of the CHNS. However, limiting the analysis to only these last four waves would have severely compromised sample sizes, so only activities from occupations and domestic chores were included. Additional information on the creation of the physical activity measures are in a recent paper by Ng and colleagues (2009). In the analytic sample, physical activity levels among Chinese men fell significantly by 37 percentage points in a span of 15 years (Figure 13a).

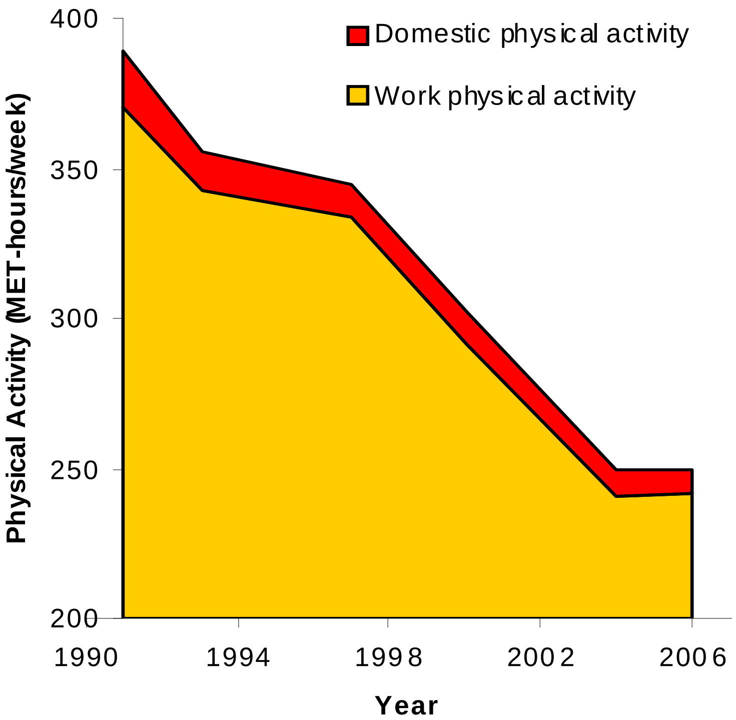
Detailed consumption data at both the household and individual level were collected over three consecutive days, which were randomly allocated from Monday to Sunday in order to determine average daily caloric intake from various macronutrient sources for each individual. Household food consumption was determined by examining changes in inventory from the beginning to the end of each day. Individual dietary intake for the same three consecutive days was surveyed all individuals from 1991 onwards based on daily self-reported 24-hour recalls on all food consumed away from home and at-home. The collection of both household and individual dietary intake allowed for quality checks. Where significant discrepancies were found, the household and the individual in question were revisited and asked about their food consumption in order to resolve these discrepancies (Wang, Ge et al., 2000).

The 1991 Food Composition Table (FCT) for China was utilized to calculate macronutrient intake values for the dietary data of 2000 and previous years (Institute of Nutrition and Food Hygiene, 1991). The UNC-CH group has worked with the National Institute of Nutrition and Food Safety to update and improve this FCT, which represents a significant advancement over the earlier China FCT, both for higher quality chemical analyses and for improved techniques of developing average nutrient values for foods whose nutrient value varies over the country in a geographic context. A newer 2000 version of the FCT (Institute of Nutrition and Food Hygiene, 2002) was used for 2004 and 2006 surveys.

Measures of the proportion of energy from dietary fat (%) and total caloric intake were used because they are able to better capture the role of dietary fat in explaining weight gain. From the consumption data, I was able to get individual-level measures of caloric fat, carbohydrate, protein and alcohol intake to allow us to determine these measures. Figure 13b shows that over the 15 year period, total caloric intake fell by about 17%, but the proportion of energy from dietary fat rose by 6% points. The fact that both physical activity levels and total caloric intake have fallen while weight has increased on average suggest that declines in physical activity have out-weighted reductions in caloric intake. However, given that the proportion of energy from fat has increased, it is possible that dietary composition has a role in explaining the weight gain.

Figure 13. Physical activity levels, daily caloric intake and proportion of energy from dietary fat among adult men in China (CHNS 1991–2006)

a. Change in work and domestic activity



b. Change in total caloric intake an energy from fat

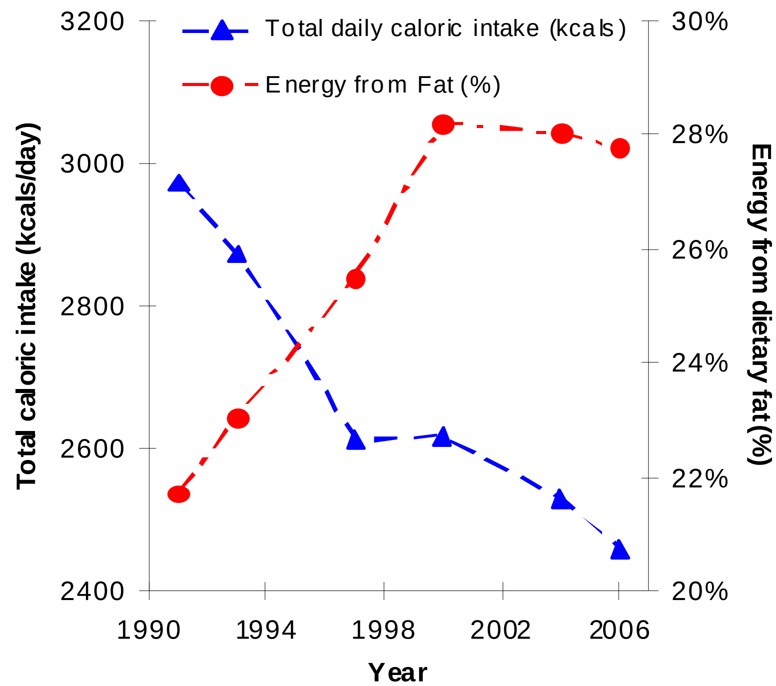


Table 11. Weight, physical activity levels, dietary intake, and other demographic characteristics among adult men in China (CHNS 1991–2006)

	Year						Change
	1991	1993	1997	2000	2004	2006	(1991–2006)
Weight (kg)	59.25	59.71	61.65	63.70	65.93	66.43	7.18 **
	(8.46)	(8.49)	(9.56)	(10.28)	(13.72)	(12.22)	
Height (cm)	166.1	165.95	166.60	167.31	167.66	167.88	1.78 *
	(6.26)	(6.17)	(6.36)	(6.38)	(6.65)	(6.88)	
BMI (kg/m^2)	21.43	21.65	22.15	22.71	23.40	23.54	2.11 **
	(2.50)	(2.55)	(2.82)	(3.07)	(4.35)	(4.01)	
Work & Domestic physical activity level (MET-hrs/week)	389.84	356.92	346.40	305.97	246.00	247.09	-142.75 **
	(220.37)	(217.01)	(215.97)	(202.97)	(180.18)	(177.90)	
Total caloric Intake (kcal)	2972.73	2872.65	2612.81	2618.09	2530.91	2458.11	-514.62 **
	(826.07)	(922.26)	(717.89)	(807.06)	(804.02)	(774.49)	
Energy from dietary fat (%)	21.72	23.06	25.50	28.22	28.03	27.79	6.07 **
Smoker (%)	68.57	65.99	63.11	61.28	60.07	57.52	-11.05 **
Drinker (%)	67.77	64.14	67.12	65.27	64.15	63.32	-4.45 *
Age (year)	35.18	35.83	36.73	38.08	39.72	40.41	5.23 **
	(9.93)	(10.08)	(10.19)	(10.10)	(9.95)	(9.78)	
Married (%)	79.69	78.60	78.70	80.0	82.08	83.93	4.24 *
Live alone (%)	0.21	0.19	0.21	0.23	0.32	0.31	0.10 **
No education (%)	15.12	11.12	9.75	6.44	4.37	6.50	-8.62 **
Highest education is primary school (%)	62.68	65.61	64.66	62.79	61.75	54.94	-7.74 **
Highest education is secondary school (%)	15.26	16.50	17.46	18.49	19.75	20.57	5.31 **
Highest education is technical school (%)	3.19	3.98	4.12	5.77	7.62	9.00	5.81 **
Has university degree or higher (%)	3.75	2.79	4.01	6.51	6.51	8.99	5.24 **
Predicted household income (2006 yuan)	2228.2	2261	2545.71	3573.33	4431.98	5243.65	3015.45 **
	(1443.17)	(3746.15)	(2362.72)	(3432.76)	(4419.80)	(8047.30)	
Number of observations	2851	2649	2841	2980	2795	2601	

Standard Deviations in parentheses

* difference between 1991 and 2006 is significant at 5%; ** significant at 1%

Dummy variables for being a smoker or drinker were included in the analyses as controls because past research has shown the smoking is negatively associated with caloric intake and weight gain as nicotine increases energy expenditure and could reduce appetite in the short term (Hofstetter, Schutz et al., 1986; Williamson, Madans et al., 1991), but heavy smoking can increases insulin resistance and is associated with central fat accumulation (Chiolero, Faeh et al., 2008; Xu, Yin et al., 2007). The relationships between drinking and weight gain are not so clear (Hu, Wang et al., 2000; Maskarinec, Meng et al., 1998), as drinking might increase total caloric intake, but can also have a protective effect on weight gain or loss (Liu, Serdula et al., 1994). The CHNS also asked respondents whether they drank any beer or other alcohol beverage in the past year; and if they are current smokers. In this sample, the smoking and drinking prevalence among Chinese men declined with age (Table 11), likely due to the both the aging effect and mortality effect (smokers and drinkers might have higher mortality rates than non-smokers and non-drinkers). Other important explanatory variables included were: a) lagged weight (based on weight in the prior wave) since weight is a stock concept that accumulates or de-cumulates over time; and b) height in centimeters, since weight will vary depending on one's height. These variables were discussed earlier.

Also, as mentioned before, a problem with these key explanatory variables is the endogeneity of decisions concerning dietary intake, physical activity and health behaviors with relation to weight due to the introduction of lagged weight as an explanatory variable. In order to correct for the possible endogeneity, there is a need to identify instrumental variables, and conduct specification tests to ensure their validity.

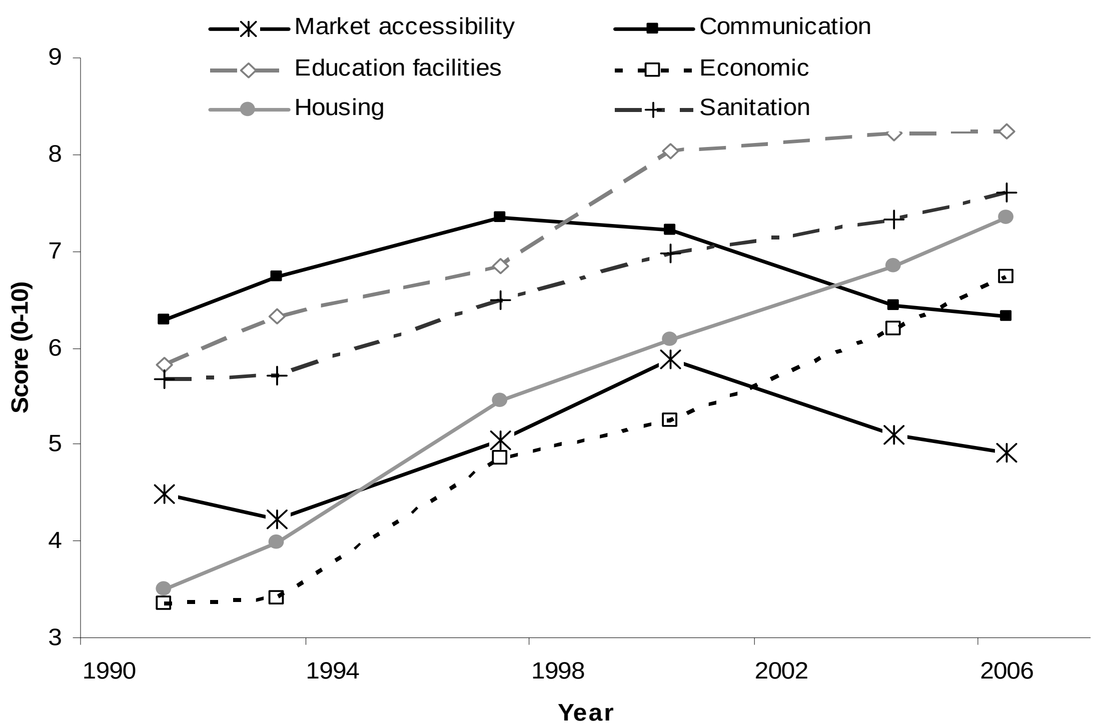
4.4.3. Potential Instruments

Potential instruments are time-varying and arguably exogenous dimensions of urbanization and prices of food items of each community. I conducted specification tests on various sets of these variables to determine the final set of instruments for use in both the instrumental variables estimation and the dynamic panel estimation.

Ten community-level measures of various dimensions of urbanization were used: population, density, market accessibility, economic wellbeing, transportation, communications, education, health facilities, sanitation and housing infrastructures. These reflect changes in the various dimensions of urbanization over time and reflect the environment in which people function. Each of these dimensions was given a score from zero to ten and was comprised of data collected from local area administrators or official records. Additional detail as to how these scores were created and their distributions over time can be found in Ng et al. (2009) and Appendix B.

The CHNS community-level measures of urbanization have also been previously used in papers by Monda et al. (2007), and Zimmer et al. (2007). Figure 14 shows that over time, the communities on average had improvements in these dimensions. Note that urbanization was not uniform across communities, with some communities experiencing declines in certain dimensions even though in general the average community might have seen improvements. China's household registration (*hukou*) system and the longitudinal nature of the CHNS data ensure that selection into communities and inclusion in the data was as independent of individual or household choices and behavior as best possible.

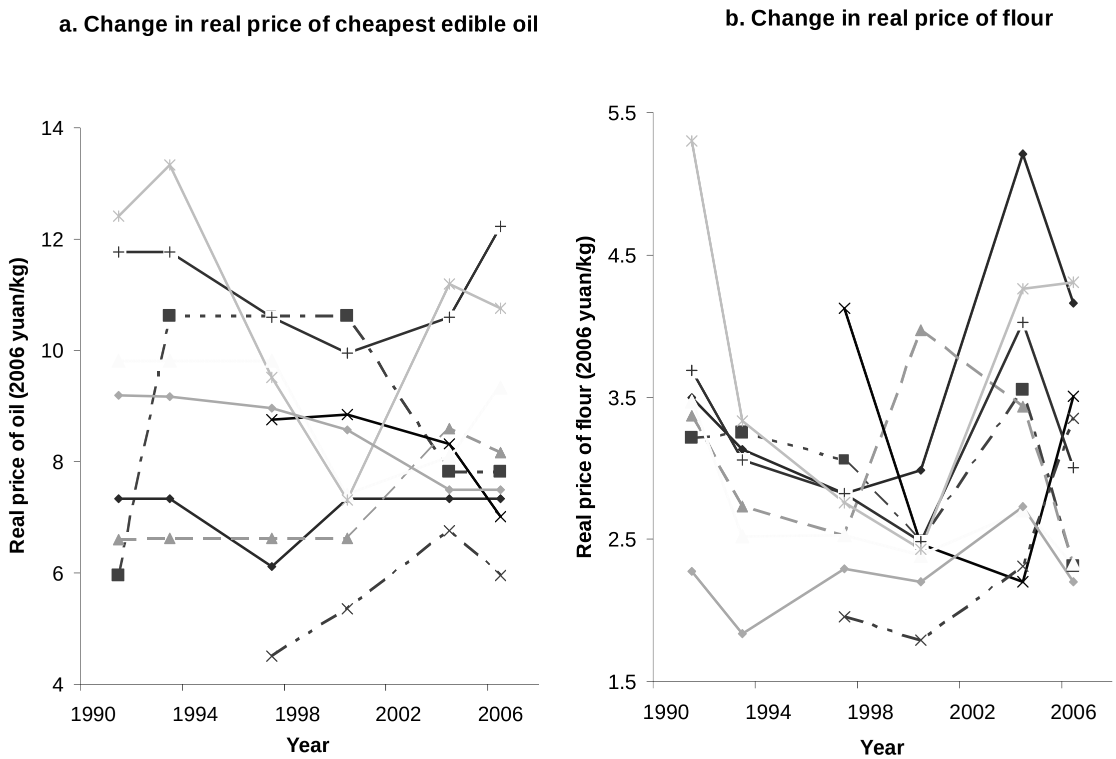
Figure 14. Average change in select urbanization domains among communities in China (CHNS 1991–2006)



Prices may affect weight gain via consumption of various types of food items. I included prices of food items that may be particularly important in the context of China, such as rice, flour, pork and oil. Community price surveys conducted on a set of sample stores and markets were used to provide price data. There were three sources of price information for a representative basket of goods. These include state store prices, free market prices collected from visits to stores in the communities surveyed, and authority price records published by the State Statistical Bureau (SSB) of China, which provides the provincial average. The state store prices were no longer used after the 1991–1992 price reform in China. Therefore, in almost all situations, the free market prices will be used as the basis, except when the goods studied were not sold in the free market, in which case, prices from the state stores will be used, followed by SSB recorded prices if the other two sources do not have the information. Farmers both produce and consume food, which adds complexity to the price issue. However, the free market prices for the food can be seen as the opportunity cost of consuming instead of selling the produce. Hence, using free market prices (when available) is appropriate.

