The Global Epidemic of Childhood Obesity and Its Non-medical Costs

by

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Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Sociology in the Graduate School of Duke University

2015
ABSTRACT
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Abstract

This dissertation consists of three parts of empirical analyses investigating temporal patterns and consequences of (childhood) overweight and obesity, mainly in the United States and the People’s Republic of China. Based on the China Health and Nutrition Survey, the first part conducts hierarchical age-period-cohort analyses of childhood overweight in China and finds a strong cohort effect driving the overweight epidemic. Results from the growth-curve models show that childhood overweight and underweight are related such that certain socio-economic groups with higher levels of childhood overweight also exhibit lower levels of childhood underweight. The second part situates the discussion on childhood obesity in a broader context. It compares temporal patterns of childhood overweight in China with those of adulthood overweight and finds that the salient cohort component is absent in rising adulthood overweight, which is dominated by strong period effects. A positive association between human development index and overweight/obesity prevalence across countries is also documented. Using multiple waves of survey data from the National Longitudinal Study of Adolescent Health, the third part analyzes the (latent) trajectory of childhood overweight/obesity in the United States. It finds that individuals with obesity growth trajectories are less likely to avoid mental depression, tend to have higher levels of neuroticism and lower levels of agreeableness/conscientiousness, and show less delinquent behaviors.
Dedication

To my wife, grandma, and my family,

for bringing love, light and joy to my life.
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1. Introduction

On December 13 2001, US Surgeon General David Satcher talked about the obesity epidemic and the life threat posed by increasing childhood obesity in America. Based on the fact that obesity was responsible for over 300,000 deaths per year, obesity was subsequently identified as an important risk factor to health because “obesity may soon cause as much preventable disease and death as cigarette smoking” (US Department of Health and Human Services 2001). In recent years, the concern about childhood obesity in the United States has already gone well beyond the academia. For instance, the Childhood Obesity Action Plan initiated by Michelle Obama catapulted this concern about childhood obesity from academia to the broader public discourse. The term “childhood obesity” is now on the lips of scholars, politicians, business managers, NGO leaders, and foundation executives. Together with the public’s concerns in childhood obesity, the increasing prevalence of childhood obesity all over the world mandates research to unearth the social causes and possible solutions of childhood obesity.

There is considerable evidence that the increased prevalence of childhood obesity is not unique to developed countries. In the global epidemic of childhood overweight and obesity, research on China can also provide scholars with insights about the recent social and economic forces driving childhood obesity in both developing countries and post-socialist societies. With several waves of social and
economic reforms initiated in the late 1970s and accelerated market transformation since the early 1990s, China has recently experienced an unparalleled increase in childhood obesity. For example, the prevalence of childhood obesity for urban Chinese children aged 2-6 increased from 1.5 percent in 1989 to 12.6 percent in 1997 (Luo and Hu 2002), which is a rapid increase in a relatively short period. Such an unparalleled increase in childhood obesity in the world’s most populous country has drawn substantial attention from scholars and policy-makers.

This comparative research focuses on the temporal patterns of childhood overweight/obesity in the United States and China. In particular, the dissertation mainly consists of three empirical analyses. 1. an age-period-cohort (APC) analysis of childhood overweight in China; 2. spatial and temporal patterns of adulthood overweight/obesity and their relevance to these of childhood overweight/obesity; and 3. latent trajectory analyses of childhood obesity in the United States and the association between latent trajectories and non-medical outcomes (e.g., personality, mental health, self-esteem and juvenile delinquency). This dissertation is organized as follows. The next sections of this chapter commence with a review of prior research literature on patterns, causes and consequences of childhood overweight/obesity, which is complemented by a brief discussion of limitations of existing studies. The next chapter investigates the temporal patterns of childhood overweight. Based on different statistical assumptions in modeling temporal effects, both age-period-cohort
analyses and growth-curve analyses are employed. To put temporal increases in childhood overweight in China in perspective, the temporal and spatial patterns of adulthood overweight/obesity are investigated in Chapter 3 to provide a comparative view of childhood overweight/obesity. Chapter 4 models latent trajectories of childhood obesity in the United States and then examines the association between these trajectories and a series of psychological and behavioral outcomes. The final chapter evaluates findings from all empirical analyses and discusses their implications on the study of childhood overweight and obesity.

1.1 Childhood Obesity and the Epidemiological Transition

The epidemiological-transition theory argues that different causes account for mortality and morbidity across different stages of human history: three major epidemiological ages were identified as the Age of Pestilence and Famine, the Age of Receding Pandemics, and the Age of Degenerative and Man-Made Diseases (Omran 1971). Using terminology similar to that of “demographic transition theory” in demography, Omran referred to this sequence of epidemiological ages as epidemiological transition theory. Building upon Omran’s work, researchers have argued that humanity had, by the last half of the twentieth century, evolved to a new epidemiological age, the Age of Delayed Degenerative Diseases, which is
characterized by pushing toward older ages the onset of degenerative diseases (Olshansky and Ault 1986).

In 2010, an article titled “Fifth phase of the Epidemiologic Transition: the Age of Obesity and Inactivity” published in the Journal of the American Medical Association argued that obesity wound account for most of deaths in the future (Gaziano 2010). However, empirical evidence in this article was exclusively based on the US, which greatly weakened this article’s arguments. Although the links between obesity and diseases (such as Type II diabetes, coronary heart diseases and hypertension) are well established, obesity and inactivity can hardly be regarded as the fifth phase of the Epidemiologic Transition if obesity appears to be a US-specific epidemic. To adjudicate whether obesity and inactivity can, indeed, be said to constitute a fifth phase of Epidemiological Transition, it is important to investigate other countries, no matter how developed they are, are also experiencing increased prevalence of obesity. Existing evidence tends to support this hypothesis because increased obesity, especially childhood obesity, has been observed in China, Africa, Latin America and other countries in the world (Armstrong, Lambert, Sharwood, and Lambert 2008; Filozof, Gonzalez, Sereday, Mazza, and Braguinsky 2001; Luo and Hu 2002). For example, among adult West African populations, a meta-analysis showed that urban residents and women had particularly high risk of obesity and the prevalence of overweight/obesity rose fast for women (Abubakari, Lauder, Agyemang,
Jones, Kirk, and Bhopal 2008).

Meanwhile, scholars should investigate whether there is a cohort component imbedded in the rise of overweight/obesity prevalence. A recent age-period-cohort analysis showed that more recent cohorts in the US are more likely to become obese, while individuals are at higher risk of obesity in recent years/time periods (Reither, Hauser, and Yang 2009). In other words, the recent overall population trend towards an increasing prevalence of obesity in the US has both birth cohort and time period effects. These findings highlight the importance of childhood obesity in the demography of the obesity epidemic from a cohort replacement perspective. That is, if the cohort component continues into the future, more obese younger generations will eventually replace older generations. Therefore, childhood obesity can be viewed as the leading edge of future changes in the population prevalence of obesity. If a new epidemiological age, the Age of Obesity and Inactivity is verified by the empirical analyses to be conducted in this project, childhood overweight and obesity will draw substantial attention from the public and be more seriously treated by parents, teachers, social workers and policy-makers.

Moreover, epistemological understanding about features and characteristics of the epidemiological transition is also important. Although a teleological assumption is not implied by this theory, standards for determining a certain phase of transition should be established before we adjudicate among empirical evidence. Based on this
reasoning, a certain phase in the epidemiological transition should at least possess the following features: 1. major risk factors (e.g., pestilence and famine; receding pandemics, and man-made diseases) specified by a certain phase significantly predict mortality and morbidity at the population level; 2. increasing incidences of risk factors pertaining to a certain phase are documented or predicted at the global level; 3. structural changes causing transition from one stage to the another are embedded in human development. In other words, the transition from one phase to another is irreversible in the absence of major countervailing forces. Therefore, it is imperative for us to understand the global patterns, causes and consequences of (childhood) overweight and obesity.

1.2 Childhood Obesity in the Global Obesity Epidemic

In childhood, obesity is found to be associated with a series of physical health outcomes, such as neurologic, gastrointestinal, endocrine, circulatory and pulmonary conditions (Deckelbaum and Williams 2001; Must and Strauss 1999). From the life course perspective, the role of childhood obesity is important not only because childhood obesity often extends into adulthood, but due to its significant cohort influence on adulthood all-cause mortality and diseases, such as cardiovascular disease, diabetes and hypertension (Dietz 1998a; Must and Strauss 1999). For
instance, scholars have found that childhood obesity is associated with high prevalence of later elevated blood pressure, respiratory disease, diabetes and psychosocial disorders (Erickson, Robinson, Haydel, and Killen 2000; Figueroa-Colon, Franklin, Lee, Aldridge, and Alexander 1997; He, Ding, Fong, and Karlberg 2000; Young, Dean, Flett, and Wood-Steiman 2000). Elevated morbidity and mortality was observed for adults who experienced adolescence overweight, even if they lose the extra weight when they grew up (Deckelbaum and Williams 2001). If it is left unabated, childhood obesity has the potential to become a major cause of morbidity and mortality in the life course.

There is considerable evidence that the increased prevalence of childhood overweight and obesity happens in both developed and developing countries. In the United Kingdom, the prevalence rate of children at obesity and overweight levels increased from 5.4% and 14.7% in 1989 to 9.2% and 23.6% in 1998 (Bundred, Kitchiner, and Buchan 2001), respectively. Meanwhile, the same trend of increase in the prevalence of obesity and overweight happened in United States, Australia, Canada and many developed countries (Ogden, Carroll, Curtin, McDowell, Tabak, and Flegal 2006; World Health Organization 2000). In 38 developing countries where longitudinal data were available to make direct comparisons between past and present prevalence rates of obesity and overweight, researchers found that nearly half of them (16 out of 38 countries) had a trend towards increasing prevalence of obesity and
overweight in preschool children (De Onis and Blossner 2000). Therefore, there seems to be a worldwide increase in the prevalence of childhood obesity and overweight (Wang, Monteiro, and Popkin 2002a).

Although childhood obesity is simply a result of energy imbalance i.e. energy intake is more than energy expenditure, causes of childhood obesity are not as simple as eat more and move less. Given that energy intake and expenditure have existed since the very beginning of mankind, a more important and relevant question is what factors caused the energy imbalance in recent years. Existing literature shows that childhood obesity in either the US or China can hardly be explained by a single major factor, but by a set of interrelated factors. Since no biological or genetic factors can evolve so quickly as to explain the recent dramatic increases in childhood overweight and obesity in the two countries, scholars believe that the elevated prevalence of childhood obesity is related to a series of structural changes across societies (Anderson and Butcher 2006). Those structural changes influencing childhood obesity include changing dietary behaviors, restructure of urban space, and different value orientations adopted by educational systems.
1.3 Explanations of the Global Epidemic of Obesity

1.3.1 Changes in Dietary Behaviors

Studies on the consumption of soft drinks revealed a similar trend of soft drink consumption to that of childhood obesity in the US (Anderson and Butcher 2006; Putnam and Gerrior 1999). Though this association cannot be interpreted as a causal relationship, previous studies do find conclusive evidence suggesting that soft drinks play a significant role in shaping obesity prevalence of American children because the consumption of soft drinks in the United States is usually associated with fast food, sedentary behaviors and food away from home, which are believed to have influence on energy imbalance and obesity (French, Lin, and Guthrie 2003; Guthrie, Lin, and Frazao 2002; Hu, Li, Colditz, Willett, and Manson 2003). In addition, the increased childhood obesity could be caused by larger portion sizes in the American food market (Rolls, Engell, and Birch 2000).