Variations in food prices across communities are due to both supply and demand side factors. On the supply side, agricultural production, transportation, marketing and distribution costs, imports of specific foods, and availability of substitutes and complements can affect prices across communities. On the demand side, preferences or food fads may vary by communities. Most price changes in China are driven by supply factors and exogenous economic decisions made at the provincial level by price commissions and other macroeconomic government decisions; hence, they can be considered exogenous variables that vary greatly over time and across communities as shown in the lack of a clear pattern in price changes among the ten most populous communities in the CHNS in Figure 15. In addition, there are also variations in inflation, measured by the Consumer Price Indices (CPI) across communities. The community-specific CPI was derived from using a consumer goods basket of 57 items and the SSB's annual province and urban-rural specific consumer price index ratio because there is no published absolute CPI for China that provides a way to compare provinces or urban and rural areas. Price and income variables were deflated by these, with urban Liaoning province for 2006 equal to 1.00 (or 100%) and made all other prices relative to this (CPC, 2006).

Figure 15. Examples of price variation over time and across the ten most populous communities (CHNS 1991–2006)



Testing validity of instruments

I tested the null hypothesis that there is exogeneity by conducting a Hausman test between the models assuming exogeneity and the instrumental variables model. Results from a Hausman test showed that the null hypothesis that there is exogeneity can be rejected ($\chi^2(21) = 52.76$). This suggests that IVs should be used in the estimation. Otherwise, the results will be biased and inconsistent (Hausman, 1978). Valid instrumental variables need to satisfy two criteria: they must be correlated with the included endogenous variables and orthogonal to the error process.

Table 12. Urbanization and prices on weight, physical activity, dietary intake, smoking and drinking among Chinese men

Community Factors	(1) Lagged Weight (kg)	(2) Lagged Physical Activity (MET-hrs/wk)	(3) Lagged Total caloric intake (kcal)	(4) Lagged % energy from Fat	(5) Lagged P(Smoke)	(6) Lagged P(Drink)
Population score (0-10)	-0.032	0.33	**6.916 ***	-0.061	0.026	-0.009
	(0.041)	(0.737)	(3.591)	(0.041)	(0.019)	(0.015)
Density score (0-10)	0.02	**-3.141 ****	**-7.733 ***	**0.138 ****	-0.017	**0.058 ****
	(0.044)	(0.802)	(3.609)	(0.042)	(0.02)	(0.016)
Market Accessibility score (0-10)	0.002	**-3.013 ****	**-11.56 ****	-0.036	**-0.031 ***	**-0.039 ****
	(0.025)	(0.624)	(2.884)	(0.035)	(0.013)	(0.011)
Transportation score (0-10)	0.024	**-3.471 ****	**-16.435 ****	**0.142 ****	0.002	0.015
	(0.036)	(0.853)	(4.055)	(0.046)	(0.018)	(0.016)
Communications score (0-10)	**0.079 +**	**-2.513 ***	-5.84	**0.268 ****	-0.02	0.009
	(0.042)	(1.08)	(4.81)	(0.056)	(0.022)	(0.019)
Economy score (0-10)	0.063	**-7.465 ****	**12.924 ****	**0.183 ****	0.012	0.012
	(0.054)	(1.078)	(5.175)	(0.068)	(0.025)	(0.021)
Educational Institution score (0-10)	**0.176 ****	**-10.403 ****	**-35.684 ****	**0.339 ****	0.001	0.018
	(0.049)	(1.106)	(4.672)	(0.056)	(0.025)	(0.02)
Health Facilities score (0-10)	0.07	**-3.918 ****	-5.407	**0.204 ****	**0.039 +**	0.015
	(0.049)	(1.05)	(4.813)	(0.054)	(0.022)	(0.018)
Sanitation infrastructure score (0-10)	**0.048 +**	**-9.085 ****	1.042	**0.197 ****	0.024	-0.008
	(0.029)	(0.775)	(4.007)	(0.039)	(0.016)	(0.014)
Housing infrastructure score (0-10)	**0.102 ***	**-6.594 ****	-5.224	**0.523 ****	-0.015	-0.031
	(0.05)	(1.208)	(6.197)	(0.068)	(0.027)	(0.023)
Log real price of Rice (yuan/kg)	**0.662 +**	-0.709	-13.521	**-0.894 +**	**0.39 ***	-0.069
	(0.382)	(8.935)	(43.193)	(0.497)	(0.202)	(0.171)
Log real price of Flour (yuan/kg)	**-1.543 ****	-3.734	-13.81	**1.663 ****	-0.012	**-0.268 +**
	(0.326)	(8.411)	(39.251)	(0.475)	(0.181)	(0.156)
Log real price of Pork (yuan/kg)	**-1.308 ****	**17.387 ****	-2.27	**-1.367 ****	0.082	-0.047
	(0.332)	(6.425)	(32.506)	(0.365)	(0.151)	(0.126)
Log real price of Chicken (yuan/kg)	**-2.495 ****	-11.037	**156.631 ****	**1.837 ****	**0.575 ****	-0.031
	(0.331)	(7.599)	(38.648)	(0.461)	(0.176)	(0.148)
Log real price of Oil (yuan/liter)	**-0.478 ***	2.847	**-54.151 ***	**-0.998 ****	-0.036	-0.134
	(0.208)	(4.476)	(22.623)	(0.244)	(0.099)	(0.082)
Log real price of Beer (yuan/bottle)	-0.364	-7.385	-20.696	0.232	-0.086	**-0.243 +**
	(0.357)	(6.99)	(34.429)	(0.412)	(0.171)	(0.142)
Log real price of Cigarettes (yuan/box of 20)	0.067	**-13.128 ****	**-33.014 ***	**0.486 ***	**-0.172 ***	-0.065
	(0.154)	(4.072)	(19.263)	(0.213)	(0.082)	(0.069)
Consumer Price Index (100=urban Liaoning)	**-8.768 ****	18.71	79.594	**14.256 ****	**1.865 ***	0.409
	(1.694)	(31.864)	(138.207)	(1.742)	(0.741)	(0.611)
Overall Statistic $\chi^2(35)$	2064 **	5970.48 **	737.72 **	3179.27 **	238.72 **	253.15 **
Joint test of significance for all community variables $\chi^2(18)$	223.34 **	1856.63 **	233.72 **	1414.28 **	37.76 **	50.45 **
Joint test of significance for urbanization measures $\chi^2(10)$	67.59 **	1402 **	176.49 **	651.03 **	13.08	28.04 **
Joint test of significance for price variables $\chi^2(8)$	156.57 **	21.28 **	27.26 **	157.36 **	23.79 **	17.84 *

8,645 observations from 4,120 unique individuals in all estimations. Controlling for height, time, age, marital status, living situation, education, and predicted household income. Robust standard errors in parentheses
+ significant at 10%;* significant at 5%; ** significant at 1%

The former condition may be readily tested by examining the first-stage regression results from the IV model, which used lagged values of the instruments and other control variables as explanatory variables for the endogenous variables of lagged weight, physical activity, dietary intake, smoking and drinking. Table 12 presents the results. I found that all but one of the lagged community urbanization measures was statistically predictive of physical activity in the prior wave. In particular, the scores for educational institutions, sanitation, economic wellbeing and housing infrastructures were high associated with declines in physical activity. The community urbanization variables were also highly predictive of the dietary intake outcomes.

The lagged community price variables were most predictive of lagged weight and energy from fat. There are a few interesting results of note. For example, a one percentage point increase in the price of pork appears to be related to a 1.36 percentage point decrease in energy from fat, and a one percentage point increase in the price of oil appears to be related to a 1 percentage point decrease in energy from fat. For endogenous variables of lagged weight, physical activity, total caloric intake and energy from fat, it appears that the ten community urbanization measures and eight price variables satisfied the requirement that these instruments are correlated with them. In general, the models did not perform as well for the health behaviors, particularly smoking. The relatively poor results for smoking are not too surprising since the model only had dichotomous variables for whether an individual was a current smoker or not. Since smoking is an addictive habit (or lifetime choice), it is unlikely that there is much variation over time to one's smoking status once an individual picks up smoking.

The latter criteria (the instruments need to be independent from an unobservable error process) can be ascertained by using tests of over-identification since there are more potential instruments then there are endogenous variables. In GMM models such as what is used in the dynamic panel approach, a Hansen's *J*-statistic is used to test for this. The *J*-statistic follows a χ^2 distribution with degrees of freedom equal to the number of over-identifying restrictions rather than the total number of moment conditions. A rejection of the null hypothesis can imply that the instruments do not satisfy the orthogonality conditions (either because they are not truly exogenous, or because they are being incorrectly excluded from the regression), or that the model specification is incorrect. In standard IV models, the Sargan statistic is calculated instead. The Sargan statistic is a special case of Hansen's *J*-statistic, which uses an estimate of the error variance from the IV regression estimated with the full set of over-identifying restrictions, and will generate a consistent estimator of the error variance under the null of instrument validity. The Sargan test of over-identification cannot be rejected ($\chi^2(12) = 11.57$), meaning that the set of instruments satisfy the requirement that the instruments be independent from unobserved error (Table 13, column 2).

4.5. Results

4.5.1. Exogenous Regressors

The results (Table 13, column 1) assuming that the regressors are exogenous suggest that height is positively related to weight (p<0.01), while prior weight is positively related to current weight (p<0.01). An increase of 10 MET-hours per week of physical activity in the prior wave is associated with a weight loss of 0.02kg (p<0.01). These results are indeed lower for caloric intake, energy from fat and caloric intake compared to the respective estimates from the IV and the GMM system approaches (Table 13, column 1). This suggests that these results are biased and inconsistent due to endogeneity. Moreover, the coefficient estimate for lagged weight is higher in this model compared to the IV and GMM system approach, suggesting that autocorrelation is also a problem.

4.5.2. Simple Instrumental Variables

In the IV model, only height was positively associated with weight (Table 13, column 2). In addition, the test of over-identification cannot be rejected (χ^2 (12) = 11.57). As expected, I found that the coefficients for the GMM system model (Table 13, column 3) and the IV model (Table 13, column 2) be closer than without correcting for the endogeneity, but the standard errors were much smaller for the dynamic panel model because the GMM system estimator is asymptotically more efficient than the IV estimator.

4.5.3. Instrumental Variables with Fixed Effects

In order to further control for unobserved individual factors, I estimated an IV-FE model and found that like the IV model, only height was positively associated with weight (Table 13, column 3).

However, the estimated coefficient for height from the IV-FE model shows that height is less positively associated with weight after controlling for individual unobservables. As expected, the standard errors from the IV-FE model were larger compared to those from the dynamic panel model, which may explain the insignificant findings.

4.5.4. Two-step system GMM

The dynamic panel two-step procedure combines in a system GMM, a regression in differences over time, and a regression in levels (i.e., within the same wave). Recall that the consistency of the GMM estimation relies on the autocorrelation of the residuals and the validity of the instrumental variables. The *xtabond2* procedure in Stata (Roodman, 2003) performs validation tests for these. In this estimation, the rejection of the presence of a second-order autocorrelation (i.e., the AR(2) *z*-statistic is not significant) satisfies the first criterion, and the rejection of the *J*-test of over-identification satisfies the second criterion (Table 13, column 4).

The difference-in-Sargan test allows us to test a subset of the original set of orthogonality conditions by computing the difference in the two Sargan statistics from the entire set of over-identifying restrictions and from the model using a smaller set of restrictions. We see that the Hansen test excluding the set of instruments is χ^2 (37) = 41.28. So, the difference-in-Sargan test of the set of 18 instruments is χ^2 (18) = 20.72. The fact that the difference-in-Sargan test of exogeneity can be rejected supports the validity of these instruments.

The coefficient estimates from the GMM system dynamic panel estimation is interpreted like regular OLS. I found that unsurprisingly, height is positively related to weight ($p < 0.05$), while prior weight is positively related to current weight ($p < 0.01$). Assuming linearity, an increase of 10 MET-hours/week of physical activity in the prior wave is associated with a weight loss of 0.03 kg ($p < 0.1$), *ceteris paribus*. This is a larger coefficient than what was found in the reduced-form model, although not quite as statistical. Also, a one percentage point increase in energy from dietary fat in the prior wave was associated with a 0.05 kg weight gain, *ceteris paribus*. When height was considered an endogenous variable in the two-step system GMM model, the results were virtually the same.

Table 13. Results from different approaches to estimate determinants of weight among Chinese men

	(1) Exogenous regressors	(2) Instrumental Variables	(3) Instrumental Variables with Fixed Effects	(4) Two-step system GMM
Current				
Height (cm)	**0.429 ****	**0.528 ***	**0.288**	**0.711 ***
	(0.031)	(0.216)	(0.052) **	(0.276)
Lagged (t-1)				
Weight (kg)	**0.512 ****	0.424	**-**	**0.313 ****
	(0.035)	(0.266)	-	(0.072)
Work & Domestic Physical activity level (MET-hours per week)	**-0.002 ****	0.008	-0.0124	**-0.003 ***
	(0.0004)	(0.008)	(0.01)	(0.002)
Total Caloric Intake (kcal)	0.0002	-0.0004	0.011	-0.0001
	(0.0001)	(0.001)	(0.011)	(0.0002)
Energy from Fat (%)	0.009	0.067	0.029	**0.047 ***
	(0.008)	(0.086)	(0.108)	(0.022)
Smoker	**-0.490 ****	-0.363	-10.193	0.299
	(0.194)	(4.633)	(5.808)	(0.597)
Drinker	0.375	1.456	4.163	0.037
	(0.204)	(4.616)	(4.629)	(0.525)
Instruments	None	Δ community variables used as instruments for lagged endogenous variables	Lagged community variables used as instruments for lagged endogenous variables	Difference equation: Δ community variables Level equation: Lagged difference for weight, physical activity, diet, smoking and drinking status for t-1 and prior
Number of Instruments used	None	35	31	79
Overall Statistic	$\chi^2(23)$= 6027.44 **	$\chi^2(23)$ = 5175.05 **	$\chi^2(18)$= 680252.02 **	$\chi^2(23)$ = 206.34 **
Difference-in-Hansen tests of exogeneity of Community variables as instruments				
Hansen test excluding group				$\chi^2(37)$ = 41.28
Difference (H_0 = exogenous)				$\chi^2(18)$ = 20.72
Sargan-Hansen's test of over-identification		$\chi^2(12)$= 11.57		$\chi^2(55)$ = 62.00
Test for Autocorrelation				
AR(1) in first differences (*z*-statistic)				-4.06 **
AR(2) in first differences (*z*-statistic)				1.38

For all estimations there were 8,645 observations made up for 4,120 unique individuals.
Among those with 2 or more consecutive waves of data. Controlling for time, age, marital status, living situation, education, and predicted household income. Robust standard errors in parentheses.
* significant at 5%; ** significant at 1%

We can also tell from these coefficients and the noted change in physical activity levels and dietary fat intake over the 1991 and 2006 period, how each of these factors may have contributed to weight gain on average. Table 14 shows the breakdown of these figures based on results from this analysis. 30 % of the increase in weight among adult Chinese men was due to declines in physical activity, while 20 % was due to increases in fat in their diets, and the remaining 50 % was due to other factors.