Though little research has been done in China, existing studies explaining China’s rising overweight epidemic is often situated in the context of China’s nutritional transition and rapid urbanization (Du, Lu, Zhai, and Popkin 2002; Monda, Gordon-Larsen, Stevens, and Popkin 2007; Ng, Zhai, and Popkin 2008; Popkin 1999; Popkin and Du 2003; Popkin 1998). As nowadays even lower-income families in China can afford a high-energy-density diet, a long-term shift towards a high-fat,
high-protein and low-fiber diets is taking place in China, which is associated with the rise in overweight prevalence (Cui and Dibley 2012; French and Crabbe 2010; Popkin 2009). Compared to Americans, eating away from home is also associated with heavy consumption of alcohol. Meanwhile, it should be noted that Chinese have a different perception of fast food. In China, fast food is not necessarily linked with the term *junk food*, even if young Chinese knew the lower prestige of fast food in the US. In contrast, fast food restaurants are regarded by Chinese youth as ideal places for gathering due to their easygoing environment compared to traditional Chinese restaurants. In China, this perception of fast food might strengthen the causal relation from fast food to childhood obesity in the near future. With the introduction of fast food and more meals away from home, time and energy ever spent on cooking gave way to prolonged sedentary behaviors, such as working, social networking, watching TV, playing video games and so forth. The changing dietary behaviors in both the US and China increases the prevalence rates of childhood obesity.

1.3.2 Restructuring of Urban Space

Restructuring of urban space influences childhood obesity primarily through longer exposure to sedentary behaviors and reduced outdoor activity. Due to geographical mismatch between living and working places/schools in the US since
1970s, daily vehicle miles traveled per household increased from 33 in 1977 to 57 in 1995 (Ewing, Pendall, Chen, and America 2002). Partially due to parental concerns about automobile traffic/accidents and high crime rates across neighborhoods, only 22 percent of American children walked or rode bikes to school in 2002, whereas more than 70 percent of their parents reported walking or biking to school when they were children (Russonello and Stewart Research and Communications 2003). This restructure of urban space undoubtedly promotes sedentary behaviors and childhood obesity. While the overall number of private automobiles in China is still low compared to that in the US, Chinese residents in metropolitan areas, such as Beijing, Guangzhou, and Shanghai, suffer from the same urban sprawl problem as Americans do. It is expected that geographical mismatch between living places and schools can influence childhood obesity in both China and the US.

On the other hand, structural changes in urban places can influence the childhood obesity epidemic in both the US and China. Associated with racial residential segregation, the concentration of inner city poverty, the rise of foreclosure crisis and declined macro-level social capital across American communities (Putnam 1995; Rugh and Massey 2010; Wilson 1987), neighborhood safety problems inhibited children’s outdoor play and made them more exposed to prolonged indoor activities, such as playing video games and watching TV (Burdette and Whitaker 2005).

The increasing prevalence rates of childhood obesity were also associated with
urban housing reform in China. Urban housing used to be regarded as a welfare policy under state socialism (Logan, Bian, and Bian 2002; Szelenyi 1983). While parents working in the same work unit (danwei) usually lived in the same neighborhood, children playing together with others tended to have more outdoor activities. As in other socialist societies, urban housing reform in China initiated in 1988 specified the central government’s determination of gradually transforming housing from a welfare policy into a commodity (Huang and Clark 2002). After 1988, the central government made multiple announcements to raise rents and implemented policies to sell the state-sector housing to households at heavily discounted prices (Davis 2004; Li 2003). It was not until 1998 that China’s central government announced full deregulation of its urban housing sector and detached housing allocation from a person’s workplace or danwei (State Council 1998), when commodity housing became the major channel for housing allocation. *Commodity housing units* refer to housing units newly developed by real estate developers and sold to all persons on the open market, which was officially introduced by the central government in 1994 (State Council 1994). While access to commodity housing is irrelevant to homeowners’ occupations and economic sectors, children no longer play together with strangers and resort to more sedentary indoor entertainment. Therefore, the inevitable urban structural changes predict energy imbalance for Chinese children.
1.3.3 Value Orientations Adopted by Educational Systems

In the United States, two different forces are shaping value orientations adopted by schools. On the one hand, the force of the market filters into schools such that lucrative contracts with soft drink companies are often signed (Anderson and Butcher 2006). Moreover, the proliferation of vending machines greatly enhanced children’s access to soft drinks and snacks. On the other hand, physical activities and physical education often give way to more homework and study time due to schools’ increasing emphasis on academic performance. While market forces can also influence childhood obesity in Chinese school settings, the greater emphasis on academic accountability assumed by Chinese primary and secondary schools deserves more attention. Although little research on the relationship between childhood obesity and school performance has ever been done in China, it is expected that greater emphasis placed on academic performance means more prolonged sedentary behavior and reduced physical activity in Chinese society. This hypothesis could be more plausible for 10th to 12th graders, when students in high schools are engaged in preparing for the National College Entrance Examination. Except for very few prestigious high schools, physical education, weekends and holidays are normally cut by the schools to provide more study time.
1.3.4 Demographic and Regional Moderators

In both the US and China, sex disparity in childhood obesity is documented. For instance, the Group of China Obesity Task Force found that the cut-off points in Body Mass Index (BMI) for childhood obesity in China tend to level off when boys approach 15 years old and girls approach 13 years old (Ji 2005). In the US, obese girls have a significantly lower chance of entering college, whereas obese boys show insignificant odds of entering college compared to their non-obese peers (Crosnoe 2007). Hence, the prevalence of childhood obesity is confounded by gender and girls may have different perceptions of obesity compared to boys.

While childhood obesity is influenced by gender in both China and the US, rural-urban divide and race/ethnicity assume different roles in shaping childhood obesity between the two countries. The rural-urban divide is frequently mentioned by research on China due to an institutional arrangement (the household registration system) established in the 1950s to drain its vast countryside of agricultural goods and to concentrate its economic resources in limited urban areas to foster rapid industrialization. Even today, the household registration system continues to play a key role in determining access to social benefits and entitlements to state resources, such as education, health care, and all other kinds of welfare entitlements. With regard to childhood obesity, the dramatic increase in the prevalence of childhood obesity from 1989 to 1997 in urban China is paralleled by reduced obesity rates in rural China.
over the same period (Luo and Hu 2002). In the US, there is no significant difference in obesity rates between rural and urban areas (Anderson and Butcher 2006). Nevertheless, the racial disparity in childhood obesity is frequently documented in the US. Scholars argue that certain minority groups, such as blacks and Hispanics, are more vulnerable to childhood obesity under the same exposure to risk factors (Crosnoe 2007; Strauss 2000). Since China’s population is relatively more racially homogeneous, this racial disparity in childhood obesity is not observed there.

2. Temporal Patterns of Childhood Overweight in China

2.1 Introduction

A dramatic increase in the prevalence of childhood and adolescent overweight in China over the past two decades has been widely reported (Cui, Huxley, Wu, and Dibley 2010; Ji 2005; Ji 2008; Li, Zhai, Yang, Schouten, Hu, He, Luan, and Ma 2007; Luo and Hu 2002; Wang, Monteiro, and Popkin 2002b). Based on the China Health and Nutrition Survey (CHNS), it has been estimated that the prevalence of overweight for urban children aged 2-6 almost doubled from 1989 (14.6%) to 1997 (28.9%). For children and adolescents aged 7-17, the estimates are that prevalence of overweight more than doubled from 5.2% in 1991 to 13.2% in 2006 (Cui, Huxley, Wu, and
Dibley 2010). This rise of childhood and adolescent overweight prevalence in the world’s most populous country, which is experiencing rapid social and economic changes, certainly merits attention.

Yet both descriptive analyses and traditional regression models have concealed temporal patterns embedded in the rise of overweight childhood in China. Questions remain as to whether each of the three temporal clocks – age, time period, and birth cohort – are associated with the observed increases in the prevalence rates, and, if so, how do they intermingle to account for the changes. That is: Are the dramatic increase in the prevalence of childhood and adolescent overweight prevalence attributable mainly to changes in age structures of children and youth (especially after the introduction of a strict family-planning program in the late 1970s)? Or to a secular and monotonic increase in overweight prevalence across time periods? Or to the replacement of older cohorts with heavier cohorts born in more recent years? And if all three temporal factors are operative, what precisely are their patterns and how do they intermingle to determine the observed rates?

Using eight waves of data from the China Health and Nutrition Survey (CHNS), I apply a recently-developed method – hierarchical age-period-cohort (HAPC) models – to estimate age, period, and cohort effects of childhood and adolescent overweight in China from 1989 to 2009. The APC analysis is also complemented by growth-curve models investigating age trajectories in overweight
prevalence. These analyses address the following three research questions. First, what temporal patterns of age, period and cohort effects are evident in the increase of childhood and adolescent overweight prevalence in the past two decades? In particular, was there a cohort effect such that children and youth in more recent birth cohorts are more likely to be overweight than those in earlier cohorts? Second, were age, period and cohort effects more pronounced for certain socio-demographic groups? Third, if all three temporal patterns are significantly operative, how do they interplay to jointly account for the observed trends in overweight prevalence and differentials among sociodemographic groups.

To address these questions, the next section reviews prior research on childhood overweight in China and highlights the relevance of three different yet related temporal dimensions – age, period, and cohort. This is followed by a description of the data, measures, and methods applied in the chapter. Results of the analyses then are presented, followed by a discussion and conclusions section.

2.2 Fat China: Existing Studies on Childhood Overweight and Obesity

The rapid increase in the prevalence of childhood overweight and obesity in China is often associated with a persistent socio-economic gradient. Temporal patterns of the increase in childhood overweight and obesity would be elaborated in Section
2.4. The current section focuses on the socio-economic gradient in childhood overweight and obesity. Findings from existing research show that obese/overweight children tend to be boys, urban residents and these from high-income families, although the socio-economic gradient appears to change over time. Using longitudinal data from the China Health and Nutrition Survey (CHNS) collected between 1991 and 1997, Wang and colleagues (2000) examined patterns of body mass index (BMI) and their determinants for children and adolescents. A child was assigned to the tracking group if he/she remained in the same BMI quartile of the population between 1991 and 1997. A child was assigned to the “move-down group” if his/her BMI in 1997 belonged to a lower quartile group than his/her initial quartile in 1991 and he/she was assigned to the “move-up group” otherwise. Compared to the proportions of moving-up children from either low-income families (26.4%) or medium-income families (30.6%) at baseline, a larger proportion of children from high-income families (35.7%) appeared in the move-up group. Meanwhile, a larger proportion of children from low-income families (32.5%) moved down than those in the medium-income (25.6%) and high-income families (28.6%). Based on three nationwide surveys conducted in the U.S. (NHANES III, 1988-1994), China (1993), and Russia (1992), cross-national comparisons revealed the relationship between childhood obesity and socio-economic status across societies (Wang 2001). Again, children (aged 6-18) from high-income families had higher rates of obesity in China
and Russia, whereas a negative relationship between per capita household income and childhood obesity was observed in the United States. A more recent Chinese study also demonstrated that children from high-income families had a higher prevalence of overweight and obesity than children from less advantaged families in 2006 (Cui, Huxley, Wu, and Dibley 2010).

With regard to regional disparities in childhood overweight and obesity, a study based on a large nationally representative sample (226,602 subjects) found that children and adolescents living in urban areas, coastal regions and northern parts of China had higher prevalence rates of overweight and obesity than those in rural areas and other regions in 2005 (Ji and Cheng 2009a). Likewise, a study based on 3,140 students ages 7 to 18 years in Tianjin showed that both urban residency and higher parental education were significantly associated with the risk of being overweight or obese in 2010 (Andegiorgish, Wang, Zhang, Liu, and Zhu 2012). When auto-correlations from repeated measurements across surveys were taken into account, a study investigating the temporal trends of childhood overweight and obesity showed that urban children constantly had higher rates than their rural peers from 1991 to 2006 (except for the prevalence of obesity in 1997) (Cui, Huxley, Wu, and Dibley 2010).

Researchers also studied the socio-economic determinants of childhood obesity using more comprehensive measures of both childhood obesity and
socio-economic status. Based on 9,356 urban children (aged 4-16) surveyed in four eastern cities in China, the positive relationship between household income and childhood obesity remained significant even when different measures of childhood overweight and obesity were adopted (Ma, Hu, Li, and Ma 2002). By conducting cross-sectional analyses on several consecutive waves of the China Health and Nutrition Survey (1989, 1991, 1993 and 1997), high and median household income were independent risk factors for childhood overweight (Luo and Hu 2002). Besides using household income as a proxy for socio-economic status, both fathers with tertiary education and households with more amenities were associated with higher BMI quartiles for boys but not for girls (Shi, Lien, Kumar, Dalen, and Holmboe-Ottesen 2005). By comparing Chinese seventh graders sampled in the greater Los Angeles area and in Wuhan city in China, a positive association between parental education and risks of overweight and obesity was observed for Wuhan city children, but a negative association was observed for the Chinese children in Southern California (Johnson, Xie, Liu, Reynolds, Chou, Koprowski, Gallaher, Spruitj-Metz, Guo, Sun, Gong, and Palmer 2006). By using more comprehensive measures of socio-economic status (personal allowance, parental education, household income, parental employment, ownership of electronics, and financial capability), parental tertiary education was found to be positively associated with overweight for both boys and girls from four Southern Chinese cities, net of other effects (Xie, Chou,
Spruijt-Metz, Reynolds, Clark, Palmer, Gallaher, Sun, Guo, and Johnson 2007). Although most studies reported positive associations between SES indicators and childhood overweight/obesity, a possible negative association is implied. A study based on children aged 1-35 months in Beijing. In this study, lower parental education was related to childhood overweight in 2005 (Jiang, Rosenqvist, Huishan, Koletzko, Guangli, Jing, and Greiner 2009). A summary of studies reviewed is listed in Table 1 in order of publication date.
<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Sample population</th>
<th>Location</th>
<th>Measures of socio-economic status</th>
<th>Measures of overweight/obesity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ma, Hu, Li and Ma 2002</td>
<td>9,356 urban children &amp; adolescents aged 4-16</td>
<td>Guangzhou, Shanghai, Jinan, and Harbin</td>
<td>Household income per capita and parental education</td>
<td>Overweight ≥ 110% normal weight (WHO 1997); Obesity ≥ 120% normal weight;</td>
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<td>Luo and Hu 2002</td>
<td>CHNS: Children aged 2-6: 944 (1989); 1,058 (1991); 903 (1993); 483 (1997) for cross-sectional analysis; 944 for longitudinal analysis</td>
<td>Eight provinces in China</td>
<td>Household income, rural-urban residency and parental education</td>
<td>Age- and sex-specific BMI cut-off points proposed by International Obesity Task Force</td>
</tr>
<tr>
<td>Author</td>
<td>Year</td>
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<td>Location</td>
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<tr>
<td>Johnson, Xie, Liu et al.</td>
<td>2006</td>
<td>1,896 healthy adolescents aged 12 and 13 (data collected in 1999)</td>
<td>Wuhan</td>
<td>Parental education</td>
</tr>
<tr>
<td>Xie, Chou, Spruijt-Metz et al.</td>
<td>2007</td>
<td>6,863 middle and high school students (7th to 11th graders), and their parents (data collected in 2002)</td>
<td>Hangzhou, Wuhan, Kunming and Chengdu</td>
<td>Personal allowance, parental education, household income, parental employment, ownership of electronics, and financial capability</td>
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<tr>
<td>Jiang, Rosenqvist, Huishan, Koletzko, Guangli, Jing, and Greiner</td>
<td>2009</td>
<td>4654 children aged 1–35 months</td>
<td>Beijing</td>
<td>Parental education</td>
</tr>
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<td>Author</td>
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<td>Sample population</td>
<td>Location</td>
<td>Measures of socio-economic status</td>
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<tr>
<td>Andegiorgish, Wang, Zhang, Liu, and Zhu</td>
<td>2012</td>
<td>3,140 students aged 7-18</td>
<td>Tianjin</td>
<td>Parental education and rural-urban residency</td>
</tr>
</tbody>
</table>

* CHNS = Chinese Health and Nutrition Survey
2.3 Data: The China Health and Nutrition Survey

Like many studies conducted in this field (Cui, Huxley, Wu, and Dibley 2010; Ji 2005; Ji 2008; Li et al. 2007; Luo and Hu 2002; Wang, Monteiro, and Popkin 2002b), the current study is based on the China Health and Nutrition Survey (CHNS), an open-cohort survey administered by the Carolina Population Center at the University of North Carolina at Chapel Hill. The first wave of the CHNS was collected in 1989, which was followed by seven waves collected in 1991, 1993, 1997, 2000, 2004, 2006, and 2009.\(^1\)

The research described here is based on data from individuals aged 2 to 25 interviewed in any of the eight waves (N=25,152). Although the CHNS is not a national representative survey, it covers nine provinces (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong) that vary substantially in economy, geography and social development. In the 1997 wave, Liaoning province in northeast China was replaced by Heilongjiang province, another province in northeast China. Liaoning returned to the study in the 2000 wave. Because the CHNS was designed to examine how the social changes and economic transformation in China are affecting the health and nutritional status of its population, information on SES indicators implied by market transformation theories, such as types of work sectors and categories of occupations, were collected.

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\(^1\) By the time when the dissertation was prepared, information allowing HAPC models to link each parent with his/her corresponding children has not been released for the 2009 wave. Therefore, this research is unable to investigate how age, period and cohort effects varied across different parental characteristics, such as parental education.
Traditional measures of SES in developed countries, including parental education and income also were collected, as were basic demographic characteristics. Anthropometrical measurements include body weight of subjects in light indoor clothing, measured to the nearest 0.1 kg with a beam balance scale and height of subjects without shoes to the nearest 0.1 cm, as measured using a portable stadiometer. Following standardized protocols, all interviewers conducting anthropometrical measurements were required to take inter-observer reliability tests.

2.4 Age-Period-Cohort (APC) Analyses

2.4.1 The Relevance of APC Analyses to Childhood Overweight

The distinction of the three temporal dimensions of age, time period, and birth cohort along which demographic and social phenomena vary has been an important topic of research since the 1960s (Mason, Mason, Winsborough, and Poole 1973; Ryder 1965; Yang, Fu, and Land 2004). Each of these dimensions is potentially a source of changes associated with the prevalence of overweight in a population.

Age effects refer to physiological, cognitive, and social changes related to the aging process. For example, it has been shown that a shift in dietary patterns from milk/formula-based diets to more diversified diets usually takes place in early childhood (Picciano, Smiciklas-Wright, Birch, Mitchell, Murray-Kolb, and McConahy 2000).
Similarly, rapid changes in both physical activity and body-mass index (BMI) have been observed during the transition from childhood to adolescence (Reading 2005). Such age-related variations in energy intake and expense can have profound influences on childhood and adolescent overweight.

*Period effects* relate to variations in childhood and adolescent overweight taking place at a period that affect all cohorts simultaneously, which correspond to concurrent influences of social, economic and environmental factors on children and youth (Glenn 1976; Yang, Schulhofer-Wohl, Fu, and Land 2008). As even lower-income families in developing countries can now afford higher fat and refined diet, it has been shown that food consumption in China is moving toward more calories and a greater proportion of diet from fat and protein (Popkin and Du 2003). With regard to energy expenditure, social, economic and urban changes occurred in China increasingly promote a sedentary lifestyle as Chinese are facing a spatial mismatch between workplace and residence, the rapid rise of a service sector in a country once dominated by agriculture, and declines in interactions with their neighbors within gated communities (Popkin 1999; Zhu, Breitung, and Li 2012).

Finally, *cohort effects* pertain to variations in overweight across groups of children and youth who share a common year of birth or other life events such as being enrolled in the same school grade in the same year, which are affected by life-course experience associated with membership in each birth cohort (Reither, Hauser, and Yang 2009).
According to the life-course perspective, cohort effects exist when the duration, timing and sequence of exposure to a series of social, economic and environmental factors have differential effects across the life course (George 2007; Yang and Lee 2009). For instance, children and youth from more recent cohorts had earlier in life, more exclusive and overwhelming exposure to electronic and mobile devices, fast food and automobiles. Accordingly, they are not only adept at working, communicating and playing in a sedentary way but also more susceptible to high-energy-density diets.

Existing research on the increasing prevalence of childhood and adolescent overweight in China has focused individually on age or period or cohort effects. This line of research has found evidence of differentials in the increased prevalence – more pronounced increases for certain socio-demographic groups, such as males, urban residents and high-income families (Cui, Huxley, Wu, and Dibley 2010; Ji 2005; Ji 2008; Li et al. 2007; Luo and Hu 2002; Wang, Monteiro, and Popkin 2002b). Based on the CHNS dataset, a study investigating time trends of childhood overweight in China documented that increases in overweight have mainly occurred in urban areas, where prevalence rates of overweight for pre-school children rose from 14.6% in 1989 to 28.9% in 1997 (Luo & Hu, 2002). This study also found that boys were significantly heavier than girls after a series of socio-economic indicators had been accounted for.