Table 14. Contribution of physical activity and energy from dietary fat on weight gain among Chinese men

	(1) Change (1991 – 2006)	(2) Coefficient from Table 13, Column 3	(3) Absolute Contribution (kg) (1)x(2)x5 intervals‡	(4) Percentage Contribution (%)
Work & Domestic Physical activity level (MET-hours per week)	-142.75	-0.003	2.14	29.81
Energy from Fat (%)	6.07	0.047	1.43	19.92
Weight (kg)	7.18		3.57	49.73
Unexplained			3.61	50.27

‡ Since the coefficients are for the change in the explanatory variable from t-1 to t, we need to multiply the coefficient by the 5 intervals.

4.6. Discussion

It is critical to combine both measures of physical activity and dietary intake in trying to understand the dynamics of these on weight. This paper uses a dynamic panel system GMM estimation model and adds to the structural understanding of relationships among macro-level factors on micro-level behavior instead of the typical reduced-form modeling approach. I found that declines in physical activities and increases in fat as a proportion of people’s diet are positively associated with weight gain among adult men in China. Of these two factors, the declines in physical activity seem to a larger contributor to weight gain, although dietary fat intake is also important.

Physical activity has been found to be a critical factor in body weight regulation in lean and obese individuals due to its protective role over time through both direct energy expenditure, improved physical fitness and resultant metabolic effects on lipid mobilization and oxidation and biochemical changes in the muscle fiber that contribute to improved regulation of body weight (Saris, 1998). Previous work have also hinted that physical activity may be a more successful strategy than dietary approaches to weight loss and maintenance among men (King, Frey-Hewitt et al., 1989).

4.6.1. Policy implications

The findings from this paper highlight the importance of promoting physical activities in order to both reduce weight gain and the prevalence of overweight and obesity, risk markers for a slew of chronic diseases. Indeed, lack of physical activity has shown to be significantly associated with increased cardiovascular problems (Hong, Bots et al., 1994; Sundquist, Qvist et al., 2005), type II diabetes (Hu, Sigal et al., 1999; Meisinger, Lowel et al., 2005), incidence of stroke (West, Gilsenan et al., 2006), cholesterol levels (Durstine, Grandjean et al., 2001) and mortality from cardiovascular diseases, cancer and all causes (Hu, Tuomilehto et al., 2005). These diseases will create new health and financial challenges for developing countries such as China.

In China, declines in physical activity have occurred mostly at work (Ng, Norton et al., 2009), therefore intervention strategies to increase physical activity levels at the workplace are one possible strategy. To increase physical activity via active leisure and travel activities such as walking and bicycling can be promoted by designing built environments that are safe and conducive for such transit or exercise modes (Forsyth, Hearst et al., 2008; Nagel, Carlson et al., 2008). It is also possible that improved access to public transit can help promote walking (Rodriguez, Aytur et al., 2008) or bicycling – a diminishing activity in urban and rural China. Policies in the form of higher taxes on automobiles, lower entry fees to parks and government run health facilities can also help promote physical activity. Moreover, disincentives for automobile ownership can discourage motorized transportation and help reduce air pollution and provide more pleasant environments for outdoor exercise. These policies can be province or community-specific depending on geographical, cultural and socio-economic circumstances.

The other side of the weight equilibrium has to do with dietary intake. In particular, there is some controversy regarding the role of fat intake on weight gain or the prevalence of obesity (Bray & Popkin, 1998; Willett, 1998). The debate concerns whether it is fat itself that increases weight or, that it is the fact that fat per gram is more energy dense, which is why both epidemiological studies and animal studies that also control for total energy intake find little significance of fat intake (Bray, Paeratakul et al., 2004). I found that the proportion of energy from fat was important, but did not find a significant relationship between total caloric intake and weight gain, which seem to suggest that the latter may be the case in this particular population. Nonetheless, regardless of whether it is the excess calories or the chemical nature of fat, it has been found that lower fat diets have been able to prevent overweight/obesity, hypertension, high total serum cholesterol, high serum triglycerides and high low density lipoprotein cholesterol (Chen, Zhao et al., 2008). Certainly, fat intake is only one environmental factor that affects the genetic expression of overweight and obesity. There is a need to tackle this growing epidemic from various angles, creating policies that target both physical activity and diets.

4.6.2. Contributions

This paper addresses the questions of the roles of physical activity and dietary intake on weight, while controlling for the complex relationships among these variables by using a dynamic panel, using time-varying macro-level factors such as urbanization measures and prices as instruments. The dynamic panel estimates are unbiased, asymptotically efficient, and allows for autocorrelation in the error terms. Hence, the GMM system dynamic panel approach is ideal for the empirical model in question. However, it requires at least two waves and data, a large sample size, detailed individual data on anthropometrics, dietary intake, measures of physical activity, and availability of valid instruments. To my knowledge this is the first paper that has used this estimation strategy in the context of weight.

4.6.3. Limitations and future directions

While this paper has provided insights into the dynamics among physical activity, diet and weight, there are a number of limitations with this analysis. First, this paper focused on a specific population— adult (18-55 year old) men in China, which limits its applicability to the general population. While gender disparities would be interesting to uncover, the CHNS data did not contain unmeasured predictors such as metabolic rate that are more operative for women. In addition, women often have the triple burden of work, children and domestic chores, which have competing effect on diet and physical activity choices and limits the variance observed in data. Second, there is better variance in the data for men because men are more likely to own technology like motorized vehicles as well as experience occupational change than women.

Second, this analysis only looked at weight as the dependent variable. Weight in and of itself is not necessarily a good indicator of health status, since for someone who is underweight, weight gain may actually be a health benefit. Diagnoses of chronic diseases may be more appropriate outcomes to use. However, in order to conduct analysis on health outcomes will first require a good understanding of the dynamic among physical activity, diet and weight.

Third, even though this research has found physical activity to be the more important factor, it does not mean that it is the most appropriate factor to target because the relationship might not be symmetrical since the cost and benefits associated with promoting physical activity or improved dietary choices are likely to be different.

There are some data limitations that may compromise the findings. For example, the use of MET-hours per week to quantify energy expenditure does not take into account individual differences that may alter the energy cost of movements (such as basal metabolic rates). Nonetheless, this approach is the best available way to systematically apply average energy cost estimates in self-reported measures (Matthews, 2002). Moreover, I included multiple sources of occupational and domestic activity to allow a more complete assessment of physical activity.

Lastly, this analysis was unable to directly estimate the interacted effect of physical activity and dietary intake. However, it does so implicitly in the dynamic panel system GMM estimation approach by including lagged weight with controls for endogeneity in the physical activity and diet variables that affect weight.

Future work should consider looking at women, or study gender disparities in the dynamics of weight gain, and perhaps to parse out the various biological processes and social or economic roles that can influence their weight gain differently. Future work should also be considered regarding joint decisions about time and energy allocation among household members, instead of just considering individuals alone.

5. CONCLUSIONS AND POLICY IMPLICATIONS

5.1. Summary of findings

This dissertation aimed to address the following research questions:

1) What urbanization factors have caused the declines in physical activity among Chinese adults?;
2) How do changes in prices and incomes affect food consumption among Chinese adults?; and
3) How do physical activity, dietary intake and other health behaviors determine weight?

These three questions are aimed at addressing the two main components of the energy balance equation (i.e. food intake and physical activity), how together they can affect weight change, how weight itself might affect these components, and what might be the important factors surrounding the context in which people make these choices. China provides an excellent case study because of its large population, the rapid changes its people have experienced in their food, economic, social and built environments as a result of economic development, and the availability of a large longitudinal dataset. The following sub-sections summarize the main findings from the analyses for each of these three questions.

5.1.1. Declines in physical activity due to urbanization

It has been suggested that urbanization and associated adverse changes in physical activity levels have played a role in the observed increase in chronic diseases in China (Janus, Postiglione et al., 1996; Popkin, 1999). Indeed, between 1991 and 2006, average weekly physical activity among adults in China fell by 32%. But why has this occurred? The SLOTH model (Cawley, 2004; Pratt, Macera et al., 2004; Sturm, 2004) suggests that it is important to consider various types of activities (i.e., occupational/work, domestic, transportation, leisure/exercise), and that urbanization and the services and facilities available in communities in which people live and work, can be significant factors in determining declines in physical activity. However, the bulk of this research focuses on developed countries, so it is not clear whether these associations will be applicable to China, where urbanization has occurred more rapidly and may have more immediate effects on physical activity decisions. Studies undertaken in China attribute the decline in physical activity to greater use of motorized transportation (Bell, Ge et al., 2002), use of computers and various work technologies (Bell, Ge et al., 2001; Popkin, 2006), greater access to markets, improved neighborhood facilities (Popkin, Paeratakul et al., 1995b) and urbanization (Caballero, 2001; Monda, Gordon-Larsen et al., 2007). Based on the findings from the limited work done in China, I hypothesized that: a) physical activity levels would be negatively associated with urbanization; b) urbanization domains that affect job functions and opportunities would contribute most to changes in physical activity levels; and c) these urbanization domains would be more strongly associated for men than for women because home activities account for a larger proportion of physical activities for women.

This research found that urbanization — measured along a series of dimensions — is associated with a significant proportion of the decline in physical activities among Chinese adults, particularly occupational physical activities. Improved housing infrastructures, better access to educational institutions, higher economic opportunities and improved sanitation services are the main community-level factors that explain this decline. These urbanization factors predict more than four-fifths of the decline in occupational physical activity over the 1991–2006 period for men and nearly two-thirds of the decline for women. They are also associated with 57% of the decline in total physical activity for men and 40% of the decline for women. These findings suggest that improvements in community infrastructures and services have strongly affected the environments in which the Chinese live, the choices available to them, and consequently the choices they make.

While the results may suggest that improvements in community infrastructure and services are significantly associated with declines in physical activity, this does not necessarily mean that urbanization *per se* is detrimental. Declines in occupational activity are signs of shifts in the job market toward less labor intensive occupations. Descriptive statistics show that leisure activity is gradually on the rise in China among both men and women, which might help attenuate the effects of declines in physical activity at work and in the home. While this is a promising trend, active leisure activity levels are clearly not rising fast enough to make up for the declines in occupational and home activities.

In China, declines in physical activity have occurred mostly at work, therefore intervention strategies to increase physical activity levels at the workplace are one possible strategy. There is also a need to increase physical activity in other domains of active leisure and transportation. Residential areas, workplaces, and public spaces should be made more activity-friendly. Sidewalks, bicycle trails, and recreational parks should be made readily available to encourage walking, cycling and other types of physical activity. Local governments should take advantage of current investments in infrastructure to incorporate such considerations into innovative architectural design, town or city planning, land-use development decisions, and provision of services.

5.1.2. Changes in diets in response to relative prices and income

The Chinese diets that were traditionally high in fiber, cereals and grains are now predominantly made up of animal source foods, are higher in fat, and more energy dense (Hu, Reardon et al., 2004; Popkin & Du, 2003). This is a troubling trend as these dietary changes have been found to be strongly associated with China's high growth rates in the development of nutrition related non-communicable diseases (Chen, Zhao et al., 2008; Raymond, Leeder et al., 2006; Wang, Mi et al., 2007; Yang, Kong et al., 2008).

Most researchers agree that the changing dietary patterns among the Chinese have been largely due to the rapid income growth, shifts in relative prices, and structural shifts in demand (Haddad, 2003). This has led some economists and policymakers to contend that if economic factors are indeed drivers of diet change, it may be possible to alter the economic environment to discourage consumption of less healthy foods, while encouraging the consumption of more healthy foods (Frazao & Allshouse, 2003; Jacobson & Brownell, 2000). To do so would require a good understanding of how consumers respond to such economic factors.

This chapter of my research provides new evidence on how consumers respond to changing prices and income by estimating the own-, cross-price and income elasticities for a number of key food-groups (rice, wheat flour, plant oils, pork, eggs and vegetables) using more recent measures of individuals' consumption to better reflect of the realities of the food economy in China. It also looks at how these elasticities vary by household income over a period of rapid economic change by using longitudinal models that account for time interactions with prices and income. In addition, the paper seeks to improve on earlier price and income estimates by controlling for contextual variables that vary both geographically and temporally, and by using the appropriate estimation models based on the distribution of consumption for each food-group.

The estimated price elasticities were all negative with the exception of pork, which might be due to substitution away from lean pork towards fatty pork. The price elasticities for oils and vegetables were negative, but did not find statistical significance. These non-significant findings may be due to the fact that the types of vegetables and oils are heterogenous due to regional variations and seasons. While changes in own-price elasticities did not vary much by income levels for foods such as flour, plant oils and vegetables, they changed over time differently by income levels for rice and lean pork foods — the better-off adults in generally were not price sensitive, but the poorer ones were.

I also found that for all food-groups, the income elasticities were higher in 1991 than in 2006. In addition, the relatively high income elasticity for pork suggests that the consumption from pork will grow the fastest as real income levels rise in China. The results from rice shows that it moved from being a necessary good in 1991 to an inferior good in 2006. Wheat flour, plant oils and vegetables were all not income responsive. Also, income elasticities flattened out over time for most food-groups as people across all income levels gained easier access to these foods.

In addition, prices can have an affect on dietary intake in China as substitution occurs among and increasingly even within food-groups. Moreover, seasonal, regional differences in food preferences, availability, and cooking styles can mean varying types of substitutions and complementary of food products both temporally and geographically. The cross-price estimates only provide a broad sense of the pattern across China. Overall, wheat flour and rice are important substitutes for each other; rice, pork and vegetables are complements; rice and pork are substitutive calories for eggs; plant oils are complements for rice.

In China, it is possible that taxing fatty pork, animal source products that have high fat content, and oils, while subsidizing lean pork and low-fat animal source products, along with public nutrition education campaigns might be feasible. The estimated elasticities here suggest that these policies may discourage the consumption of fatty pork and plant oils without adversely burdening the poor.

5.1.3. Importance of both physical activity and diet in determining weight gain

Modeling an individual's energy balance appears straightforward: define the number of calories consumed and expended, and determine the resulting trends in weight gain. Unfortunately, there are many layers of complexity lost in this simplistic formulation of weight change.

For one, despite a consistent relationship between low physical activity, high caloric intake and weight in cross-sectional studies, the direction of the association cannot be determined. It is possible that lower physical activity and increased sedentary behaviors among those who are heavy may be the consequence of being heavy (social stigma, excluded from sports, etc.). Similarly, it is possible that people consume more (as a coping mechanism) in reaction to being marginalized. Moreover, diet and activity combined can interact to affect weight (Astrup, 1999). Therefore, there is a need to try to untangle the possible reverse causalities and confounding often discussed in the diet, physical activity and weight relationships. Second, even if one is able to properly remove reverse causality and confounding, there might also be a different effect of diet on weight depending on the type of food consumed, since calories from fat versus calories from carbohydrates or proteins can affect weight change differently (Miller, Lindeman et al., 1990; Tryon, 1987). Lastly, it is unclear if physical activity or diet matter more, and the importance of each of these is likely to be context specific.

To handle these complexities and to determine the directions and strength of the diet, physical activity and weight relationships, I apply a dynamic panel system GMM model estimation, in which current weight depends on prior weight and endogenous decisions about physical activity, diet and health behaviors. This method controls for the simultaneity problem and for temporal autocorrelation. I extend past economic models on the dynamics of weight change by explicitly including macro-level factors such as urbanization and prices in the model to determine how they interact with micro-level choices of physical activity, diet and health behaviors to affect weight change over time.