By examining the prevalence of overweight across socio-demographic groups, Cui, Huxley, Wu, and Dibley (2010) more recently estimated that prevalence rates of
overweight steadily increased from 5.2% in 1991 to 13.2% in 2006 for children aged 7-17, while the prevalence of childhood overweight (individuals aged 7-12) was generally higher than that of adolescent overweight (individuals aged 13-17) over the period of study. This study also found that the sex and regional disparities in both childhood and adolescent overweight remained salient. In particular, the highest prevalence of overweight appeared in children from high-income families in 2006. Using data from the 2002 National Nutrition and Health Survey, Wu et al. (2009) estimated that the prevalence rates of overweight of boys was higher than these of girls aged 7-17, although girls aged 0-6 had slightly higher prevalence rates of overweight than boys of the same age interval (Wu, Huxley, Li, and Ma 2009). Based on the 1985 wave of the Survey on Students' Constitution and Health (CNSSCH), Ji (2008) found that boys aged 13-18 had lower prevalence of overweight than girls of the same ages in both Beijing and Shanghai, although boys aged 7-12 had higher prevalence of overweight than corresponding girls. However, this sex crossover was not observed at the 1991, 1995 and 2000 waves of the CNSSCH study, when boys across different age groups had consistently higher prevalence rates of overweight than girls at both Beijing and Shanghai (Ji 2008).

All of these findings on trends over time and sociodemographic differentials are based either on cross-sectional studies that include several cohorts across different age groups of a single survey year or on studies utilizing longitudinal data that do not fully differentiate and control for all three temporal clocks – age, time period, and birth cohort.
It thus remains unclear what the patterns of temporal effects are when all three sets are studied simultaneously and how these patterns relate to sociodemographic differentials.

2.4.2 Measures and Covariates

The traditional BMI cut-point of 25 was employed to screen overweight children and youth for individuals aged 18 and above (Flegal, Graubard, Williamson, and Gail 2005; Ogden et al. 2006; Wang, Monteiro, and Popkin 2002b). For individuals age 2 to 18, I used the age- and sex-specific BMI cut-points proposed by the International Obesity Task Force (IOTF) to identify childhood and adolescent overweight (Cole, Bellizzi, Flegal, and Dietz 2000). The IOTF standard for overweight was chosen for two reasons. First, this standard was based on samples from six countries and regions (Brazil, Great Britain, Hong Kong, Netherlands, Singapore, and the United States) over a wide geographical range and thus recommended for international use. Second, by restricting the fitted BMI centile curves across countries to pass through the cut-point for overweight of 25 kg/m² at age 18, the resulting IOTF standard for individuals aged below 18 directly corresponds to the BMI cut-point at and above age 18 (BMI=25), which avoids a sudden change in the BMI cut-points around age 18. Yet, it should be noted that the IOTF only provided BMI cut-points for six-month intervals. To obtain BMI cut-points for each individual study member’s exact age, a polynomial method was used to generate
continuous age- and sex-specific cut-points for individuals aged below 18. Using Matlab 7.0, these fitted continuous curves from this polynomial interpolation achieved an almost perfect fit for both male and female subjects (see Figure 1: $R^2 > 0.9999$ and the sum of squared residuals is less than 0.07 for all four panels). After calculating each individual’s exact age from date of birth and date of measurement, individuals aged 2-25 with BMI equal to or above corresponding age- and sex-specific cut-points were identified as overweight and obese.

Figure 1 Cut-off points for body mass index for overweight by sex
Three dichotomous variables were included in this research to examine temporal effects of childhood and adolescent overweight across different socio-demographic groups. *Sex* denotes whether an individual was male or female, and *residency* refers to whether an individual was interviewed at rural or urban areas. After inflation adjustment, individuals with per capita family income below the median of the distribution of family income surveyed in the same wave were coded as *low-income families*. Otherwise, individuals were coded as *high-income families*. From the 1989 wave to the 2009 wave, the levels of per capita family income for determining whether an individual belonged to high-income families or low-income families were 2227.7 yuan in 1989, 2246.0 yuan in 1991, 2367.3 yuan in 1993, 3118.7 yuan in 1997, 3854.0 yuan in 2000, 4442.3 yuan in 2004, 4768.5 yuan in 2006 and 7044.9 yuan in 2009.

### 2.4.3 Method

Hierarchical age-period-cohort models, which have recently been used to study temporal effects of a series of health outcomes and subjective well-being (e.g., Masters 2012b; Reither, Hauser, and Yang 2009; Yang 2008; Zheng, Yang, and Land 2011), were applied to analyze the CHNS data on childhood and adolescent overweight in China from 1989 to 2009. The level-1 (within-unit) fixed-effects part of the HAPC model can be expressed in logistic regression form as:
where \( p_{ijk}^{overweight} \) represents the probability of being overweight for the \( i^{th} \) individual in the \( j^{th} \) period of observation and the \( k^{th} \) birth cohort. The square of age is also included in the model to investigate possible curvilinear effects of age on the probability of being overweight.

The level-2 (between-unit) random effects part of the HAPC model for estimating period and cohort effects is:

\[
\pi_0 + t_{0j} + c_{0k}
\]  

where \( \pi_0 \) is the mean averaged over all periods and cohorts when all level-1 variables (age and its square and cubic terms) are zero; the \( t_{0j} \) s are residual random effects of period \( j \) averaged over all birth cohorts, which are assumed to be normally distributed with variance \( \tau_{t0} \); and the \( c_{0k} \) s are residual random effects of cohort \( k \) averaged over all periods of observation, which are assumed to be normally distributed with variance \( \tau_{c0} \) (Raudenbush and Bryk 2002; Yang and Land 2006). A \( \chi^2 \) test is conducted to compare whether a model with random period and cohort effects significantly fits data better than a
corresponding reduced model without random effects. The HAPC models are estimated by SAS PROC GLIMMIX (Littell, Milliken, Stroup, Wolfinger, and Schabenberger 2006). Due to moderate sample sizes, birth cohorts are grouped into five year categories. Moreover, individuals born before 1970 are combined into the 1965 birth cohort and individuals born at the year 2000 and after are combined into the 2000 birth cohort.

2.4.4 Results

Observed prevalence rates of childhood and adolescent overweight across different socio-demographic groups are shown in Table 2. From age 2 to 24, the prevalence of overweight first show consistent declines to about age 18 followed by increases into young adulthood. Across socio-demographic groups, urban residents and individuals from high-income families have consistently higher rates of overweight than their counterparts, but this pattern does not hold for the sex disparity in overweight – although preschool girls have higher prevalence rates of overweight than preschool boys at the pre-school ages, boys generally have higher prevalence of overweight after they enter school.

With regard to observed prevalence across waves of survey, the prevalence rates for the overall population declined from 1989 to 1991 and then steadily increased over the period of study, which illustrates the rising epidemic of childhood and adolescent
overweight in China. Likewise, the regional and income disparities in overweight persisted from 1989 to 2009. Although females had higher prevalence of overweight than males did in the 1989 and 1991 waves, females had lower prevalence rates of overweight in more recent waves.

Across different birth cohorts, it is clear that more recent cohorts had higher prevalence of overweight: the prevalence rate of the cohort born at and after the year 2000 was 11.2% higher than that of the cohort born before the year 1970. Again, urban residents and individuals from high-income families had higher prevalence rates of overweight than rural counterparts or individuals from medium- and low-income families did. Finally, a sex crossover in overweight also appears across birth cohorts. Although males born before 1975 had lower prevalence of overweight than females did, a reverse pattern was observed for more recent cohorts except for the cohort born at and after the year 2000.
Table 2 The prevalence of childhood and adolescent overweight in China by age, period and cohort, CHNS 1989-2009

<table>
<thead>
<tr>
<th>Age</th>
<th>Overall population</th>
<th>Male</th>
<th>Female</th>
<th>Urban Residents</th>
<th>Rural Residents</th>
<th>High-income</th>
<th>Low- &amp; medium-income</th>
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<td>3.9%</td>
<td>4.5%</td>
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</tr>
<tr>
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<tr>
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<td>19.3%</td>
<td>14.6%</td>
<td>18.0%</td>
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Results from hierarchical age-period-cohort analyses are shown in Table 3. The estimated coefficients of the level-1 age function have significant negative linear effects on overweight across different models, which are moderated by significant quadratic coefficients. These estimated quadratic age functions have minimums at around age 15. This is consistent with the observed prevalence rates in Table 2 described above.

The HAPC analyses further indicate that both period and cohort effects are present and statistically significant in the increasing prevalence of childhood and adolescent overweight in China. The period effects increase steadily across the recent seven waves of survey, after a substantial decline from the 1989 wave to the 1991 wave. Period effects associated with socio-demographic groups generally follow this pattern and tend to be significant in earlier (e.g., the 1991 wave and the 1993 wave) or more recent waves of survey (e.g., the 2006 wave and the 2009 wave). Net of age and cohort effects, it is clear that these secular changes, or period effects, were responsible for the increase of overweight childhood and youth prevalence in China.

With regard to cohort effects, more recent cohorts have much higher estimated effect coefficients on overweight than these of earlier cohorts. Although the increase in cohort effects declined somewhat for the cohort born at and after the year 2000, the dramatic and chronological increase in estimated cohort effects in Table 3 demonstrate the important contribution of cohort effects to the rising epidemic of obesity. Particularly, the increase in cohort effects is striking for males (from -1.296 for the 1965 cohort to 0.816
for the 1995 cohort) and individuals from high-income families (from -0.752 for the 1965 cohort to 0.729 for the 1995 cohort). In addition, the random components of both period and cohort effects are largely significant across different models.
### Hierarchical age-period-cohort analyses of overweight for children and youth and socio-demographic groups, CHNS 1989-2009

<table>
<thead>
<tr>
<th></th>
<th>Overall population</th>
<th>Male</th>
<th>Female</th>
<th>Urban Residents</th>
<th>Rural Residents</th>
<th>High-income</th>
<th>Low- and medium-income</th>
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<tr>
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<td></td>
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</tr>
<tr>
<td>Intercept</td>
<td>-1.087**</td>
<td>-1.386**</td>
<td>-0.513*</td>
<td>-0.701*</td>
<td>-0.754**</td>
<td>-1.202**</td>
<td>-0.640**</td>
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<tr>
<td>Age</td>
<td>-0.268***</td>
<td>-0.242***</td>
<td>-0.318***</td>
<td>-0.241***</td>
<td>-0.304***</td>
<td>-0.212***</td>
<td>-0.340**</td>
</tr>
<tr>
<td>Age2</td>
<td>0.009***</td>
<td>0.009***</td>
<td>0.010***</td>
<td>0.007***</td>
<td>0.010***</td>
<td>0.007***</td>
<td>0.011***</td>
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<td></td>
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<tr>
<td>1989</td>
<td>0.141</td>
<td>0.085</td>
<td>0.062</td>
<td>-0.045</td>
<td>-0.056</td>
<td>0.154</td>
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<tr>
<td>1991</td>
<td>-0.195*</td>
<td>-0.198*</td>
<td>-0.272*</td>
<td>-0.484**</td>
<td>-0.344**</td>
<td>-0.227*</td>
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<tr>
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<tr>
<td>1997</td>
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<td>0.100</td>
<td>0.156</td>
<td>0.083</td>
<td>0.301*</td>
<td>0.256*</td>
<td>0.142</td>
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<tr>
<td>2009</td>
<td>0.174*</td>
<td>0.169</td>
<td>0.286*</td>
<td>0.399*</td>
<td>0.411**</td>
<td>0.176</td>
<td>0.311*</td>
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<tr>
<td>(\sigma_{pi})</td>
<td>0.022***</td>
<td>0.026**</td>
<td>0.045**</td>
<td>0.099</td>
<td>0.067**</td>
<td>0.030**</td>
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<td><strong>Cohort effects</strong></td>
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<tr>
<td>1965</td>
<td>-0.807***</td>
<td>-1.296***</td>
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<td>-0.273</td>
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<td>-0.752**</td>
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<tr>
<td>1970</td>
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<td>-0.038</td>
<td>0.079</td>
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<tr>
<td>1985</td>
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<td>0.085</td>
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<td>0.180</td>
<td>0.211*</td>
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<tr>
<td>1990</td>
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<td>0.489*</td>
<td>-0.027</td>
<td>-0.005</td>
<td>0.118</td>
<td>0.283</td>
<td>0.057</td>
</tr>
<tr>
<td>1995</td>
<td>0.644</td>
<td>0.816**</td>
<td>0.170*</td>
<td>0.379**</td>
<td>0.237*</td>
<td>0.729*</td>
<td>0.222*</td>
</tr>
<tr>
<td>2000+</td>
<td>0.329**</td>
<td>0.415</td>
<td>0.003</td>
<td>-0.055</td>
<td>-0.104</td>
<td>0.378</td>
<td>-0.031</td>
</tr>
<tr>
<td>(\sigma_{ci})</td>
<td>0.245***</td>
<td>0.552***</td>
<td>0.013*</td>
<td>0.055*</td>
<td>0.043***</td>
<td>0.265**</td>
<td>0.052**</td>
</tr>
<tr>
<td>(\chi^2)</td>
<td>154.73***</td>
<td>129.46***</td>
<td>28.02***</td>
<td>56.22***</td>
<td>71.63***</td>
<td>93.18***</td>
<td>33.34***</td>
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</tbody>
</table>