I found that the dynamic panel model performed well. I was unable to find statistical significance in the relationship between total caloric intake and weight. However, I found that declines in physical activities and increases in fat as a proportion of people's diet are positively associated with weight gain among adult men in China. Of these two factors, the declines in physical activity seem to be a larger contributor to weight gain, although dietary fat intake is also important suggesting that analysis of dietary composition above simple caloric intake is essential.

5.2. Implications

The findings from this research highlight the importance of promoting both physical activity and healthier consumption habits in order to reduce both weight gain and the prevalence of overweight and obesity, which are also risk markers for a slew of chronic diseases. Nonetheless, it is unclear if these choices should be left solely up to individuals, or whether social and government forces should be involved.

5.2.1. Does Big Bao need a big brother?

Being overweight is at first glance a personal problem, involving self control and tradeoffs between current and future utility. If we were to assume that the classical rational choice theory applies to the problem of weight, then there is no role for government intervention. Is there really no cause for the public to be alarmed at the rising rates of overweight and obesity that much of the world is now experiencing, or should the government step in to alter incentives and influence decisions?

I would argue for the latter on the following grounds. First, there are externalities involved with an individual being overweight, meaning that the true costs of individual lifestyle choices are not borne only by themselves, but also by others. This is likely the case in China, where familial relations are strong; the onset of chronic illnesses affects not just the unhealthy individual, but also his/her family. These externalities are worsened as the proportion of the population who are overweight, or unhealthy as a result of being overweight, increases. Greater frequency and longer periods of illness and absences from work among those who are overweight reduce productivity and impose costs on individuals, their families and society. In addition, increases in mortality from weight-related diseases reduce the national output relative to its potential level. These costs are magnified in the context of China given the age distribution of its population, where the dependency ratio has risen dramatically due to population control measures (Bloom, Canning et al., 2000; Hussain, 2002). It is very difficult to forecast the health care costs of China's nutrition transition as it is unclear what the role of prescription drugs and other treatments might play, and how chronic some of these NR-NCDs might be. Still, conservative estimates (that do not account for changing availability of pharmaceutical drugs and medical advancements) place the indirect costs of these negative lifestyle changes at around 4 percent of China's GNP in 2000, and are predicted to be around 9 percent of China's projected GNP by 2025 (Popkin, Kim et al., 2006; Raymond, Leeder et al., 2006).

Second, individuals receive at best imperfect information regarding the relationships between their diets and health. Food safety labeling is relatively new in China, having been officially required only since January 2008 (Xinhua News, 2008), while nutrition labeling guidelines were only established in May 2008 (China Daily, 2008), partly so that Chinese food exports could remain competitive globally. Nutritional education in China is also limited, and so it will take time and effort for individual Chinese consumers to learn how to interpret these new labels (Hawkes, 2008; Hu, Reardon et al., 2004).

Third, the environments in which individuals live are not in their control. A number of studies suggest that humans are in part unable to prevent weight gain because of mechanisms triggered by the cues in the environment that facilitate automatic and unconscious eating and the extent of their physical activities. Greater food availability, variety and novelty augmented by aggressive commercial promotion cause people to override internal signals of satiety, while conditioning and priming that tie food to other desirable outcomes increase the frequency with which hunger is stimulated by environmental cues (Acs & Lyles, 2007; Cohen, 2008).

Lastly, it is likely that the urban poor and the rural population might be disproportionately affected both financially and in terms of health outcomes. Past studies show that shifts in diet towards less healthy options have been particularly pronounced for the poor, who tend to be more price and income responsive (Du, Mroz et al., 2004; Guo, Mroz et al., 2000). Besides this, access to and affordability of health education, preventative health care and treatment are limited for this population. The decentralization of China's public health and medical care systems since the 1980s has meant that increasingly, health care costs are borne at the level of local (city or municipal) governments. This puts the poorer rural areas at a precarious financial situation, and has meant lower coverage and preventative health care usage by these populations (Blumenthal & Hsiao, 2005). Moreover, rural health insurance is virtually non-existent, although the central government has recently been experimenting with rudimentary safety nets. However, because of their modest funding, these plans cover only inpatient care (with a very high deductible) and leave most of the rural population without adequate primary care services and drugs (Blumenthal & Hsiao, 2005). Meanwhile, the implementation of Social Health Insurance in urban China shrank coverage, particularly among the urban poor whose employers do not contribute to their health accounts (Liu, 2002; Rosner, 2004).

For these reasons, it appears imperative that the Chinese Central and local governments consider seriously the rising prevalence of overweight and its associated health problems, and take steps towards mitigating them.

5.2.2. What can be done?

In the United States and Europe, physical activity has been considered the 'best buy' in public health (CDC, 2000; De Backer & De Bacquer, 2004; Morris, 1994), which may be the case in a developing country like China as well. However, proper cost-effectiveness and cost-benefit studies will need to be conducted to verify this.

In China, declines in physical activity have occurred mostly in the work environment; therefore intervention strategies to increase physical activity levels at the workplace are one possible strategy. Examples include encouraging stair use in buildings by placing signs near stairways and escalators, or by making stairways more centrally located and escalator use less convenient. To increase physical activity in other domains, active leisure and travel activities such as walking and bicycling can be promoted by designing built environments that are safe and conducive for such transit or exercise modes (Forsyth, Hearst et al., 2008; Nagel, Carlson et al., 2008). It is also possible that parking can be made less accessible to promote walking, or improved access to public transit can help promote walking (Rodriguez, Aytur et al., 2008) or bicycling — a diminishing activity in urban and rural China. Pricing policies in the form of higher taxes on automobiles, lower entry fees to parks and government-run health facilities can also help promote physical activity. Moreover, disincentives for automobile ownership can discourage motorized transportation and help reduce air pollution and provide more pleasant environments for outdoor exercise. Such recommendations will be challenging, but is likely more feasible in a centrally planned country like China compared to countries like the United States. China's central and local governments should take advantage of current and future infrastructural transformations to incorporate such considerations into policies on town or city planning or design, land-use development decisions, and provision of recreational services.

The other side of the weight equilibrium has to do with dietary intake. Currently, it appears critical to increase nutrition education across the wider Chinese population. Past studies have shown that nutrition education is particularly low in rural areas (Guldan, Zhang et al., 1991), where educational levels tend to be lower and access to health messages is limited. While an array of nutrition education publications such as the Chinese Food Guide Pagoda have been created (The Chinese Nutrition Society, 2000), they have only been disseminated in limited and unorganized ways, and there has yet to be a systematic national nutrition education campaign (Zhai, Fu et al., 2002). Greater investments by the central and local governments into educating the public about nutritional choices will be needed to complement the new nutritional labeling guidelines, particularly in light of the growing demand for pre-made, processed or pre-packaged foods. Meanwhile, continued progress towards ensuring food safety and quality is needed.

The economic approach of using of pricing policies to influence dietary choices is a challenging task for a number of reasons. First, everyone has to eat. Hence, untargeted taxes will be regressive and impose a particularly heavy burden on the poor. Second, it is difficult to identify the offending food item. There are many characteristics to any one food item that can make it both desirable and undesirable. There can also be a wide spectrum of substitutes and range of quality for any given food item; and there is a need to understand the food culture in terms of how foods are used together and prepared. Third, a significant proportion of China's food consumers are also food producers, and so the effect of food prices affects both food consumption and income levels. These difficulties need to be acknowledged, and explains why the use of pricing policies requires a thorough understanding of dietary needs and preferences.

A number of studies in developed countries have discussed the use of both taxes to discourage the consumption of foods considered unhealthy and subsidies to encourage the consumption of foods considered to be healthier (Caraher & Cowburn, 2005; Cash, Sunding et al., 2005; French, 2003). Such strategies may face opposition from both consumers and the food industry particularly in developed nations (Elston, Stanton et al., 2007). In China, such concerns may be alleviated given the political structure, so the concept of taxing fat and subsidizing lean, along with public nutrition education campaigns might be feasible.

Lastly, as the Chinese government has recognized, there is a need to reduce disparities and financial barriers to access in health care by strengthening the government's role in the health care industry; increasing government investment in the health care sector; expanding health insurance coverage; and strengthening primary care, community health care, and disease prevention (Ma, Lu et al., 2008). Currently, there appears to be progress in this direction, with piloted health systems being evaluated in urban areas (Li & Jiang, 2007) and the expansion of the New Cooperative Medical Scheme in rural areas (Wagstaff, Lindelow et al., 2007; You & Kobayashi, 2009). However, China's health care financing problems are vast and will take political commitment of resources to improve.

5.3. Contribution

This research extends past studies that consider the neo-classical framework by considering the inter-related nature of various communities, household and individual-level factors which influence weight gain. I used six waves of data in order to determine the role of infrastructure development, prices and income on changes in physical activity and diet, and hence weight gain. The availability of six waves of CHNS data over 15 years offers a rich empirical basis that allows for panel analyses and a structural understanding of how choices in consumption, activity and other health behaviors vary over time and with an evolving environment.

The CHNS data has detailed community-level information about prices of a variety of food and non-food items, population, facilities and services, as well as individual information from all adults about their demographics, occupations, physical activity, food intake, and measured height and weight. This comprehensive dataset allowed for more convincing findings than in prior studies that have had to combine various datasets across possibly varying populations.

Moreover, this research provided empirical evidence on the relationship between physical activity and dietary intake, using instrumental variables to control for potential endogeneity. The results can also be used to inform on food pricing policies, as well as land-use and building planning. By estimating the proportional role of these factors, policymakers in China can use the results to help prioritize interventions or consider how best to continue encouraging development and improvements in the quality of life of their people without compromising their health.

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5.4. Limitations and Future Directions

While this dissertation research has provided insights into the role of built and economic environments on physical activity and diet, as well as the dynamics among physical activity, diet and weight, there are a number of additional issues that should be addressed in future work.

First, this paper focused on a specific population— adults (18-55 year olds) in China, which limits its applicability to the general population. Additional work should also look at the nutrition transition among children as they move into adolescence and adulthood, particularly because the dependency ratio in China will only get worse given her population control measures.

Second, the dependent variables used in the analyses were measures of weight, physical activity and diet. These measures in and of themselves are not necessarily a good indicator of health status. Diagnoses of chronic diseases may be more appropriate outcomes to use. However, analysis based on health outcomes first requires a good understanding of the contributing dynamics among physical activity, diet and weight, and the nature of these relationships across built and economic environments.

Third, there are some data limitations that may compromise the findings. For example, the use of MET-hours per week to quantify energy expenditure does not take account for individual differences that may alter the energy cost of movements (such as basal metabolic rates). Nonetheless, this approach is the best available way to systematically apply average energy cost estimates in self-reported measures (Matthews, 2002). Moreover, I included multiple sources of occupational and domestic activity to allow a more complete assessment of physical activity.

The wide range of elasticity estimates and the different estimates depending on the time period studied and the types of data used suggest that there is a need for continued collection of information regarding individual-level consumption, incomes and representative price data given where people live. There is also a need for more nuanced studies of the effects of price changes for more specific types of foods rather than broad food-groups, especially as new food items enter, spread and gain dominance in the Chinese market (e.g., caloric beverages).

Even though this research has found physical activity to be the more important factor, it does not mean that it is the most appropriate factor to target because the relationship might not be symmetrical since the cost and benefits associated with promoting physical activity or improved dietary choices are likely to be different.

In addition, future work should consider studying gender disparities in the dynamics of weight gain, and should perhaps aim to parse out the various biological processes and social or economic roles that can influence weight gain among population subgroups differently. Joint decisions about time and energy allocation among household members, instead of just considering individuals alone should also be considered, particularly to understand if there are gender and/or generational health disparities based on these joint decisions.

APPENDIX A: NEO-CLASSICAL ECONOMIC THEORY OF WEIGHT

One of the main theories considered in trying the understand the economics of obesity (Lakdawalla & Philipson, 2006; Rashad & Grossman, 2004) is the neo-classical model. This model is based on the idea of maximizing utility under a set of changing constraints due to changes in relative prices of goods, income, and time allocation (Cawley, 2004; Chou, Grossman et al., 2004; Drewnowski & Darmon, 2005; Sturm, 2004).

Most of the empirical work applying this model to nutrition or overweight trends has been done in the context of developed countries, particularly the United States (Cawley, 2004; Kuchler, Tegene et al., 2004; Lakdawalla & Philipson, 2002). Meanwhile, studies on developing countries tend to be descriptive and often limited to aspects of food insecurity (Shariff & Khor, 2005). Studies on emerging economies focus on economic drivers due to the rapid development trajectories of these countries (Guo, Mroz et al., 2000; Guo, Popkin et al., 1999), and are based on the neo-classical model because of its strength in argument and the relative ease with which it can be tested empirically.

Hence, it would be sensible to apply the neo-classical conceptualization of the economics of obesity to the case of China, in attempting to understand individual choices regarding diet, activity levels and the resultant weight changes. This assumes that individuals are rational and forward-looking, making choices about their consumption and physical activity levels given a set of well-defined time, budget and biological constraints (Cawley, 2004; Lakdawalla & Philipson, 2002; Lakdawalla, Philipson et al., 2005; Sturm, 2004). The individual’s weight control problem has been carefully modeled by Cawley (2004) and Lakdawalla and Philipson (2005). I have used Lakdawalla and Philipson’s approach as the basis for modeling the dynamics of weight change under the neo-classical framework, but have also investigated the role of additional parameters, most notably urbanization and price factors, in affecting the steady state determinants of weight, food consumption and physical activity.

Dynamics of Weight Change

I follow Lakdawalla et al. (2005), where an individual's utility in current period, *t*, depends on food consumption, *F*, other consumption, *C*, and current weight, *W*. We can write this as $U_t (F_t, C_t, W_t)$, where *U* rises in food consumption and other consumption, but is only monotonically increasing in weight if current weight is less than ideal weight, $\ddot{W}$, otherwise *U* declines in *W*. To summarize, the partial derivations of utility with respect to each argument are: $U_F \geq 0$; $U_C \geq 0$; $U_W \geq 0$ if $W \leq \ddot{W}$; and $U_W < 0$ if $W > \ddot{W}$.

In reality, food intake is multi-dimensional, comprising of calories, the nutritional content of foods eaten, and the types of foods eaten. For simplicity, in this modeling section I only consider food intake as a scalar. Let's assume that food consumption and other consumption are not substitutes in the sense that $U_{FC} \geq 0$. We also assume that there is no direct utility from activity, *A*. Instead, *A* is a determinant of weight and affects utility indirectly through its effect on weight. This is because it not clear if this effect is positive or negative since U_A could be > 0 for people who enjoy exercise, and < 0 for people who do not.

Let's consider an individual who manages weight according to a dynamic problem where his weight, *W* is the state variable. Weight is a capital stock that depreciates over time (where δ can be thought of as basal metabolism, because holding food intake and activity constant, there is some metabolic cost of living to the next period), and can be accumulated by food consumption, *F*, or decreased by activity, *A*. Moreover, an individuals' activity level depends on how developed a place he or she lives and works is, *D*, such that $A_t = A(D_t)$. Thus, an individual's weight at time *t*, depends on prior period's weight, food consumption and activity level:

(A1) $$W_t = (1-\delta)W_{t-1} + g(F_{t-1}, A(D_{t-1})),$$

where $\delta < 1$ and *g* is continuous, concave, increasing in food consumption and decreasing in activity level ($g_F \geq 0$ and $g_A \leq 0$). This is also known as the transition equation.

Over multiple time periods, an individual's value function (or lifetime-indirect utility) depends on the current period's utility and the value function from future time periods, such that:

(A2) $$v(W_t) = \max_{F,C,W} \{U_t(F_t, C_t, W_t) + \beta v(W_{t+1})\},$$

where β is the discount factor. This is subject to the transition equation mentioned above, and a budget constraint: $p_F F + p_c C \leq I$, where p_F, and p_c are the prices of food and other consumption goods respectively. Standardizing by p_c, we can write the budget constraint as:

(A3) $$C \leq I - p_F F\ .$$

Combining Eq (A2) and Eq (A3), and taking the first order conditions with respect to F_t and C_t, and setting them to zero so that one is maximizing their utility, gives:

(A4) $$U_F(F_t, W_t) + \beta v'(W_{t+1}) g_F = U_C[F_t, (I_t - p_F F_t), W_t]\ .$$

That is: Marginal utility of eating plus discounted marginal utility of weight in future period due to eating equals the marginal utility of consuming other goods.

Taking first order conditions of Eq (A2) with respect to W, we can get the envelope theorem:

(A5) $$v'(W_t) = U_W[F_t, (I_t - p_F F), W_t] + \beta(1-\delta)v'(W_{t+1})\ ,$$

which shows that the long run marginal value of weight is equal to the marginal utility of weight in the current period plus the discounted marginal utility of weight.

These will yield a steady-state in food consumption, activity and weight as long as the marginal utility of food consumption is falling in weight, and that the marginal utility of activity is rising in weight. Rewriting the optimality condition,

(A6) $$v'\{W + g[F_t, A(D_t)]\} = \left[(p_F U_C - U_F)/g_F\right],$$

which is the marginal benefit of weight in the future equaling the marginal cost of spending on weight change.

Steady State Determinants of Weight

The steady state choices of weight, food consumption and physical activity can be determined by income, I, food prices, p_F, and urbanization, D, such that $W^*(I, p_F, D)$, $F^*(I, p_F, D)$, $A^*(I, p_F, D)$. If these factors are exogenous to weight, diet and physical activity, and vary spatially and over time, then they would make ideal instruments for use in correcting for the simultaneity bias and autocorrelation found in estimating weight dynamics.

Food Prices

Increasing the price of food, p_F, raises the marginal cost of spending on food, but the marginal benefit of weight tomorrow remains the same. An increase in the price of food decreases the marginal "joy of eating", so food consumption decreases, so that $F_{pF}^*(p_F, D, I) < 0$. The decrease in food consumption will have a negative effect on weight, so that $W_{pF}^*(p_F, D, I) < 0$. Hence, prices are important determinants of weight change and are exogenous factors that need to be included in any structural modeling of weight change.

Income

W_I^* can have an inverted U-shape so that increases in income will initially raise weight, but at high levels of income, further increases could actually lower weight such that $U_{WC} > 0$ for the underweight but $U_{WC} < 0$ for the overweight. This is because an increase in income lowers the marginal cost of spending on weight gain (food consumption), and also affects the marginal value of weight, v', depending on whether an individual is under- or over-weight (relative to their ideal weight, $\ddot{W}$). For the underweight, increase in income raises U_W because it raises the marginal utility of being close to ideal weight. Conversely, for the overweight, an increase in income lowers U_W because it raises the marginal disutility of being overweight, which thus lowers the marginal benefit of gaining weight. In addition, among the underweight ($W < \ddot{W}$), as income rises, weight may increase until $W = \ddot{W}$, at which point, the individual will no longer place any value on weight gain. However, among the overweight ($W > \ddot{W}$), weight may fall as income rises until $W = \ddot{W}$, at which point, the individual will no longer place any value on weight loss. Thus, $W_I^*(p_F, p_H, I) > 0$ if $W < \ddot{W}$, but $W_I^*(p_F, p_H, I) < 0$ if $W > \ddot{W}$.

The effects on food consumption are identical. For the underweight, increase in income raises U_F, so $F_I^*(p_F, I, D) > 0$ if $W < \ddot{W}$. However, for the overweight, an increase in income lowers U_F because it raises the marginal disutility of being overweight, which thus lowers the marginal benefit of eating: $F_I^*(p_F, I, D) < 0$ if $W > \ddot{W}$.

Income can also affect one's activity level, such that A is a function of job characteristics which are also reflected in earned income. This is like a substitution effect (i.e., the quantity of activity changes but the individual derives the same level of utility). Hence, the total effect of income on weight includes the direct income effect along with effect of earned income on activity levels, $dW^*/dI = W_I^* + W_A A_I (p_F, I, D)$

Assume that $W_A < 0$ since holding all else constant, increasing activity levels should lead to decreasing weight. However, as discussed above, the direct effect of income on weight can be positive for those who are underweight and can be negative for those who are overweight. In addition, it is not clear what the relationship between income and activity level is.

However, for a developing country with a large rural population, such as China, those who are poorer generally work in areas that require greater physical activity. Thus, I assume that $A_I < 0$. This means that the total effect of income on weight will be positive when an individual is underweight, or when an individual is overweight and the negative direct effect of income on weight is less than the indirect effect of activity level on weight. The total effect of income on weight will only be negative when an individual is overweight and the negative direct effect of income on weight is greater than the indirect effect of activity level on weight.

Urbanization

Community level urbanization, *D* is exogenous to individual choice assuming that people who move to other communities do not do so based primarily on these community-level characteristics. It can certainly affect prices of food, other consumption goods, and income, such that increased development will lower prices and raise incomes. Hence it can be thought of as an argument for p_F, and *I*. Using chain rule, the effect of urbanization on food consumption and activity levels are $F_D^* > 0$ and $A_D^* < 0$. The effect of urbanization on weight will depend on the relationships between income, prices and weight:

W_D^* > 0 if $dW/dI > 0$

> 0 if $dW/dI < 0$ and $(dp_F/dD)\cdot(dW/dp_F) > |(dI/dD)\cdot(dW/dI)|$

< 0 if $dW/dI < 0$ and $(dp_F/dD)\cdot(dW/dp_F) < |(dI/dD)\cdot(dW/dI)|$

The direction of these effects should not be surprising. Urbanization would certainly lower physical activity at work due to shifts in labor market needs and job functions, access to technologies that aid work and domestic activities, and availability of motorized transportation, for example. Also, one would expect urbanization at the community level to reduce food prices such as through lowering transportation costs, and lessening the time costs involved in purchasing food.

Other Economic Models

Two other models have also been discussed in the literature on the economics of obesity. The rational addiction model is taken from studies of substance use and smoking, and focuses on individual-level non-steady movements such as binging and purging using the idea of marginal utilities and the theories of reinforcement and tolerance (Becker & Murphy, 1988; Gruber & Koszegi, 2001; Levy, 2002). Lastly, the behavioral model discusses within individual time-inconsistencies (Cutler, Glaeser et al., 2003; Gruber & Koszegi, 2001; Komlos, Smith et al., 2004) seen when an individual changes his mind about planned decisions as he approaches the time of actually taking action. However, empirical work based on the rational addiction and behavioral models is limited by their extensive data requirements (which require individual-level thought experiments and choice decisions).

APPENDIX B: CHINA HEALTH AND NUTRITION SURVEY (CHNS)

This research will use the longitudinal and full-household sample design of the China Health and Nutrition Survey (CHNS), a collaborative project of the National Institute of Nutrition and Food Safety (INFS), the Chinese Center for Disease Control and Prevention (CCDC), and the University of North Carolina at Chapel Hill (UNC-CH). The CHNS was designed to study how the socio-economic transformation of Chinese communities and society affect the health and nutritional behaviors and status of its population. Surveys were conducted in 1989, 1991, 1993, 1997, 2000, 2004, and 2006, covering the nine provinces shown on the map (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong). The CHNS has been used by numerous scholars in published works and are listed at http://www.cpc.unc.edu/projects/china/publication.

Sampling

The CHNS sample is diverse in demography, geography, economic development, public resources, and health indicators. A multistage, random cluster process was used to draw the sample surveyed in each of the provinces. Counties in the nine provinces were stratified by income and a weighted sampling scheme was used to randomly select four counties in each province. Villages and townships within the counties and urban and suburban neighborhoods within the cities were selected randomly into primary sampling units (PSUs). The same households were surveyed over time as best possible in order to allow for a panel study, and newly formed households began to be surveyed in 1993.

Figure 16. Map of provinces included in the China Health and Nutrition Surveys (CHNS)

Data Collection and Management

All field work was completed by trained public health workers who were professionally engaged in the nutrition surveys at the provincial and sub-provincial levels. Almost all interviewers were graduates of post-secondary schools; many had four-year degrees. In addition, three days of specific training in the collection of dietary data were provided for this survey. The internal controls on quality of measurement are based on collected measures of selected factors from multiple perspectives and then using the data to refine the measurements. The CHNS data are housed at the Carolina Population Center (CPC) and managed by Dr. Shufa Du. The longitudinal household- and individual-level data are available to the public online (http://www.cpc.unc.edu/projects/china), and the community-level price data are available for researchers upon approval after signing a Data Use Agreement. The data will be organized and analyzed using Stata version 9.0 or 10.0 (StataCorp, 2005, 2007).

Analytic Sample

The CHNS is a longitudinal dataset. Hence, the observation level is person-wave. My analysis requires data on all adults (18-55 years old) interviewed during any of the survey waves. Therefore I will exclude the 1989 wave altogether since health and nutritional data were only collected from adults aged 20-45 in this first wave of the survey. I will also drop observations when: 1) the observation belongs to a household that only has one wave of data for it; or 2) there is missing age, gender, diet or activity data for the individual during a particular wave.

Dependent Variables

Weight and BMI

Trained health workers (in teams of two, with four teams per PSU) collected anthropometric data during a comprehensive physical exam at a local clinic or at the respondent’s home if necessary. Height was measured without shoes to the nearest 0.2 centimeter (cm) using a portable stadiometer; weight was measured without shoes and in light clothing to the nearest 0.1 kg on a calibrated beam scale. Underweight/normal-weight/overweight/obesity statuses were defined using the Body Mass Index (weight in kg/height m^2) cut-off points of 18.5, 25 and 30, respectively (WHO, 1995).

Dietary Intake

Detailed consumption data at both the household and individual level were collected over three consecutive days, which were randomly allocated from Monday to Sunday in order to determine average daily caloric intake (in kcal) and macronutrient intake of protein (in grams; % total energy from protein); fats (in grams; % total energy from fats); and carbohydrates (in grams; % total energy from carbohydrates) for each individual. Household food consumption was determined by examining changes in inventory from the beginning to the end of each day. All processed foods remaining after the last meal before initiation of the survey were weighed and recorded. All purchases, home production, and processed snack foods were also recorded. Whenever foods were brought into the household unit, they were weighed and preparation waste (e.g., spoiled rice, discarded food fed to pets or animals) was estimated when weighing was not possible. At the end of the survey, all remaining foods were again weighed and recorded. The number of household members and visitors were recorded at each meal. Individual dietary intake for the same three consecutive days was surveyed all individuals from 1991 onwards based on daily self-reported 24-hour recalls on all food consumed away from home and at-home. The collection of both household and individual dietary intake allowed for quality checks. Where significant discrepancies were found, the household and the individual in question were revisited and asked about their food consumption in order to resolve these discrepancies (Wang, Ge et al., 2000).

The 1991 Food Composition Table (FCT) for China was utilized to calculate macronutrient (caloric energy, protein and fat) intake values for the dietary data of 2000 and previous years. The UNC-CH group has worked with the National Institute of Nutrition and Food Safety to update and improve this FCT, which represents a significant advancement over the earlier China FCT both for higher quality chemical analyses and for improved techniques of developing average nutrient values for foods whose nutrient value varies over the country in a geographic context. A new version of the FCT (2002) was used for 2004 and 2006 surveys. Due to the rigor in obtaining the data, it is believed that reporting errors on household members and the measurement errors of food consumed were minimized.

Physical Activity

<u>Occupational activity</u>

Respondents reported wage-earning occupation(s) worked in the last year from jobs both market-sector jobs as well as those worked from home. Data were included from up to two market-based jobs; home-based jobs included working on a farm, working in a vegetable garden or orchard, raising livestock or poultry, work fishing, and working in a home business. For each occupation, respondents reported the average number of hours per week worked in the last year. Adult respondents were also directly interviewed as part of their individual dietary intake survey about the activity level of their occupations that produced income in cash or kind. The interviewers categorized each respondent into five levels of activity (very light, light, moderate, heavy, and very heavy). The

Compendium of Physical Activities (Ainsworth, Haskell et al., 2000) was used to assign specific MET intensity values based on these self-reported occupation types and activity levels (see Table below). Then, time spent in each occupation was multiplied by these MET intensity values to get MET-hours/week. Given the enormous heterogeneity in activities within a narrow occupation, this provides a much more precise measure of energy expenditures at work than a classical measure of occupation.

Table 15. Work METs assigned based on occupation type and self-reported activity level

Assigned METs	**Self-reported activity level**				
Self-reported Occupation Type	Very light	Light	Moderate	Heavy	Very heavy
Market-Based					
Professional/ Administrative/ Office staff	1.25	1.5	2	2.5	2.75
Farmer/ Logger/ Fisherman/ Hunter	1.5	2.5	4	6	8
Technical Skilled Laborer	2	3	4.5	5.5	7
Army/Police Officer	1.5	2	3	4	5
Driver	1.5	2	3	4	5
Service Worker	2	2.5	3	3.5	4
Athlete/Actor/Musician	2	3	4	6	8
Home-Based					
Work on a farm	2.5	3.5	5	6.5	8
Work in a vegetable garden or orchard	1.5	2.5	4	5.5	7
Raise livestock or poultry	1.5	2.5	4	6	8
Fishing	2	2.5	3.5	4.5	6
Work in a home business	1.5	2	3	4	5

Domestic activity

Four different domestic activities were reported: time spent preparing food, buying food, doing laundry, and in childcare. All activities were reported in average hours/week spent in the past year. Time spent in each activity was multiplied by a specific MET intensity value; final units were

MET-hours/week. The Compendium of Physical Activities (Ainsworth, Haskell et al., 2000) was used to assign specific MET intensity values: 2.3 for buying food; 2.25 for preparing or cooking food; 2.15 for doing laundry; 2.75 for childcare. Individual MET-hours/week values were summed to obtain total domestic energy expenditure.

Leisure activity

Since 1997, adults (>18 years old) were asked about their participation in leisure physical activities in the past year (whether participated more than 12 times), and the average time spent per week in those activities [U145 – U156]. The Compendium of Physical Activities (Ainsworth, Haskell et al., 2000) was used to assign specific MET intensity values: 4.5 for marital arts; 7.5 for jogging or swimming; 5 for dancing or aerobics; 6 for playing basketball, volleyball, or soccer; 5 for tennis, badminton or ping pong. Time spent in each activity was multiplied by these specific MET intensity value; final units were MET-hours/week. Individual MET-hours/week values were summed to obtain a measure of total leisure energy expenditure.

Travel Activity

Since 1997, adults (>18 years old) were asked about their mode and time spent traveling to and from work or school. The Compendium of Physical Activities (Ainsworth, Haskell et al., 2000) was used to assign specific MET intensity values: 3 if traveled by walking; 4 if traveled by bicycling; 1.5 for driving or riding a motorized vehicle. Time spent in each activity was multiplied by these specific MET intensity value; final units were MET-hours/week. Individual MET-hours/week values were summed to obtain a measure of total travel energy expenditure.

Total physical activity

For 1997 through 2006 only, this is derived from summing occupational, domestic, leisure and travel MET-hours/week.

Exogenous Explanatory Variables

Prices

There were three sources of price information for a representative basket of goods. These include state store prices, free market prices collected from visits to stores in the communities surveyed, and authority price records published by the State Statistical Bureau (SSB) of China, which provides the provincial average. The state store prices were no longer used after the 1991–1992 price reform in China. Therefore, in almost all situations, the free market prices will be used as the basis, except when the goods studied were not sold in the free market, in which case, prices from the state stores will be used, followed by SSB recorded prices if the other two sources do not have the information. Farmers both produce and consume food, which adds complexity to the price issue. However, I would argue that the free market prices for the food can be seen as the opportunity cost of consuming instead of selling the produce. Hence, using free market prices (when available) is appropriate.

Deflation

There is no published absolute consumer price index for China that provides a way to compare prices in provinces or urban and rural areas. Rather the State Statistical Bureau (SSB) publishes annually a consumer price index ratio that shows for urban and rural areas in each province the shift in the cost of living within that geographic area. Thus, the CHNS team created its own cost of living index. To do this, they used a consumer goods basket of 57 items created by the government and urban price data published to create urban costs for this consumer goods basket. The CHNS urban and rural price data were then used to create a ratio of urban and rural costs for elements of this consumer goods basket. These were used to create costs of the consumer basket for each time period for urban and rural areas in each province in the CHNS. Lastly, they set China's food costs for urban Liaoning province for 1988 equal to 1.00 (or 100%) and made all other prices relative to this (CPC, 2006). Price and income variables need to be deflated by these in order to remove the effect of inflation and allow the analysis to focus on the effect of the increase in real price and real income.