Note: \(\sigma_{pi}\) and \(\sigma_{ci}\) are the variance of period and cohort random effects, respectively.

b The likelihood ratio \(\chi^2\) test compares the full model with random effects for period and cohort with a reduced model omitting random effects.

\* p<.10; * p<.05; ** p<.01; *** p<.001 (two-tailed tests)
To visually display sex, regional and economic disparities in age, period and cohort effects, expected prevalence rates of overweight across socio-demographic groups were calculated from the estimated HAPC models in Table 3. The results are displayed in Figures 2 and 3. For the overall population, the prevalence rate of overweight declines during childhood (see Figure 2). After it reaches its bottom of 4.8% at age 15, it rises during the transition from adolescent to adulthood. As also shown in Table 2, period effects showed substantial increases over the period of study, although a temporary decline is estimated from the 1989 wave to the 1991 wave. Likewise, the prevalence rates of overweight maintain a strong upward trend for cohorts born before the year 2000, from 3.2% of cohorts born before 1965 to 12.2% of cohorts born between 1995 and 2000.

While the trends of estimated age, period and cohort effects across socio-demographic groups largely follow these of the overall population, patterns and variations in sex, regional and economic disparities deserve further attention. First, a discernible sex crossover in overweight is evident for both age and cohort effects, while males had higher prevalence rates of overweight than females in terms of period effects. For individuals who are younger or from earlier cohorts, females had higher prevalence rates of overweight. However, a sex crossover happened around age 11 or cohorts born between 1975 and 1980, when prevalence rates of males began to catch up with or even exceed those of females. In particular, the dramatic increase in cohort-based prevalence for males is striking. With regard to predicted prevalence rates estimated from age or
period or cohort effects, urban residents and individuals from high-income families generally have higher prevalence rates of overweight than their corresponding counterparts. Yet, the regional disparity in overweight tended to converge at the lower and higher ends of the age interval investigated. For more recent cohorts, a sharp increase in overweight is observed for children and youth from high-income families.
Figure 2 Predicted prevalence of overweight for children and youth in China and groups defined by sex, CHNS 1989-2009
Age

Period of Observation
2.5 Growth Curve Analyses

2.5.1 Introduction

Using hierarchical age-period-cohort (HAPC) models, the last section examines temporal patterns of overweight prevalence. As HAPC models deals with repeated cross-sectional data, this section further estimates age trajectories of overweight prevalence by tracking certain cohorts of children across childhood. While overweight and underweight issues are often regarded as flip sides of a coin, the second task of this section is to examine whether age trajectories of childhood overweight and underweight
follow each other.

Childhood overweight and underweight are two epidemiological problems with essential consequences not only because they often extend to adulthood but because they are associated with the early onset of a series of diseases and excess deaths (Dietz 1998c). While the global rise of childhood obesity and its association with demographic, socio-economic and spatial factors are drawing increasing attention from epidemiologists and social scientists, it has been argued that households at both developed and developing countries face the dual burden of nutritional problems (the coexistence of both underweight and overweight persons) during the nutrition transition (Doak, Adair, Bentley, Fengying, and Popkin 2002; Doak, Adair, Bentley, Monteiro, and Popkin 2004). Studies on China can shed light on the progress of the two global epidemics not only because the nutrition transition in China is believed to be intertwined with the growth of its market economy, but because a substantial increase in the prevalence of childhood overweight has been documented in this populous country once characterized by the scarcity of food and economic resources not long ago (Cui, Huxley, Wu, and Dibley 2010; Johnson et al. 2006; Luo and Hu 2002; Popkin 1998). Although existing research has suggested sex, socioeconomic and regional disparities in the epidemics of childhood overweight and underweight in China, scholars remain unclear whether demographical, socio-economic and spatial characteristics at the individual level are associated with age trajectories of BMI and the likelihood of being underweight or overweight across
childhood. Again, based on a longitudinal dataset of the China Health and Nutrition Survey (CHNS), growth-curve models with unstructured variance-covariance matrices were employed to examine sex, socioeconomic and regional disparities in BMI trajectories across childhood and their implications for underweight and overweight in reform-era China.

2.5.2 Sample

This research is based on data from the China Health and Nutrition Survey (CHNS). To examine sex, socioeconomic and regional disparities in age trajectories, the sample used for this study included 1,694 children (2-11 years old) who were interviewed in 1993. Follow-up interviews were conducted in 1997 when they were age 6-15 (N = 1,222), in 2000 at ages 9-18 (N = 1,075), in 2004 at ages 13-22 (N = 471) and in 2006 at ages 15-24 (N = 278). The total number of observations is 4,741, which means that each of the 1,694 children first interviewed in 1993 participated in 2.8 waves on average.

2.5.3 Measures and Covariates

The first anthropometric measure was each participant’s body mass index (kg/ m²). After subjects were asked to be barefooted and wear lightweight clothing during the measurement, trained interviewers measured both weight (in kilogram) and height (in
centimeter) to the nearest 0.10 unit of measurement. BMI cut-points for overweight and underweight proposed by the International Obesity Task Force and recommended for international use were adopted to determine overweight and underweight status, respectively (Cole, Bellizzi, Flegal, and Dietz 2000; Cole, Flegal, Nicholls, and Jackson 2007). Because the discrete reference cut-points were given for six-month intervals, a polynomial method was also adopted to provide continuous curves for screening overweight and underweight individuals. Results from this polynomial interpolation can readily provide age- and sex-specific BMI cut-points for an individual’s exact age. These fitted continuous curves for both overweight and underweight had achieved almost a perfect fit (See Figure 4: $R^2 > 0.999$ and the sum of squared residuals <0.05 for all four panels). After calculating each individual’s exact age from date of birth and date of measurement, subjects with BMI equal to or above their age-specific criterion for overweight were identified as overweight, whereas subjects with BMI below their age-specific criterion for underweight were identified as underweight.
Male was a dichotomous variable denoting the sex of each subject (male=1 and female=0). Two variables measuring socio-economic status were used. Economic advantage was a dichotomous variable denoting whether per capita household income was at the top 25% of household income surveyed in that wave. Parental years schooling was a continuous variable denoting the average years of schooling of parents. Next, three measures of regional disparities were included. Urban China was a dichotomous variable denoting whether a household lived in an urban area in 1993. Due to China’s rural-urban
divide, living in urban areas in the pre-reform era defined a person’s entitlement to a variety of social and economic resources, such as education, health care and housing (Fu and Ren 2010; Wu and Treiman 2007). Because a substantial difference in the prevalence of underweight between southern and northern China has been reported elsewhere (Doak et al. 2002), *Southern China* was a dichotomous variable denoting whether a household lived in the southern part of China. *Eastern & Middle China* was a dichotomous variable denoting whether a household lived in the middle or eastern part of China. Compared with middle and eastern regions, the western region is underdeveloped and its economic growth lags behind other regions, which led to the national go-west campaign launched in 1999. All the socio-demographic variables were taken from the first wave of CHNS (the 1993 wave) examined in the current study. This strategy has been adopted by similar studies conducting growth-curve analyses of body composition (Danner 2008; Harris, Perreira, and Lee 2009).

2.5.4 Method

Growth-curve modeling was employed to examine the sex, socioeconomic and regional disparities in age trajectories of BMI, underweight and overweight. To capture curvilinear BMI growth during childhood and adolescence, a second order of age (acceleration) was included. Using a two-stage model formulation of hierarchical linear
models, this growth curve model can be expressed as follows. (Raudenbush and Bryk 2002)

Level-1 or within-person model:

\[
BMI_{ij} = \pi_{0i} + \pi_{1i} \times age_{ij} + \pi_{2i} \times age_{ij}^2 + \epsilon_{ij}
\]  \hspace{1cm} (3)

Level-2 or between-person models:

Intercept

\[
\pi_{0i} = \beta_{00} + \sum_{q=1}^{Q_i} \beta_{0q} X_{qi} + r_{0i}
\]  \hspace{1cm} (4)

Slope

\[
\pi_{1i} = \beta_{10} + \sum_{q=1}^{Q_i} \beta_{1q} X_{qi} + r_{1i}
\]  \hspace{1cm} (5)

Acceleration

\[
\pi_{2i} = \beta_{20} + \sum_{q=1}^{Q_i} \beta_{2q} X_{qi} + r_{2i}
\]  \hspace{1cm} (6)

Meanwhile, these models can be reparameterized as follows by a single formula using the interactions between age (square) and other variables:
\[ BMI_{ij} = (\beta_{20} + \sum_{q=1}^{Q} \beta_{2q} X_{qj} + r_{2i}) \times \text{age}_{ij}^2 + (\beta_{10} + \sum_{q=1}^{Q} \beta_{1q} X_{qj} + r_{1i}) \times \text{age}_{ij} + \sum_{q=1}^{Q} \beta_{0q} X_{qj} + \beta_{00} + r_{0i} + \varepsilon_{ij} \]
\[ = \beta_{20} \cdot \text{age}_{ij}^2 + \beta_{10} \cdot \text{age}_{ij} + \sum_{q=1}^{Q} \beta_{0q} X_{qj} + (\sum_{q=1}^{Q} \beta_{2q}) \cdot \text{age}_{ij}^2 + \sum_{q=1}^{Q} \beta_{1q} X_{qj} \cdot \text{age}_{ij} \]
\[ + (\sum_{q=1}^{Q} \beta_{0q}) \cdot X_{qj} \cdot \text{age}_{ij} + \beta_{00} + r_{2i} \cdot \text{age}_{ij}^2 + r_{1i} \cdot \text{age}_{ij} + r_{0i} + \varepsilon_{ij} \]  