Community Infrastructure development/ Urbanization

These were exogenous characteristics of the community so that variables were as independent of individual or household choices and behavior as best possible. They reflect changes in various dimensions of infrastructure development over time and will better reflect the environment that people function in. These variables will come from data from the community, and comprise the following ten components as described in Table 16.

Table 16. Community Urbanization scores over time (CHNS 1991–2006)

Community Urbanization scores (standardized to 0-10)		Statistics	1991	1997	2006
Population	2, 4, 6, 8 and 10 points assigned based on cut-points of 1000,1500, 2000, 3000 people determined by the distribution of the CHNS data and the standard strategies for classifying areas as urban or rural (United Nations Economic and Social Commission for Asia and the Pacific, 1993).	Mean	6.1	5.8	7.2
		Std. Dev.	2.9	3.0	3.0
		% < 3	19.2	23.0	13.8
		3 ≤ % <6	22.3	23.5	13.8
		% ≥ 6	58.5	53.5	72.5
Density	2, 4, 6, 8 and 10 points assigned based on cut-points of 250, 5000, 1000 and 2000 persons/km^2 determined by the distribution of the CHNS data and the standard strategies for classifying areas as urban or rural (United Nations Economic and Social Commission for Asia and the Pacific, 1993).	Mean	6.8	6.3	6.6
		Std. Dev.	2.8	3.1	3.0
		% < 3	12.8	23.0	18.4
		3 ≤ % <6	17.6	15.5	14.7
		% ≥ 6	697	61.5	67.0
Access to markets	Sum of the availability of seven goods (gains, oil, vegetable, meat, fish, beancurd, and fuel) in major shopping areas within each community at each wave, where one point was assigned for each good available within the community and half-a point was assigned for each good available in a neighboring community < 1 km away[‡].	Mean	4.6	5.1	4.9
		Std. Dev.	3.1	3.5	3.9
		% < 3	36.2	28.9	37.6
		3 ≤ % <6	26.1	28.3	27.5
		% ≥ 6	37.8	42.8	34.9
Transportation infrastructure	Communities were assigned two points each if their leaders reported that the community had mostly paved roads, a bus-stop or train station within their perceived community boundaries and were assigned one point if there was a bus-stop or train station in a neighboring community < 1 km away[‡].	Mean	4.9	5.3	5.8
		Std. Dev.	3.0	2.6	2.6
		% < 3	25.5	17.7	11.5
		3 ≤ % <6	32.5	38.0	32.1
		% ≥ 6	42.0	44.4	56.4
Communication infrastructure	Availability of provincial newspaper, a TV station, a radio station, telephone network, postal service, facsimile and telegraph services and a movie theatre. The information on the TV and radio station availability is based on whether ≥ 20% of households in a community reported having a TV or radio.	Mean	6.5	7.5	6.3
		Std. Dev.	2.5	2.4	2.0
		% < 3	16.0	9.1	8.3
		3 ≤ % <6	28.7	18.2	44.0
		% ≥ 6	55.3	72.7	47.7
Economic Wellbeing	Based on community records or leaders' report of % employment in non-agricultural jobs, % employment fully within the community, and average male wage.	Mean	3.4	4.9	6.7
		Std. Dev.	1.1	2.4	1.9
		% < 3	47.9	29.4	0.9
		3 ≤ % <6	52.1	44.9	35.8
		% ≥ 6	0.0	25.7	63.3
Educational Institution	Each of the five possible levels of schooling (preschool, elementary, middle, high, and vocational schools) was assigned two points if the school was located within the community. For all institutions except preschools and elementary schools, one point was assigned if the school was not in the community but was < 5 km outside the community[‡].	Mean	6.0	7.0	8.1
		Std. Dev.	2.8	2.7	2.6
		% < 3	19.7	8.6	6.9
		3 ≤ % <6	19.7	18.7	9.6
		% ≥ 6	60.6	72.7	83.5

Community Urbanization scores (standardized to 0-10)		Statistics	1991	1997	2006
Health Facilities	Health facilities available within the community were given 1 point for each village or work unit clinic, 2 points for neighborhood or maternal child health (MCH) clinics, 3 points for town hospital, 4 points for district hospital, 5 points for county, work unit or army hospital, 6 points for private for city hospital, and 7 points for university hospital. Facilities available outside the community but < 10km away‡ were given half of the listed points.	Mean	6.7	6.8	5.8
		Std. Dev.	2.2	2.3	2.7
		% < 3	4.8	8.6	21.1
		3 ≤ % <6	33.5	28.3	26.2
		% ≥ 6	61.7	63.1	52.8
Sanitation infrastructure	Based on percentage of households in each community reporting availability of water treatment plant, and each household's overall index of the presence or absence of excreta in the vicinity (based on interviewers' observation).	Mean	5.9	6.7	7.7
		Std. Dev.	4.0	3.7	3.1
		% < 3	23.9	16.0	6.4
		3 ≤ % <6	33.0	33.7	33.9
		% ≥ 6	43.1	50.3	59.6
Housing infrastructure	Based on percentage of households in each community reporting use of natural gas, piped water, indoor toilets and electric lighting, and on community-level reports on the availability and reliability of electricity (hours/day).	Mean	3.6	5.5	7.3
		Std. Dev.	2.7	2.9	2.2
		% < 3	55.3	30.5	4.6
		3 ≤ % <6	28.2	25.1	28.0
		% ≥ 6	16.5	44.4	67.4
	Number of communities		188	187	218

Only reporting data from 1991, 1997 and 2006 because these are the baselines and final wave of interest. Questionnaires used in the China Health and Nutrition Surveys can be found at the survey's website (CPC, 2008).‡ For items involving distances, these were relative to the center of the community, determined by latitudes and longitudes on official maps.

Geographical markers

Region and Province

The measurement of region was developed by the World Bank in collaboration with the SSB (World Bank, 1995) reflecting contiguous groupings with comparable income levels. With respect to agricultural economics and food behavior, samples from the nine provinces of the CHNS were regrouped into three regions: the North (Liaoning, Heilongjiang, Shangdong); the Central Core (Henan, Hubei, Jiangsu); and the South Hinterland (Guizhou, Guangxi, Hunan).

Urban/rural

Communities were coded as either urban or rural based on geographical identifying data.

Age

It is difficult to obtain an accurate age in China because the Western and Chinese calendars are used interchangeably. To ensure consistency all Chinese lunar calendar dates were converted to Western dates, and reported birth dates were used to calculate age at the time of the interviews. Note that the average age of the sample will increase with time due to an 'aging effect' of a longitudinal sample. The analysis will also use age-splines or the square of age to test if the relationship between age and the independent variables may be non-linear.

Year/Time

The year variables are a set of dummy variables for the wave of the CHNS that observation is from. A variable for time since baseline (1991) and a squared version of that will also be created.

Endogenous Explanatory Variables

Health behaviors (alcohol consumption and smoking)

The CHNS asked respondents whether they drank any beer or other alcohol beverage in the past year; and if they are current smokers. These will be included in the analyses to control for health behaviors. This is particularly because some studies have shown that smoking is negatively related to food intake. I plan to use real prices of common cigarettes and local beer which were obtained at the community level as instruments for current smoking and drinking status respectively.

Household Income

Household income can be approximated from each wave of the CHNS through responses to direct questions about income and through the summation of net receipts from all reported activities. This detailed estimation of income represents a significant advance in the measurement of income in China, allowing the inclusion of non-monetary government subsidies, such as state-subsidized housing. I will assume that income is indeed zero if it is reported in the data and when all individuals in the household reported themselves to be unemployed (in the market and also home production). Otherwise, for missing income information, I will impute it by taking predictions from individuals with reported income based on their education, age, gender and housing characteristics.

Education

Each respondent was asked to report years of completed schooling they had (in years) and the highest level of schooling (primary, lower middle, upper middle, vocational/technical, college/university, masters or higher), which will be coded into a set of dummy variables.

REFERENCES

Acs, Z. J., & Lyles, A. (Eds.). (2007). *Obesity, Business and Public Policy*. Cheltenham, U.K. and Northhampton, Mass.: Edward Elgar.

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J., et al. (2000). Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc, 32*(9 Suppl), S498-504.

Ainsworth, B. E., Richardson, M. T., Jacobs, D. R., Jr., Leon, A. S., & Sternfeld, B. (1999). Accuracy of recall of occupational physical activity by questionnaire. *J Clin Epidemiol, 52*(3), 219-227.

Alonso-Borrego, C., & Arellano, M. (1999). Symmetrically Normalized Instrumental-Variable Estimation Using Panel Data. *Journal of Business & Economic Statistics, 17*(1), 36-49.

Angeles, G., Guilkey, D., & Mroz, T. A. (2002). *The Impact of Community Level Variables on Individual Level Outcomes: Theoretical Results and Demographic Applications*. Chapel Hill, N.C.: University of North Carolina at Chapel Hill.

Arbués, F., Barberán, R., & Villanúa, I. (2004). Price impact on urban residential water demand: A dynamic panel data approach. *Water Resrouce Research, 40*(W11402).

Arellano, M., & Bond, S. (1998). *Dynamioc Panel Data Estimation Using DPD98 for Gauss: A Guide for Users*.Unpublished manuscript, London.

Astrup, A. (1999). Macronutrient balances and obesity: the role of diet and physical activity. *Public Health Nutr, 2*, 341-347.

Becker, G. S., & Murphy, K. M. (1988). A Theory of Rational Addiction. *Journal of Political Economy, 96*(4), 675-700.

Bell, A. C., Ge, K., & Popkin, B. M. (2001). Weight gain and its predictors in Chinese adults. *Int J Obes Relat Metab Disord, 25*(7), 1079-1086.

Bell, A. C., Ge, K., & Popkin, B. M. (2002). The road to obesity or the path to prevention: motorized transportation and obesity in China. *Obes Res, 10*(4), 277-283.

Bloom, D. E., Canning, D., & Malaney, P. N. (2000). Population Dynamics and Economic Growth in Asia. *Population and Development Review, 26*, 257-290.

Blumenthal, D., & Hsiao, W. (2005). Privatization and Its Discontents -- The Evolving Chinese Health Care System. *N Engl J Med, 353*(11), 1165-1170.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics, 87*(1), 115-143.

Blundell, R., & Bond, S. (2000). GMM Estimation with persistent panel data: an application to production functions. *Econometric Reviews, 19*(3), 321 - 340.

Blundell, R., Bond, S., & Windmeijer, F. (2000). *Estimation in dynamic panel data models: improving on the performance of the standard GMM estimator*: Institute for Fiscal Studies.

Blundell, R., Pashardes, P., & Weber, G. (1993). What do we Learn About Consumer Demand Patterns from Micro Data? *The American Economic Review, 83*(3), 570-597.

Bond, S. R. (2002). Dynamic panel data models: a guide to micro data methods and practice. *Portuguese Economic Journal, 1*(2), 141.

Box, G. E. P., & Cox, D. R. (1964). An Analysis of Transformations. *Journal of the Royal Statistical Society. Series B (Methodological), 26*(2), 211-252.

Bradsher, K. (2007, June 8, 2007). Rise in China's Pork Prices Signals End to Cheap Output. *New York Times*, from http://www.nytimes.com/2007/06/08/business/worldbusiness/08prices.html

Bray, G. A., Paeratakul, S., & Popkin, B. M. (2004). Dietary fat and obesity: a review of animal, clinical and epidemiological studies. *Physiol Behav, 83*(4), 549-555.

Bray, G. A., & Popkin, B. M. (1998). Dietary fat intake does affect obesity! *Am. J. Clinical Nutrition, 68*(6), 1157-1173.

Brown, T. T., Coffman, J. M., Quinn, B. C., Scheffler, R. M., & Schwalm, D. D. (2006). Do Physicians Always Flee from HMOs? New Results Using Dynamic Panel Estimation Methods. *Health Services Research, 41*(2), 357-373.

Caballero, B. (2001). Introduction. Symposium: Obesity in developing countries: biological and ecological factors. *J Nutr, 131*(3), 866S-870S.

Caballero, B. (2005). A nutrition paradox - Underweight and obesity in developing countries. *New England Journal of Medicine, 352*(15), 1514-1516.

Cameron, A. C., & Trivedi, P., K. (2005). *Microeconometrics: Methods and Applications*. New York: Cambridge University Press.

Capps, O. J., & Schmitz, J. (1991). A Recognition of Health and Nutrition Factors in Food Demand Analysis. *Western Journal of Agricultural Economics, 16*(1), 21-35.

Caraher, M., & Cowburn, G. (2005). Taxing food: implications for public health nutrition. *Public Health Nutrition, 8*(08), 1242-1249.

Carstensen, K., & Toubal, F. (2004). Foreign direct investment in Central and Eastern European countries: a dynamic panel analysis. *Journal of Comparative Economics, 32*(1), 3-22.

Cash, S., Sunding, D., & Zilberman, D. (2005). Fat taxes and thin subsidies: Prices, diet, and health outcomes. *Acta Agriculturae Scandinavica, Section C - Economy, 2*, 167-174.

Cawley, J. (2004). An economic framework for understanding physical activity and eating behaviors. *American Journal of Preventive Medicine, 27*(3), 117-125.

CDC. (2000). *Promoting Physical Activity: A Best Buy in Public Health*. Hyattsville, MD: Centers for Disease Control and Prevention.

Chen, C. M., Zhao, W., Yang, Z., Zhai, Y., Wu, Y., & Kong, L. (2008). The role of dietary factors in chronic disease control in China. *Obes Rev, 9 Suppl 1*, 100-103.

China Daily. (2008, January 24, 2008). Manufacturers urged to use nutrition labels. *China Daily*. Retrieved January 27, 2009, from http://www.china.org.cn/english/government/240517.htm

Chiolero, A., Faeh, D., Paccaud, F., & Cornuz, J. (2008). Consequences of smoking for body weight, body fat distribution, and insulin resistance. *Am J Clin Nutr, 87*(4), 801-809.

Chou, S. Y., Grossman, M., & Saffer, H. (2004). An economic analysis of adult obesity: results from the Behavioral Risk Factor Surveillance System. *Journal of Health Economics, 23*(3), 565-587.

Cohen, D. A. (2008). Obesity and the built environment: changes in environmental cues cause energy imbalances. *Int J Obes, 32*(S7), S137-S142.

Cole, T. J., Bellizzi, M. C., Flegal, K. M., & Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *Bmj, 320*(7244), 1240-1243.

CPC. (2006). Creation of our CHNS Consumer Price Index for equating Income in the CHNS. 2006, from http://www.cpc.unc.edu/projects/china/data/documentation/income/cprindex.0800.pdf

CPC. (2008). China Health and Nutrition Surveys: Questionnaires/Interviewer Manual. 2008, from http://www.cpc.unc.edu/projects/china/data/questionnaires.html

Cutler, D. M., Glaeser, E. L., & Shapiro, J. M. (2003). Why have Americans become more obese? *Journal of Economic Perspectives, 17*(3), 93-118.

Davidson, R., & MacKinnon, J. G. (1985). Testing Linear and Loglinear Regressions against Box-Cox Alternatives. *The Canadian Journal of Economics / Revue canadienne d'Economique, 18*(3), 499-517.

Davison, A. C., & Hinkley, D. V. (1997). *Bootstrap methods and their application*. Cambridge; New York, NY, USA: Cambridge University Press.

De Backer, G. G., & De Bacquer, D. (2004). Be physically active: the best buy in promoting heart health. *Eur Heart J, 25*(24), 2183-2184.

De Stefano, G. F., Hauser, G., & Neumuller, J. (2004). Growth and malnutrition in Ethiopia. *Collegium Antropologicum, 28*, 133-140.

Deaton, A., & Muellbauer, J. (1980). An Almost Ideal Demand System. *American Economic Review, 70*(3), 312.

Delgado, C. L. (1999). *Livestock to 2020: The Next Food Revolution*. Washington, DC: IFPRI.

Delgado, C. L., Rosegrant, M., & Meijer, S. (2001). *Livestock to 2020: The Revolution Continues*. Paper presented at the International Agricultural Trade Research Consortium. from http://www.iatrcweb.org/oldiatrc/Papers/Delgado.pdf

Drewnowski, A., & Darmon, N. (2005). The economics of obesity: dietary energy density and energy cost. *American Journal of Clinical Nutrition, 82*(1), 265s-273s.

Du, S., Lu, B., Zhai, F., & Popkin, B. M. (2002). A new stage of the nutrition transition in China. *Public Health Nutr, 5*(1A), 169-174.

Du, S., Mroz, T. A., Zhai, F., & Popkin, B. M. (2004). Rapid income growth adversely affects diet quality in China particularly for the poor! *Social Science & Medicine, 59*(7), 1505-1515.

Dulloo, A. G. (2008). Thrifty energy metabolism in catch-up growth trajectories to insulin and leptin resistance. *Best Practice & Research Clinical Endocrinology & Metabolism, 22*(1), 155-171.

Dulloo, A. G., Jacquet, J., Seydoux, J., & Montani, J. P. (2006). The thrifty `catch-up fat' phenotype: its impact on insulin sensitivity during growth trajectories to obesity and metabolic syndrome. *Int J Obes, 30*(S4), S23-S35.

Durstine, J. L., Grandjean, P. W., Davis, P. G., Ferguson, M. A., Alderson, N. L., & DuBose, K. D. (2001). Blood lipid and lipoprotein adaptations to exercise: a quantitative analysis. *Sports Med, 31*(15), 1033-1062.

Elston, J. A., Stanton, K. R., Levy, D. T., & Acs, Z. J. (2007). Tax solutions to the external costs of obesity. In Z. J. Acs & A. Lyles (Eds.), *Obesity, Business and Public Policy* (pp. 171-190). Cheltenham, U.K. and Northampton, Mass.: Edward Elgar Publishing.

Fan, S. G., Wailes, E. J., & Cramer, G. L. (1995). Household demand in rural China: a two-stage LES-AIDS model *American Journal of Agricultural Economics, 77*(1), 54-62.

Ferraro, R., Lillioja, S., Fontvieille, A. M. R., R., Bogardus, C., & Ravussin, E. (1992). Lower sedentary metabolic rate in women compared with men. *J Clin Invest 90*(3), 780-784.

Fezeu, L., Minkoulou, E., Balkau, B., Kengne, A. P., Awah, P., Unwin, N., et al. (2006). Association between socioeconomic status and adiposity in urban Cameroon. *International Journal of Epidemiology, 35*(1), 105-111.

Flegal, K. M., Williamson, D. F., Pamuk, E. R., & Rosenberg, H. M. (2004). Estimating deaths attributable to obesity in the United States. *American Journal of Public Health, 94*(9), 1486-1489.

Folsom, A. R., Li, Y., Rao, X., Cen, R., Zhang, K., Liu, X., et al. (1994). Body mass, fat distribution and cardiovascular risk factors in a lean population of South China. *Journal of Clinical Epidemiology, 47*(2), 173-181.

Forsyth, A., Hearst, M., Oakes, J. M., & Schmitz, K. H. (2008). Design and Destinations: Factors Influencing Walking and Total Physical Activity. *Urban Stud, 45*(9), 1973-1996.

Frazao, E., & Allshouse, J. (2003). Strategies for Intervention: Commentary and Debate. *J. Nutr., 133*(3), 844S-847.

French, S. A. (2003). Pricing Effects on Food Choices. *J. Nutr., 133*(3), 841S-843.

Frisancho, A. R. (2003). Reduced rate of fat oxidation: A metabolic pathway to obesity in the developing nations. *American Journal of Human Biology, 15*(4), 522-532.

Gale, F., & Huang, K. (2007). *Demand for Food Quantity and Quality in China* (No. 32). Washington, DC: US Department of Agriculture.

Gao, X. M., Wailes, E. J., & Cramer, G. L. (1996). A Two-Stage Rural Household Demand Analysis: Microdata Evidence from Jiangsu Province, China. *American Journal of Agricultural Economics, 78*(3), 604-613.

Ge, K., Weisell, R., Guo, X., Cheng, L., Ma, H., Zhai, F., et al. (1994). The body mass index of Chinese adults in the 1980s. *Eur J Clin Nutr, 48 Suppl 3*, S148-154.

Gould, B. W. (2002). Household composition and food expenditures in China. *Agribusiness, 18*(3), 387-407.

Gould, B. W., & Villarreal, H. J. (2006). An assessment of the current structure of food demand in urban China. *Agricultural Economics, 34*(1), 1-16.

Gruber, J., & Koszegi, B. (2001). Is addiction "rational"? Theory and evidence. *Quarterly Journal of Economics, 116*(4), 1261-1303.

Gu, D. F., Jiang, H., Wu, X. G., Reynolds, K., Gan, W. Q., Liu, D. H., et al. (2003). Prevalence, awareness, treatment and control of hypertension in Chinese adults. *Zhonghua Yu Fang Yi Xue Za Zhi, 37*(2), 84-89.

Guldan, G. S., Zhang, Y., Li, Z., Hou, Y., Long, F., Pu, L., et al. (1991). Designing Appropriate Nutrition Education for the Chinese: the Urban and Rural Nutrition Situation in Sichuan. *J Trop Pediatr, 37*(4), 159-165.

Guo, X. G., Mroz, T. A., Popkin, B. M., & Zhai, F. Y. (2000). Structural change in the impact of income on food consumption in China, 1989-1993. *Economic Development and Cultural Change, 48*(4), 737-760.

Guo, X. G., Popkin, B. M., Mroz, T. A., & Zhai, F. (1999). Food price policy can favorably alter macronutrient intake in China. *Journal of Nutrition, 129*(5), 994-1001.

Haddad, L. (2003). Redirecting the Diet Transition: What Can Food Policy Do? *Development Policy Review, 21*(5-6), 599-614.

Haines, P. S., Guilkey, D. K., & Popkin, B. M. (1988). Modeling Food Consumption Decisions as a Two-Step Process. *American Journal of Agricultural Economics, 70*(3), 543-552.

Harnack, L., & Schmitz, K. (2006). The Role of Nutrition and Physical Activity in the Obesity Epidemic. In C. D & J. R (Eds.), *Obesity Prevention in the 21st Century: Public Health Approaches to Tackle the Obesity Pandemic* (pp. 21-36). New York: Oxford.

Haskell, W. L., Lee, I.-M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., et al. (2007). *Physical Activity and Public Health: Updated Recommendation for Adults from the American College of Sports Medicine and the American Heart Association*: American College of Sports Medicine and American Health Association.

Hausman, J. A. (1978). Specification Tests in Econometrics. *Econometrica, 46*(6), 1251-1271.

Hawkes, C. (2008). Agro-food industry growth and obesity in China: what role for regulating food advertising and promotion and nutrition labelling? *Obesity Reviews, 9*(s1), 151-161.

Heckman, J. J. (1979). Sample Selection Bias as a Specification Error. *Econometrica, 47*(1), 153-161.

Hofstetter, A., Schutz, Y., Jequier, E., & Wahren, J. (1986). Increased 24-hour energy expenditure in cigarette smokers. *N Engl J Med, 314*(2), 79-82.

Hong, Y., Bots, M. L., Pan, X., Wang, H., Jing, H., Hofman, A., et al. (1994). Physical Activity and Cardiovascular Risk Factors in Rural Shanghai, China. *Int. J. Epidemiol., 23*(6), 1154-1158.

Horioka, C. Y.-J., & Wan, J.-M. (2006). *The Determinants of Household Saving in China: A Dynamic Panel Analysis of Provincial Data*: National Bureau of Economic Research, Inc.

Hu, D., Reardon, T., Rozelle, S., Timmer, C. P., & Wang, H. (2004). The Emergence of Supermarkets with Chinese Characteristics: Challenges and Opportunities for China's Agricultural Development. *Development Policy Review, 22*(5), 557-586.

Hu, F. B., Sigal, R. J., Rich-Edwards, J. W., Colditz, G. A., Solomon, C. G., Willett, W. C., et al. (1999). Walking compared with vigorous physical activity and risk of type 2 diabetes in women: a prospective study. *JAMA, %20;282*, 1433 - 1439.

Hu, F. B., Wang, B., Chen, C., Jin, Y., Yang, J., Stampfer, M. J., et al. (2000). Body Mass Index and Cardiovascular Risk Factors in a Rural Chinese Population. *Am. J. Epidemiol., 151*(1), 88-97.

Hu, G., Tuomilehto, J., Silventoinen, K., Barengo, N. C., Peltonen, M., & Jousilahti, P. (2005). The effects of physical activity and body mass index on cardiovascular, cancer and all-cause mortality among 47 212 middle-aged Finnish men and women. *Int J Obes (Lond), 29*, 894 - 902.

Huang, J., & David, C. C. (1993). Demand for cereal grains in Asia: the effect of urbanisation. *Agricultural Economics, 8*, 107-124.

Hussain, A. (2002). Demographic Transition in China and its Implications. *World Development, 30*(10), 1823-1834.

Institute of Nutrition and Food Hygiene. (1991). *Chinese Food Composition Tables 1991* Beijing, PRC: People’s Health Publishing House

Institute of Nutrition and Food Hygiene. (2002). *China Food Composition Table 2002*. Beijing, PRC: Beijing Medical University Publishing House.

Jacobson, M. F., & Brownell, K. D. (2000). Small taxes on soft drinks and snack foods to promote health. *Am J Public Health, 90*(6), 854-857.

James, W. P., & Ralph, A. (1999). New understanding in obesity research. *Proc Nutr Soc, 58*(2), 385-393.

Janus, E. D., Postiglione, A., Singh, R. B., & Lewis, B. (1996). The modernization of Asia. Implications for coronary heart disease. Council on Arteriosclerosis of the International Society and Federation of Cardiology. *Circulation, 94*(11), 2671-2673.

Jiang, B., & Davis, J. (2007). Household food demand in rural China. *Applied Economics, 39*, 373-380.

Kennedy, A., Gettys, T. W., Watson, P., Wallace, P., Ganaway, E., Pan, Q., et al. (1997). The Metabolic Significance of Leptin in Humans: Gender-Based Differences in Relationship to Adiposity, Insulin Sensitivity, and Energy Expenditure. *J Clin Endocrinol Metab, 82*(4), 1293-1300.

King, A. C., Frey-Hewitt, B., Dreon, D. M., & Wood, P. D. (1989). Diet vs exercise in weight maintenance. The effects of minimal intervention strategies on long-term outcomes in men. *Arch Intern Med, 149*(12), 2741-2746.

Klesges, R. C., Klesges, L. M., Haddock, C. K., & Eck, L. H. (1992). A longitudinal analysis of the impact of dietary intake and physical activity on weight change in adults. *Am J Clin Nutr, 55*(4), 818-822.

Komlos, J., Smith, P. K., & Bogin, B. (2004). Obesity and the rate of time preference: Is there a connection? *Journal of Biosocial Science, 36*(2), 209-219.

Kuchler, F., Tegene, A., Harris, J. M., & United States. Dept. of Agriculture. Economic Research Service. (2004). *Taxing snack foods what to expect for diet and tax revenues*. Washington, D.C.: Economic Research Serivce U.S. Dept. of Agriculture.

Lakdawalla, D., & Philipson, T. J. (2002). *The Growth of Obesity and Technological Change: A Theoretical and Empirical Examination*.Unpublished manuscript.

Lakdawalla, D., & Philipson, T. J. (2006). Economics of Obesity. In A. M. Jones (Ed.), *The Elgar companion to health economics* (pp. 72-82). Massachusetts: Edward Elgar Publishing Inc.

Lakdawalla, D., Philipson, T. J., & Bhattacharya, J. (2005). Welfare-enhancing technological change and the growth of obesity. *American Economic Review, 95*(2), 253-257.

Levy, A. (2002). Rational eating: can it lead to overweightness or underweightness? *Journal of Health Economics, 21*(5), 887-899.

Li, L., & Jiang, J. (2007). Turning Point of Chinese Health Care Reform (in Chinese). *Chinese Health Economics, 126*(4), 5-9.

Liu, S., Serdula, M. K., Williamson, D. F., Mokdad, A. H., & Byers, T. (1994). A prospective study of alcohol intake and change in body weight among US adults. *Am J Epidemiol, 140*(10), 912-920.

Liu, Y. (2002). Reforming China's urban health insurance system. *Health Policy, 60*(2), 133-150.

Lopez, A. D., Mathers, C., Ezzati, M., Jamison, D. T., & Murray, C. J. L. (2006). *Global Burden of Disease and Risk Factors* Washington DC.: World Bank Publications.

Lovejoy, J. C., & Sainsbury, A. (2009). Sex differences in obesity and the regulation of energy homeostasis. *Obesity Reviews, 10*(2), 154-167.

Ma, J., Lu, M., & Quan, H. (2008). From A National, Centrally Planned Health System To A System Based On The Market: Lessons From China. *Health Aff, 27*(4), 937-948.

Mark, B. A., Harless, D. W., McCue, M., & Xu, Y. (2004). A Longitudinal Examination of Hospital Registered Nurse Staffing and Quality of Care. *Health Services Research, 39*(2), 279-300.

Maskarinec, G., Meng, L. X., & Kolonel, L. N. (1998). Alcohol intake, body weight, and mortality in a multiethnic prospective cohort. *Epidemiology, 9*(6), 654-661.

Matsuzawa, Y., Nakamura, T., Shimomura, I., & Kotani, K. (1995). Visceral fat accumulation and cardiovascular disease. *Obes Res, 3 Suppl 5*, 645S-647S.

Matthews, C. E. (2002). Use of self-report instruments to assess physical activity. In G. Welk (Ed.), *Physical activity assessments for health-related research* (pp. x, 269). Champaign, IL: Human Kinetics.

McDade, T. W., & Adair, L. S. (2001). Defining the "urban" in urbanization and health: a factor analysis approach. *Soc Sci Med, 53*(1), 55-70.

Meisinger, C., Lowel, H., Thorand, B., & Doring, A. (2005). Leisure time physical activity and the risk of type 2 diabetes in men and women from the general population. The MONICA/KORA Augsburg Cohort Study. *Diabetologia, 48*, 27 - 34.

Mendez, M. A., Du, S., & Popkin, B. M. (2003). *Urbanization, income and the nutrition transition in China: A case study.* Rome, Italy.: United Nations Food and Agricultural Organization.

Michaud, P.-C., & van Soest, A. (2008). Health and wealth of elderly couples: Causality tests using dynamic panel data models. *Journal of Health Economics, 27*(5), 1312-1325.

Miller, W. C., Lindeman, A. K., Wallace, J., & Niederpruem, M. (1990). Diet composition, energy intake, and exercise in relation to body fat in men and women. *Am. J. Clinical Nutrition, 52*(3), 426-430.

Mokdad, A. H., Serdula, M. K., Dietz, W. H., Bowman, B. A., Marks, J. S., & Koplan, J. P. (1999). The spread of the obesity epidemic in the United States, 1991-1998. *Jama-Journal of the American Medical Association, 282*(16), 1519-1522.

Monda, K. L., Adair, L., Zhai, F., & Popkin, B. M. (2007). Longitudinal relationships between Occupational and Domestic Physical Activity patterns and body weight in China. *Eur J Clin Nutr*.

Monda, K. L., Gordon-Larsen, P., Stevens, J., & Popkin, B. M. (2007). China's transition: The effect of rapid urbanization on adult occupational physical activity. *Soc Sci Med, 64*(4), 858-870.

Monda, K. L., & Popkin, B. M. (2005). Cluster analysis methods help to clarify the activity-BMI relationship of Chinese youth. *Obes Res, 13*(6), 1042-1051.