(7)

The unstructured variance-covariance matrix for level-2 random effects is given as below. To account for dependence among random components, \( \tau_{ij} \) \((i \neq j)\) is not restricted to be zero in the estimation.

\[ T = \begin{bmatrix} \tau_{00} & \cdots & \cdot \\
\tau_{10} & \tau_{11} & \cdots \\
\tau_{20} & \tau_{21} & \tau_{22} \end{bmatrix} \]

(8)

Based on the age- and sex-specific cut-points for overweight and underweight generated by the aforementioned polynomial method, prevalence rates of overweight and underweight from childhood to adulthood (age 6-18) were predicted by hierarchical logistic models using the same set of independent variables and estimation strategy, with the exception that insignificant random components at the level-1 slope and acceleration were omitted to achieve statistical convergence. A three-point moving-average data-smoothing process was applied to predicted prevalence.
2.5.5 Results

The characteristics of the 1,694 subjects aged 2-11 in 1993 are shown in Table 4. The subjects had an average BMI of 15.79 and were, on average, 6.86 years old. More than half of these children were boys (53.8%). This is not surprising given the well-established unbalanced birth sex ratio in China. (Zeng, Tu, Gu, Xu, Li, and Li 1993) Less than 20 percent of these children came from high-income families and the average years of schooling of their parents was 7.198 years. Children residing in urban China constituted about 20% of the sample surveyed in 1993. The majority of children lived in southern China. About 30% of the children were initially interviewed at western China.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>S.D.</th>
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</thead>
<tbody>
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<td>Body Mass Index</td>
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</tr>
<tr>
<td>Age</td>
<td>6.856</td>
<td>2.393</td>
</tr>
<tr>
<td>Male</td>
<td>53.8%</td>
<td></td>
</tr>
<tr>
<td>High-income families</td>
<td>18.5%</td>
<td></td>
</tr>
<tr>
<td>Parental years of schooling</td>
<td>7.198</td>
<td>3.098</td>
</tr>
<tr>
<td>Urban China</td>
<td>19.9%</td>
<td></td>
</tr>
<tr>
<td>Southern China</td>
<td>64.2%</td>
<td></td>
</tr>
<tr>
<td>Eastern &amp; Middle China</td>
<td>70.6%</td>
<td></td>
</tr>
</tbody>
</table>

With regard to age trajectories of BMI over childhood, results obtained from growth curve models are shown in Table 5. As suggested by the Model 1 in Table 5, both
age and age square had significant effects on BMI, while the average BMIs in 1997, 2000 and 2004 were higher than that in 1993, net of other effects. When a series of socio-demographic indicators are included in Model 2, all of them except urban residence have significant effects on BMI. Net of other effects, males and subjects from high-income families had higher BMI, whereas subjects with higher parental years of schooling or located in southern or western China had lower BMI. Yet, results from both Model 1 and Model 2 have concealed heterogeneity in the BMI trajectories from childhood to adolescence, which was addressed in Model 3. When the interactions between age (square) and these indicators were taken into account in Model 3, the main effects of socio-demographic variables essentially correspond to differential intercepts of age trajectories across socio-demographic groups. Whereas males and individuals from southern and non-western China had significantly higher intercepts of age trajectories of BMI than their counterparts did, individuals from high-income families or urban China had significantly lower intercepts of age trajectories than their counterparts did. Meanwhile, the significant main effect of age (square) on BMI has been explained by their interactions with socio-demographic variables. With regard to the interaction between age and socio-demographic variables (or the level-1 slope), the age trajectories of BMI increased significantly faster for individuals from high-income families, urban China, northern China or families with lower parental years of schooling. Yet, these increases (or decreases) in age trajectories were moderated by the interactions between
age square and socio-demographic variables (or level-1 acceleration) because the sign of level-1 acceleration is opposite to that of the level-1 slope for each socio-demographic group. In particular, the moderating effects on age trajectories of BMI are significant for almost all socio-demographic groups (except sex). Finally, the validity of assuming random components during estimation is supported by the significant off-diagonal elements in the variance-covariance matrix from Model 1 to Model 3.
Table 5 Growth curve models on BMI trajectories of children and youth in China: 1993-2006

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th></th>
<th>Model 2</th>
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<th>Model 3</th>
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<td>Coeff.</td>
<td>S.E.</td>
<td>Coeff.</td>
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<td>-0.391</td>
<td>0.043***</td>
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<td>0.031</td>
<td>0.002***</td>
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<td>0.102**</td>
<td>0.355</td>
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<td>The 2000 wave</td>
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<td>0.731</td>
<td>0.149***</td>
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<td>0.259***</td>
<td>1.063</td>
<td>0.251***</td>
<td>1.035</td>
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<td>0.086*</td>
<td>0.917</td>
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<td>0.115**</td>
<td>-1.413</td>
<td>0.460**</td>
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<td>0.108</td>
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<td>-1.907</td>
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<td>0.102***</td>
<td>1.401</td>
<td>0.406**</td>
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<tr>
<td>Eastern &amp; Middle China</td>
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<td>1.396</td>
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<td>16.829</td>
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<td>14.118</td>
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<td>$\tau_{22}$ (age square)</td>
<td>$\tau_{00}$ (intercept)</td>
<td>$\tau_{21}$ (age, age square)</td>
<td>$\tau_{10}$ (age, intercept)</td>
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<td>3.295</td>
<td>0.117***</td>
<td>3.361</td>
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</table>

Note: Statistical significance: * p < 0.05; ** p<0.01; ***p<0.001 (two-tailed tests); For the Model 1 in Table 1, the unexplained variance $\sigma^2$ is 4.394 (.111) in the absence of random effects in slope and acceleration and 6.454 (.133) in the absence of any random effects.

To examine the implications of age trajectories in BMI on childhood overweight and underweight, age trajectories of overweight and underweight prevalence rates in the transition from childhood to adulthood (age 6-18) were predicted. In Figure 5, overweight and underweight prevalence rates were estimated based on partial coefficients of full models (the same set of covariates as those in Model 3 of Table 5). The socio-demographic disparities in age trajectories were generally greater for underweight than for overweight, except for those in southern and northern China. Over the age interval investigated, the prevalence rates of underweight grew steadily from age 6 to age
13, then either leveled off or declined afterwards. The age trajectories in the prevalence of overweight largely showed a long-term decline, although the decline slowed down around age 12 for most socio-demographic groups. In particular, females’ prevalence rates of underweight were consistently higher than those of males. Although males had higher prevalence rates of overweight than females, the sex disparity in overweight was barely noticeable until age 12 when the sex difference widened. Children from high-income families had lower prevalence rates of underweight and higher prevalence rates of overweight than children from medium- and low-income families, while the income disparity in overweight increased for older children. There was virtually no difference in the age trajectories of overweight for children having different parental years of schooling and this result was robust with different cut-off points for parental years of schooling (e.g., 7 years or 9 years). Net of other effects, individuals with higher parental years of schooling were slightly more likely to be underweight.

With regard to regional disparities in age trajectories of overweight and underweight, the prevalence rates of underweight for children in urban China showed a steady decline from age 6 to age 18, whereas the prevalence of underweight for their peers in rural China dramatically increased from age 6 to age 13 and then decreased. Although urban children had higher prevalence of overweight than their peers in rural China, the age trajectories began to converge around age 13 and a regional crossover happened afterwards. From age 6 to 18, children living in southern China and western
China had consistently higher prevalence rates of underweight and lower prevalence rates of overweight than their peers living in northern and middle & eastern China, respectively. However, the gaps in both overweight and underweight prevalence rates among children located at different geographical locations in China (south versus north, west versus middle and east) tended to decrease after age 13.
Overweight: High-income families
Overweight: Low- & medium-income families
Underweight: High-income families
Underweight: Low- & medium-income families

Overweight: 9 years of schooling (average parental education)
Overweight: 6 years of schooling (average parental education)
Underweight: 9 years of schooling (average parental education)
Underweight: 6 years of schooling (average parental education)
Figure 5 Age trajectories of the prevalence in overweight and underweight as moderated by sex, socioeconomic status and regional disparity (children and youth aged 6-18)

Note: The prevalence rates of overweight and underweight are predicted from the estimated partial regression coefficients of the full model of growth-curve analyses.

2.6 Discussion and Conclusions

Based on eight waves of the China Health and Nutrition Survey (CHNS) from 1989 to 2009 and an established international standard for childhood overweight, one aim of this chapter is to study the temporal patterns of age, period and cohort effects associated with the increasing prevalence of childhood and adolescent overweight in China and the differential association of these temporal effects with various
socio-demographic groups. Results from hierarchical age-period-cohort models showed a consistent curvilinear pattern of age effects on overweight prevalence combined with period and cohort effects, while. Moreover, a sex crossover in overweight prevalence, which was suggested by previous studies, was manifested in both age and cohort effects. While regional and economic disparities in overweight prevalence remained persistent such that urban residents and persons from high-income families had higher prevalence rates of overweight than their peers, the increase in cohort effects was particularly striking for males and persons from high-income families.

Recently, the increasing prevalence of childhood and adolescent overweight in China has been an important topic for medical and epidemiological research (Ji and Cheng 2009b; Olds, Maher, Zumin, Peneau, Lioret, and Castetbon 2011; Onis, Blössner, and Borghi 2010). However, traditional epidemiological analyses concealed a great deal of heterogeneity in the temporal effects embedded in the increasing prevalence. In a populous country experiencing rapid social, economic and nutritional transitions (Bian and Logan 1996; Drewnowski and Popkin 1997; Nee 1989; Popkin 1999), it is essential to identify the temporal patterns of effects responsible for the rapid increases in overweight prevalence. By estimating age, period and cohort effects separately using HAPC models, I found both period and cohort effects as the major temporal components embedded in the rise of childhood and adolescent overweight prevalence in China. By illustrating temporal effects embedded in the rise of overweight prevalence and their
differential trajectories across socio-demographic groups, this research highlights the severity of the childhood and adolescent overweight epidemic in China. As previous cohorts are constantly replaced by heavier cohorts who had earlier, more intensive and extensive exposure to a series of social, economic and environmental risk factors associated with overweight, the overweight epidemic can preserve and magnify itself in the long run and set a stage for the fifth phase of the epidemiologic transition (Gaziano 2010), the age of obesity and inactivity, in China.

Results from HAPC analyses also indicate that certain socio-demographic groups are more susceptible to the rise of overweight prevalence. First, this research confirmed the existence of a sex crossover in overweight prevalence for both age and cohort effects (Ji 2008; Wu, Huxley, Li, and Ma 2009). Second, urban residents had persistently higher prevalence rates of overweight than rural residents for all three types of temporal effects, which further demonstrates the influence of China’s rural-urban divide on the overweight epidemic (Fu and Ren 2010; Wu and Treiman 2007). Third, the higher prevalence rates of individuals from high-income families were also consistent with existing studies (Cui, Huxley, Wu, and Dibley 2010; Wang, Ge, and Popkin 2000). Last but not the least, the substantial increases in cohort effects for both males and individuals from high-income families deserve serious attention.