Monteiro, C. A., Conde, W. L., & Popkin, B. M. (2002). Is obesity replacing or adding to undernutrition? - Evidence from different social classes in Brazil. *Public Health Nutrition, 5*(1A), 105-112.

Moore, M. S. (2000). Interactions between physical activity and diet in the regulation of body weight. *Proc Nutr Soc, 59*(2), 193-198.

Morris, J. N. (1994). Exercise in the prevention of coronary heart disease: today's best buy in public health. *Med Sci Sports Exerc, 26*(7), 807-814.

Nagel, C. L., Carlson, N. E., Bosworth, M., & Michael, Y. L. (2008). The Relation between Neighborhood Built Environment and Walking Activity among Older Adults. *Am. J. Epidemiol., 168*(4), 461-468.

Nakamura, T., Tokunaga, K., Shimomura, I., Nishida, M., Yoshida, S., Kotani, K., et al. (1994). Contribution of visceral fat accumulation to the development of coronary artery disease in non-obese men. *Atherosclerosis, 107*(2), 239-246.

National Institutes of Health. (1995, December 18-20). *Physical Activity and Cardiovascular Health.* Paper presented at the NIH Consensus Statement 1995, Bethesda, MD.

Ng, S. W., Norton, E. C., & Popkin, B. M. (2009). Why have physical activity levels declined among Chinese adults? Findings from the 1991-2006 China health and nutrition surveys. *Soc Sci Med, 68*(7), 1305-1314.

Ng, S. W., Zhai, F., & Popkin, B. M. (2008). Impacts of China's edible oil pricing policy on nutrition. *Social Science & Medicine, 66*(2), 414-426.

Oakes, J. M., Forsyth, A., & Schmitz, K. H. (2007). The effects of neighborhood density and street connectivity on walking behavior: the Twin Cities walking study. *Epidemiol Perspect Innov, 4*, 16.

Omran, A. R. (1971). The epidemiologic transition. A theory of the epidemiology of population change. *Milbank Mem Fund Q, 49*(4), 509-538.

Paeratakul, S., Popkin, B. M., Keyou, G., Adair, L. S., & Stevens, J. (1998). Changes in diet and physical activity affect the body mass index of Chinese adults. *Int J Obes Relat Metab Disord, 22*(5), 424-431.

Pinstrup-Andersen, P. (1993). *The political economy of food and nutrition policies*. Baltimore, MD: Johns Hopkins University Press.

Popkin, B. M. (1999). Urbanization, lifestyle changes and the nutrition transition. *World Development, 27*(11), 1905-1916.

Popkin, B. M. (2001). Nutrition in transition: the changing global nutrition challenge. *Asia Pac J Clin Nutr, 10 Suppl*, S13-18.

Popkin, B. M. (2006). Technology, transport, globalization and the nutrition transition food policy. *Food Policy, 31*(6), 554-569.

Popkin, B. M. (2007). Understanding Global Nutrition Dynamics as a step toward controlling cancer morbidity and mortality. *Nature Reviews Cancer 247*, 61-67

Popkin, B. M., Conde, W., Hou, N., & Monteiro, C. (2006). Is there a lag globally in overweight trends for children compared with adults? *Obesity (Silver Spring), 14*(10), 1846-1853.

Popkin, B. M., & Du, S. (2003). Dynamics of the Nutrition Transition toward the Animal Foods Sector in China and its Implications: A Worried Perspective. *J. Nutr., 133*(11), 3898S-3906.

Popkin, B. M., Kim, S., Rusev, E. R., Du, S., & Zizza, C. (2006). Measuring the full economic costs of diet, physical activity and obesity-related chronic diseases. *Obesity Reviews, 7*(3), 271-293.

Popkin, B. M., Paeratakul, S., Zhai, F., & Ge, K. (1995a). Dietary and environmental correlates of obesity in a population study in China. *Obes Res, 3 Suppl 2*, 135s-143s.

Popkin, B. M., Paeratakul, S., Zhai, F., & Ge, K. (1995b). A review of dietary and environmental correlates of obesity with emphasis on developing countries. *Obes Res, 3 Suppl 2*, 145s-153s.

Popkin, B. M., Wolney, C., Ningqi, H., & Carlos, M. (2006). Is there a lag globally in overweight trends for children as compared to adults? *Obesity 14*, 1846-1853.

Pratt, M., Macera, C. A., Sallis, J. F., O'Donnell, M., & Frank, L. D. (2004). Economic interventions to promote physical activity: Application of the SLOTH model. *American Journal of Preventive Medicine, 27*(3, Supplement 1), 136-145.

Proper, K. I., Cerin, E., Brown, W. J., & Owen, N. (2007). Sitting time and socio-economic differences in overweight and obesity. *International Journal of Obesity, 31*(1), 169-176.

Pudney, S., & Wang, L. (1991). Rationing and consumer demand in China: simulating effects of a reform of the urban food pricing system. *The Development Economics Research Program Working Paper, 15*.

Rabin, B. A., Boehmer, T. K., & Brownson, R. C. (2007). Cross-national comparison of environmental and policy correlates of obesity in Europe. *Eur J Public Health, 17*(1), 53-61.

Rashad, I., & Grossman, M. (2004). The economics of obesity. *Public Interest*(156), 104-112.

Raymond, S. U., Leeder, S., & Greenberg, H. M. (2006). Obesity and cardiovascular disease in developing countries: a growing problem and an economic threat. *Current Opinion in Clinical Nutrition and Metabolic Care, 9*(2), 111-116.

Reddy, K. S., & Katan, M. B. (2004). Diet, nutrition and the prevention of hypertension and cardiovascular diseases. *Public Health Nutr, 7*, 167-186.

Remacle, C., Bieswal, F., & Reusens, B. (2004). Programming of obesity and cardiovascular disease.(International Symposium "Childhood Obesity: From basic knowledge to effective prevention" and the 14th Workshop "European Childhood Obesity Group".)(Paper). *International Journal of Obesity, 28*(S3), S46.

Reynolds, K., Gu, D., Muntner, P., Wu, X., Chen, J., Huang, G., et al. (2003). Geographic variations in the prevalence, awareness, treatment and control of hypertension in China. *J Hypertens, 21*(7), 1273-1281.

Rodriguez, D. A., Aytur, S., Forsyth, A., Oakes, J. M., & Clifton, K. J. (2008). Relation of modifiable neighborhood attributes to walking. *Prev Med*.

Roodman, D. (2003). XTABOND2: Stata module to extend xtabond dynamic panel data estimator (Version S435901): Boston College Department of Economics.

Rosner, H. J. (2004). China's health insurance system in transformation: Preliminary assessment, and policy suggestions. *International Social Security Review, 57*(3), 65-90.

Saelens, B. E., Sallis, J. F., & Frank, L. D. (2003). Environmental correlates of walking and cycling: Findings from the transportation, urban design, and planning literatures. *Ann Behav Med, 25*(2), 80-91.

Sallis, J. F., Bauman, A., & Pratt, M. (1998). Environmental and policy interventions to promote physical activity. *Am J Prev Med, 15*(4), 379-397.

Sallis, J. F., Haskell, W. L., Wood, P. D., Fortmann, S. P., Rogers, T., Blair, S. N., et al. (1985). Physical activity assessment methodology in the Five-City Project. *Am J Epidemiol, 121*(1), 91-106.

Saris, W. H. (1998). Fit, fat and fat free: the metabolic aspects of weight control. *Int J Obes Relat Metab Disord, 22 Suppl 2*, S15-21.

Schroeter, C., Lusk, J., & Tyner, W. (2008). Determining the impact of food price and income changes on body weight. *Journal of Health Economics, 27*(1), 45-68.

Shariff, Z. M., & Khor, G. L. (2005). Obesity and household food insecurity: evidence from a sample of rural households in Malaysia. *European Journal of Clinical Nutrition, 59*(9), 1049-1058.

Short, S., Chen, F., Entwisle, B., & Zhai, F. (2002). Maternal Work and Child Care in China: A Multi-Method Analysis. *Population and Development Review, 28*(1), 31-57.

SSB. (1992). *The 1991 Price Statistical Yearbook for China [in Chinese]*. Beijing, China: China Statistical Publication House.

SSB. (1994). *The 1993 Price Statistical Yearbook for China [in Chinese]*. Beijing, China: China Statistical Publication House.

SSB. (1998). *The 1997 Price Statistical Yearbook for China [in Chinese]*. Beijing, China: China Statistical Publication House.

SSB. (2001). *The 2000 Price Statistical Yearbook for China [in Chinese]*. Beijing, China: China Statistical Publication House.

SSB. (2005). *The 2004 Price Statistical Yearbook for China [in Chinese]*. Beijing, China: China Statistical Publication House.

SSB. (2007). *The 2006 Price Statistical Yearbook for China [in Chinese]*. Beijing, China: China Statistical Publication House.

StataCorp. (2005). Stata Statistical Software: Release 9. College Station, TX: StataCorp LP.

StataCorp. (2007). Stata Statistical Software: Release 10. College Station, TX: StataCorp LP.

Sturm, R. (2004). The economics of physical activity - Societal trends and rationales for interventions. *American Journal of Preventive Medicine, 27*(3), 126-135.

Subramanian, S. V., & Smith, G. D. (2006). Patterns, distribution, and determinants of under- and overnutrition: a population-based study of women in India. *American Journal of Clinical Nutrition, 84*(3), 633-640.

Sullivan, J., Roningen, V., Leetmaa, S., & Gray, D. (1992). A 1989 Global Database for the Static World Policy Simulation (SWOP-SIM) Modelling Framework. In. Washington, DC: US Department of Agriculture.

Sundquist, K., Qvist, J., Johansson, S. E., & Sundquist, J. (2005). The long-term effect of physical activity on incidence of coronary heart disease: a 12-year follow-up study. *Prev Med, 41*, 219 - 225.

The Chinese Nutrition Society. (2000). Dietary Guidelines and the Food Guide Pagoda. *Journal of the American Dietetic Association, 100*(8), 886-887.

Theil, H. (1965). The information approach to demand analysis. *Econometrica, 33*, 67-87.

Theil, H. (1975). The theory of rational random behavior and its application to demand analysis. *European Economic Review, 6*(3), 217-226.

Timmer, C. P., & Alderman, H. (1979). Estimating Consumption Parameters for Food Policy Analysis. *American Journal of Agricultural Economics, 61*(5), 982-987.

Today's China. (1988). *Agriculture of today's China.* Beijing, PRC.

Tryon, W. W. (1987). Activity as a function of body weight. *Am. J. Clinical Nutrition, 46*(3), 451-455.

Tudor-Locke, C., Ainsworth, B. E., Adair, L. S., Du, S., Lee, N., & Popkin, B. M. (2007). Cross-sectional comparison of physical activity and inactivity patterns in Chinese and Filipino youth. *Child Care Health and Development, 33*(1), 59-66.

Tudor-Locke, C., Ainsworth, B. E., Adair, L. S., Du, S., & Popkin, B. M. (2003). Physical activity and inactivity in Chinese school-aged youth: The China Health and Nutrition Survey. *International Journal of Obesity, 27*(9), 1093-1099.

United Nations Economic and Social Commission for Asia and the Pacific. (1993). *Urbanization and Socio-Economic Development in Asia and the Pacific*. New York: United Nations.

Wagstaff, A., Lindelow, M., Gao, J., Xu, L., & Qian, J. (2007). *Extending health insurance to the rural population : an impact evaluation of China's new cooperative medical scheme*: The World Bank.

Wang, Y., Bentley, M. E., Zhai, F., & Popkin, B. M. (2002). Tracking of dietary intake patterns of Chinese from childhood to adolescence over a six-year follow-up period. *J Nutr, 132*(3), 430-438.

Wang, Y., Ge, K., & Popkin, B. M. (2000). Tracking of body mass index from childhood to adolescence: a 6-y follow-up study in China. *Am J Clin Nutr, 72*(4), 1018-1024.

Wang, Y., Mi, J., Shan, X. Y., Wang, Q. J., & Ge, K. Y. (2007). Is China facing an obesity epidemic and the consequences? The trends in obesity and chronic disease in China. *Int J Obes (Lond), 31*(1), 177-188.

Wang, Y., Monteiro, C., & Popkin, B. M. (2002). Trends of obesity and underweight in older children and adolescents in the United States, Brazil, China, and Russia. *Am J Clin Nutr, 75*(6), 971-977.

Webb, S. E. H., Webbs, A. J., & Coyle, W. T. (1992). *China's food consumption and production patterns in the year 2000: implications for trade.* . Washington, DC: US Department of Agriculture.

West, R., Gilsenan, A., Coste, F., Zhou, X. L., Brouard, R., Nonnemaker, J., et al. (2006). The ATTEMPT cohort: a multi-national longitudinal study of predictors, patterns and consequences of smoking cessation; introduction and evaluation of internet recruitment and data collection methods. *Addiction, 101*(9), 1352-1361.

Westerterp, K. R., & Goran, M. I. (1997). Relationship between physical activity related energy expenditure and body composition: a gender difference. *International Journal of Obesity & Related Metabolic Disorders, 21*(3), 184.

WHO. (1995). *Physical Status: The Use and Interpretation of Anthropometry* (No. 854). Geneva: World Health Organization.

Willett, W. C. (1998). Dietary fat and obesity: an unconvincing relation. *Am J Clin Nutr, 68*(6), 1149-1150.

Williamson, D. F., Madans, J., Anda, R. F., Kleinman, J. C., Giovino, G. A., & Byers, T. (1991). Smoking cessation and severity of weight gain in a national cohort. *N Engl J Med, 324*(11), 739-745.

Wilson, D. K., Kirtland, K. A., Ainsworth, B. E., & Addy, C. L. (2004). Socioeconomic status and perceptions of access and safety for physical activity. *Ann Behav Med, 28*(1), 20-28.

Windmeijer, F. (2005). A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics, 126*(1), 25-51.

World Bank. (1995). *China regional disparities. Report no. 14496-CHA.* Washington, DC: World Bank.

World Cancer Research Fund-American Institute for Cancer Research. (2007). *Food, Nutrition, Physical Activity and the Prevention of Cancer: a Global Perspective*. Washington DC World Cancer Research Fund in association with the American Institute for Cancer Research.

Wu, Y., Li, E., & Samuel, N. (1995). Food consumption in urban China: an empirical analysis. *Applied Economics, v27*(n6), p509(507).

Wu, Z., Yao, C., Zhao, D., Wu, G., Wang, W., Liu, J., et al. (2001). Sino-MONICA project: a collaborative study on trends and determinants in cardiovascular diseases in China, Part I: morbidity and mortality monitoring. *Circulation, 103*(3), 462-468.

Xinhua News. (2008, December 23, 2007). Chinese food products to require quality safety label starting 2008*. Xinhua News*. Retrieved January 27, 2009, from http://english.peopledaily.com.cn/90001/90776/90884/6325600.html

Xu, F., Yin, X. M., & Wang, Y. F. (2007). The association between amount of cigarettes smoked and overweight, central obesity among Chinese adults in Nanjing, China. *Asia Pacific Journal of Clinical Nutrition, 16*(2), 240-247.

Yang, G., Kong, L., Zhao, W., Wan, X., Zhai, Y., Chen, L. C., et al. (2008). Emergence of chronic non-communicable diseases in China. *The Lancet, 372*(9650), 1697-1705.

Yen, S. T., Fang, C., & Su, S.-J. (2004). Household food demand in urban China: a censored system approach. *Journal of Comparative Economics, 32*(3), 564-585.

You, X., & Kobayashi, Y. (2009). The new cooperative medical scheme in China. *Health Policy, In Press, Corrected Proof*.

Zhai, F., Fu, D., Du, S., Ge, K., Chen, C., & Popkin, B. M. (2002). What is China doing in policy-making to push back the negative aspects of the nutrition transition? *Public Health Nutr, 5*(1A), 269-273.

Zimmer, Z., Kaneda, T., & Spess, L. (2007). An examination of urban versus rural mortality in China using community and individual data. *J Gerontol B Psychol Sci Soc Sci, 62*(5), S349-357.