In concluding, several limitations of the current study should be acknowledged. First, it remains unclear whether the temporary drop in overweight from the 1989 wave to
the 1991 wave resulted from the sample attrition problem (Ng, Zhai, and Popkin 2008) or tightened state control after the year 1989. Although conservative economic and social policies had been adopted by the central government in response to the demise of socialist regime in the late 1980s, this study cannot adjudicate causes of the temporary drop in period effects in the absence of survey data before 1989. Second, whether the decline in cohort effects for cohorts born at and after the year 2000 was temporary or indicative of a permanent change cannot be determined. As the life-course experience of these cohorts remained limited, future research should rely on future waves of the CHNS to evaluate the trends of overweight as these latest cohorts then will have longer and more extensive exposure to risk factors associated with overweight.

By tracking certain cohorts of children across time, the second aim of this chapter is to examine sex, socioeconomic and regional disparities in age trajectories of BMI across childhood using growth curve models. Net of other effects, results showed that boys and children from high-income families had significantly higher BMI, whereas children with higher parental education, living in southern or western China had lower BMI. Moreover, the significant main effects of age and age square on childhood BMI could be explained by their interactions with socio-demographic variables. Based on a polynomial method and logistic growth-curve analyses, the implication of BMI trajectories on underweight and overweight in the transition from childhood to adulthood (age 6-18) was also investigated. Although parental education had little effect on age
trajectories of overweight or underweight, boys and children from high-income families were associated with lower underweight prevalence and higher overweight prevalence. Substantial regional disparities in age trajectories of underweight and overweight were observed. Children from urban areas, northern China or non-western China showed higher prevalence rates of overweight, whereas their counterparts (children from rural areas, southern China or western China) had higher prevalence rates of underweight.

The sex disparities in age trajectories of BMI, underweight and overweight were not surprising given the strong preference of boys over girls in Confucian culture because sons, instead of daughters, were more relevant to the continuation of family lines, the intergenerational transfers of property rights and the living arrangements of older parents. (Lee and Wang 2001; Poston Jr., Gu, Liu, and McDaniel 1997) Meanwhile, the income disparity in age trajectories was also expected as high-income families had better access to nutrition than others. The absence of an educational disparity in age trajectories of overweight suggested that knowledge of public health, especially that relevant to overweight, had not been incorporated in formal education in China. (Kan and Tsai 2004) Consistent with results from existing studies, (Doak, Adair, Monteiro, and Popkin 2000; Luo and Hu 2002) the results pointed to the significance of China’s rural-urban divide in shaping childhood underweight and overweight. Because China adopted Soviet Russia’s model of prioritizing urban industrial growth at the cost of rural development in the early 1950s, the socialist state’s bias towards urbanites and its
development ideology that rural persons should be self-reliant deprived rural persons’ entitlements to a variety of social benefits and state resources, such as subsidized food, health care and social welfare. (Chan and Zhang 1999; Wu and Treiman 2007) As energy intake was not in line with physical growth in the transition from childhood to adolescence, a dramatic increase in the prevalence rates of underweight was observed for rural children from age 6 to age 13, whereas the prevalence of underweight for their urban peers showed a steady decrease over the same age interval. The rural-urban convergence in trajectories of overweight suggests a selection effect of massive rural-urban migration in China. (Chen 2011; Wang, Li, Stanton, and Fang 2010) The body weight of healthy rural migrant workers was catching up with that of their urban peers. Finally, the differences in the prevalence of overweight and underweight between children from western China and non-western China were expected because economic and social development in western China greatly lagged behind other regions. (Grogan 1995) Different dietary patterns account for the south-north differences in childhood underweight and overweight. (Doak et al. 2002; Zhou, Zhang, Zhu, Zhao, XHU, Ruan, Zhu, and Liang 1994)

These findings from growth-curve models also have important implications. They suggest that the dual burden of nutritional problems in reform-era China is more like two sides of a coin than two separate health issues. Children who had lower prevalence rates of underweight in the transition from childhood to adulthood (such as boys, children from
high-income families, children living in urban China, etc.) also exhibited higher prevalence rates of overweight than their counterparts did. As demonstrated by the age trajectories of underweight and overweight, children aged 6 to 13 were more vulnerable to underweight, whereas older children who were at the age for secondary education were more vulnerable to overweight. Although these results do not necessarily mean that the focus of intervention programs should be shifted from underweight in primary schools to overweight in secondary schools in China, policy makers, health workers and school teachers should be aware of the critical periods for intervening in childhood underweight and overweight, respectively. Regional disparities also play an important role in driving the distribution of childhood overweight and underweight. This suggests that public health efforts to reduce both underweight and overweight should be targeted at regions where the need is greatest.

3. Overweight and Obesity: A Comparative Perspective

3.1 Introduction

In the previous chapter, the temporal patterns of childhood overweight in China are investigated using HAPC and growth-curve models. This chapter explores the overweight and obesity issues from a comparative perspective. In particular, it addresses the following two research questions. First, do childhood overweight and adulthood
overweight in China share the same temporal patterns? If not, how are they different? Second, from a global perspective, what is the association between economic and social development and the prevalence of obesity across countries? If the UNDP’s (United Nations Development Program) Human Development Index (HDI) is employed, should we expect that the HDI has a positive, negative or no relation with the obesity prevalence across countries? These issues are investigated in the next sections of Chapter 3.

3.2 Adulthood Obesity in China: An Age-Period-Cohort Analysis

3.2.1 Introduction

As China has urbanized and moved towards a market-oriented economy, the intake of high-fat and high-carbohydrate diet has risen in tandem with the proliferation of a more sedentary living and working style. Given the link between overweight prevalence and an array of negative health outcomes and diseases, adulthood overweight and obesity, if left unabated, will impose a gigantic health and fiscal burden in the foreseeable future (Bongaarts 2006; Doak et al. 2004; Kelly, Yang, Chen, Reynolds, and He 2008; Wu, Huxley, Li, and Ma 2009).

Based on 55,683 adults interviewed in eight waves of the China Health and Nutrition Survey (CHNS), this study applies hierarchical age-period-cohort (HAPC) models (Yang and Land 2006, 2008, 2013) to estimate the age, period, and cohort
components of the temporal trends of adulthood overweight prevalence in China. As a socio-demographic gradient in the overweight epidemic has been well documented in existing studies (Cui, Huxley, Wu, and Dibley 2010; Ji and Cheng 2009b; Jones-Smith, Gordon-Larsen, Siddiqi, and Popkin 2011; Pampel, Denney, and Krueger 2012; Scharoun-Lee, Gordon-Larsen, Adair, Popkin, Kaufman, and Suchindran 2011; Wang, Monteiro, and Popkin 2002b), I also investigate the dynamics of a socio-demographic gradient in overweight prevalence across time periods. Moreover, the HAPC analysis, which simultaneously accounts for age, period and cohort effects, allows us to study the cohort-specific consequences of childhood nutritional deprivation (i.e. the Great Chinese Famine) on adulthood overweight prevalence.

This study thus addresses three research questions. First, is the rising epidemic of overweight among Chinese adults primarily driven by age, period or cohort effects? Second, as China is in the midst of massive and far-reaching social and economic changes, does the socio-demographic gradient in the overweight epidemic shift over the period of study? Third, do certain birth cohorts who experience the Great Chinese Famine (1958 - 1961) in utero, infancy and childhood bear a physiological imprint left by early nutritional deprivation when they grow up? To address these questions, the next sections highlight the relevance of three different yet related temporal dimensions – age, period, and cohort. This is followed by a description of the data, measures, and methods applied in the present study. Results of the analyses then are presented, followed by a discussion and
3.2.2 Age Effects: Age Trajectories of Overweight

As we discussed in the previous chapter, *age effects* refer to physiological, psychological, and behavioral changes in the human aging process. With respect to studies of adulthood overweight prevalence, studies based on data from Western countries have found that body weight rises gradually as an adult ages but the gradual increase in body weight tends to level off around age 60 and then declines afterwards with the loss of lean body mass (Miller and Wolfe 2008; Zamboni, Mazzali, Zoico, Harris, Meigs, Di Francesco, Fantin, Bissoli, and Bosello 2005). In the absence of intentional weight control, the weight loss at older ages is associated with a series of physiological and non-physiological factors in the aging process, such as less food intake, reduced hunger sensations, and a diminished senses of taste (Lennie, Moser, Heo, Chung, and Zambroski 2006). Although mixed findings have been reported regarding whether weight loss is beneficial in the elderly, rapid and unintentional declines in body weight at older ages are often associated with co-morbid conditions such that anorexia, lipolysis, and protein breakdown caused by (the treatment of) chronic and acute diseases (Bales and Ritchie 2002; Miller and Wolfe 2008).
3.2.3 Period Effects: The Reversal Hypothesis

Again, period effects relate to temporal variations taking place in specific time periods that simultaneously affect all age groups and birth cohorts, corresponding to the impacts of social, economic and environmental factors on adulthood overweight (Reither, Hauser, and Yang 2009). As the benefits of China’s market transformation have spread unequally throughout its society over the past two decades, it has been observed that individuals with certain (beneficial) socio-demographic characteristics were first and most affected by the overweight epidemic due to their early access to high-energy-density diets and a more sedentary way of living, which leads to a socio-demographic gradient in overweight prevalence. For example, after the household registration system (hukou) was established to drain China’s vast rural areas and concentrate its economic and social resources in urban areas to foster urban industrialization, a person’s entitlement to a variety of resources and opportunities, such as social welfare, health care, education and employment, were determined by his/her place of residence (Chan and Zhang 1999; Fu and Ren 2010; Wu and Treiman 2007). Correspondingly, it has been observed that the prevalence rates of overweight in urban China are significantly higher than these in rural China (Gu, Reynolds, Wu, Chen, Duan, Reynolds, Whelton, and He 2005; Reynolds, Gu, Whelton, Wu, Duan, Mo, and He 2012; Wang, Monteiro, and Popkin 2002b). Although mixed findings have been reported regarding sex, income and educational disparities in the rise of the overweight epidemic in China, overweight individuals tend to be female,
come from higher-income families or have higher educational attainment, especially in the earlier years of China’s economic transformation (Cai, He, Song, Zhao, and Cui 2013; Doak et al. 2002; Gordon-Larsen, Adair, Meigs, Mayer-Davis, Herring, Yan, Zhang, Du, and Popkin 2012; Gu et al. 2005; Luo and Hu 2002; Reynolds et al. 2012; Wang, Ge, and Popkin 2000).

The shifts and dynamics of the socio-demographic gradient in overweight prevalence across time periods also deserve attention. First, risk factors of overweight prevalence are no longer restricted to affluent or high socio-economic status individuals. While food consumption of China’s entire society has already moved towards more calories and a greater proportion of diets from fat and protein (Popkin and Du 2003), massive and fundamental reforms in the economy and society are fostering a sedentary lifestyle through the spatial mismatch between workplace and residence, increasing non-manual labor, and declines in neighborly interactions within gated communities (Hsing 2010; Popkin 1999; Zhu, Breitung, and Li 2012). Second, as posited by the fundamental causes of disease theory (Link and Phelan 1995; Phelan and Link 2005), advances in medical technology and knowledge have become readily available for individuals with better social and economic resources, which has profound implications on changes in the socio-demographic gradient in overweight. As those with higher socio-economic status increasingly have more rapid and easier access to emerging knowledge, tools and technology in controlling and preventing overweight, the once
positive association between socio-economic status and overweight will diminish, disappear or even reverse. This reversal hypothesis on the linkage between SES and body weight during economic development has been supported by a recent cross-national study suggesting that the association between SES and overweight shifts from positive to negative as national product increases (Pampel, Denney, and Krueger 2012), and a longitudinal study also lends support to the reversal hypothesis and finds that low SES has become a risk factor for overweight prevalence among Chinese women in more recent years, although high SES is still associated with higher odds of overweight for men (Jones-Smith, Gordon-Larsen, Siddiqi, and Popkin 2011).

3.2.4 Cohort Effects: The Long Arm of the Great Famine

Cohort effects, as discussed before, pertain to temporal variations in overweight prevalence across individuals who share a common year (or a relatively small number of years) of birth, which correspond to a shared life-course experience originating from membership in each birth cohort (Reither, Hauser, and Yang 2009; Yang and Land 2013). With regard to cohort effects, it has been argued that the effect of early nutritional deprivation on adulthood overweight tends to be more pronounced if the exposure to nutritional deprivation takes place during certain critical periods in utero, infancy and childhood (Dietz 1994; Dietz 1998b; Druet and Ong 2008). Moreover, this critical-period
hypothesis also posits that life-course effect on adult body composition varies with the timing of early exposure to nutritional deprivation (Dietz 1994). For example, exposure to the Dutch famine of 1944-1945 during the last trimester of pregnancy and the first months of life was shown to be associated with significantly lower rates of adulthood overweight prevalence, whereas exposure during the first half of pregnancy resulted in significantly higher rates of adulthood overweight prevalence (Ravelli, Stein, and Susser 1976). In addition, adiposity rebound (AR), during which BMI accumulated in the first year of life reaches a nadir and then increases again at ages 6-8, appears to be another critical period when childhood exposure to nutritional deprivation has life-course influence on overweight prevalence (Dietz 1994; Dietz 1997). An early AR, which is significantly associated with higher parental BMI, predicts adulthood overweight prevalence (Dorosty, Emmett, Cowin, and Reilly 2000; Whitaker, Pepe, Wright, Seidel, and Dietz 1998).

In this regard, early exposure to the Great Chinese Famine (1958 - 1961) and its life-course impact on adulthood overweight prevalence deserve attention. As the worst, largest and most tragic famine ever recorded in human history, the Famine dragged down China’s annual population growth rate by almost 3 percent from 1957 to 1961, which led to about 30 million excess deaths (around 5 percent of China’s population size at that time)

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2 Although the duration of the Great Chinese Famine was officially reported as 1959-1961, it has been shown that serious food shortage had already appeared in several regions at the end of 1958, which is also referred by some scholars as the beginning of the Famine (See: Ashton, Basil, Kenneth Hill, Alan Piazza, and Robin Zeitz. 1984. "Famine in China, 1958-61." Population and Development Review 10:613-645.).
and negative population growth rates of the most populous country (Ashton, Hill, Piazza, and Zeitz 1984; Cai and Feng 2005; Coale 1981). Existing studies suggest that the impact of nutritional deprivation on infants and children tends to be more striking at the beginning of the Famine when strict measures of food rationing and allocation were virtually absent (Ashton, Hill, Piazza, and Zeitz 1984). Being obsessed with the unrealistic goal of yielding more industrial output (especially iron and steel) than that of Western countries during the Great Leap (1957 - 1960), the socialist regime drained enormous resources and labor from agricultural production to promote industrial growth (Peng 1987). With the proliferation of “backyard iron furnaces” and public kitchens of the People’s Communes across China, the central government not only failed to anticipate the dire consequences of the breakup of agricultural production, unchecked supply and waste of free food in communal kitchens and the over-emphasis on industrial growth but ignored massive food scarcity at the beginning of the Famine (Ashton, Hill, Piazza, and Zeitz 1984; Li and Yang 2005). Consequently, it has been suggested that infant and childhood mortality rates increased substantially from 1958 to 1959 but reduced subsequently with the establishment of effective rationing measures (Ashton, Hill, Piazza, and Zeitz 1984; Li and Yang 2005).

The Great Chinese Famine thus provides us an opportunity to investigate the critical-period hypothesis regarding cohort effects of China’s overweight epidemic. As compared with successive cohorts, existing studies have shown that cohorts born during
the Great Chinese Famine (1958-1961) are significantly associated with higher adulthood BMI and overweight prevalence rates (Huang, Li, Wang, and Martorell 2010; Luo, Mu, and Zhang 2006; Wang, Wang, Kong, Zhang, and Zeng 2009). Yet, no prior study has estimated the cohort effects separately from other two temporal effects, which mandates further investigation of the critical-period hypothesis.

3.2.5 Data and Measures

This research is also based on data from the China Health and Nutrition Survey (CHNS). All adult respondents aged between 18 and 64 in any of the eight waves are included in the current research (N=55,683). For adults aged 18 to 64, their overweight status is determined by the widely used adult BMI cut-point of 25 kg/m² (WHO Expert Consultation 2004). To calculate each person’s accurate BMI, the CHNS anthropometrical measurements include the body weight of subjects in light indoor clothing, measured to the nearest 0.1 kg with a beam balance scale and height of subjects without shoes to the nearest 0.1 cm, as measured using a portable stadiometer. Following standardized protocols, all interviewers conducting anthropometrical measurements were required to take inter-observer reliability tests.

Because sex, regional and socio-economic disparities in overweight have been widely reported by existing studies (Cai et al. 2013; Doak et al. 2002; Gordon-Larsen et
al. 2012; Gu et al. 2005; Luo and Hu 2002; Reynolds et al. 2012; Wang, Ge, and Popkin 2000), this research also includes four socio-demographic covariates to examine changes and patterns of overweight across different socio-demographic groups. *Male* is a dichotomous variable denoting the sex of the respondents such that female was coded as zero and male was coded as one. Male respondents account for 47.5% of the overall sample used in the current study. Given China’s salient rural-urban divide and its implications on the overweight epidemic (Chen and Korinek 2010; Fu and Ren 2010; Gu et al. 2005; Wu and Treiman 2004), *urban* is a dichotomous variable denoting the residence of respondents (urban residence coded as one versus rural residence coded as zero). Urban residents account for 32.7% of the overall sample. Individuals with per capita household income higher than or equal to the third quartile (75%) of per capita household income surveyed in the same wave were coded as from *high-income families* (coded one) and others were coded as from *low- or medium-income families* (coded zero). As the nine-year compulsory education in China ends with the completion of middle school (or junior secondary education), the sample was divided by a dichotomous variable denoting whether a respondent’s educational attainment is middle school or

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3 Another way of measuring the effect of the rural-urban divide is to examine type of household registration, or *hukou* status (agricultural hukou versus non-agricultural hukou). However, the information of *hukou* status was only included in more recent CHNS waves, which precludes the use of *hukou* status. As interviewees of the CHNS were virtually recruited from their *de jure* place of residence in lieu of *de facto* location, their (rural versus urban) residence is a valid variable for measuring the effect of rural-urban divide on overweight.
below (coded zero) or high school or above (coded one). Individuals who have (at least) completed high school account for 23.0% of the overall sample.

3.2.6 Methods

Hierarchical age-period-cohort cross-classified random effects (HAPC-CCREM) logistic regression models are still employed to study the temporal patterns and socio-demographic disparities in the rising overweight epidemic in China from 1989 to 2009 (Masters 2012a; Reither, Hauser, and Yang 2009; Yang and Land 2008; Yang and Land 2013; Yang and Land 2006). Because the sample size pertaining to the study of adulthood overweight is fairly large and thus allows for specification of interactions between random temporal effects and socio-economic indicators, the HAPC model specification used in this chapter nevertheless differs from that in Chapter 2. The level-1 within-group (where the groups are defined by a cross-classification of sample respondents by the time period of the survey to which they responded and the birth cohort to which they belong) fixed-effects part of the HAPC-CCREM logistic regression model can be expressed as follows:

\[
\log \frac{p_{ijk}^{overweight}}{1 - p_{ijk}^{overweight}} = a_{jk} + \beta_{1jk} \text{age} + \beta_{2jk} \text{age}^2 + \beta_{3jk} \text{M} + \beta_{4jk} \text{UR} + \beta_{5jk} \text{HS} + \beta_{6jk} \text{HI} + \sum_{p=2}^{P} \beta_{p} X_p \quad (9)
\]
where \( p_{ijk}^{\text{overweight}} \) represents the probability of being overweight for the \( i^{th} \) individual in the \( j^{th} \) period of observation and the \( k^{th} \) birth cohort. Given the fact that the adult age range investigated in the current study is relatively long (ages 18-64), the square term of age is included in the model to estimate possible curvilinear effects of age on the probability of being overweight. For other covariates in the model, \( M \) denotes being male; \( UR \) denotes urban residence; \( HS \) denotes the completion of (at least) high school; and \( HI \) denotes individuals from high-income households. The \( X_p \) term consists of possible interactions between (the square of) age and other level-1 covariates (i.e., \( M, UR, HS \) and \( HI \)). Because an auxiliary analysis shows that, among all possible interactions between (the square of) age and socio-demographic indicators only their interactions with sex and urban residence are significant, \( X_p \) includes four terms (\( p=4 \)): \( age \times M \), \( age^2 \times M \), \( age \times UR \) and \( age^2 \times UR \). Finally, the \( \beta \)'s are the level-1 coefficients and \( a_{jk} \) is the level-1 intercept denoting the group mean for individuals who were at the (hypothetical) age zero, included in reference groups, interviewed in the \( j^{th} \) period and born in the \( k^{th} \) birth cohort.

The level-2 (between-group) random effects parts of the HAPC-CREEM model for estimation of period and cohort effects are expressed as follows:

\[
\begin{align*}
a_{ij} &= \pi_0 + t_{0j} + c_{0k} & t_{0j} &\sim N(0, \tau_{t0}) & c_{0k} &\sim N(0, \tau_{c0}) \\
\beta_{3jk} &= \pi_3 + t_{3j} & t_{3j} &\sim N(0, \tau_{t3})
\end{align*}
\] (10)
where $\pi_0$ is the mean averaged over all periods and cohorts when all level-1 variables (age and its squared term) are zero; the $t_{0j}$s are residual random effects of period $j$ averaged over all birth cohorts, which are assumed to be normally distributed with variance $\tau_{00}$; and the $c_{0k}$s are residual random effects of cohort $k$ averaged over all periods of observation, which are assumed to be normally distributed with variance $\tau_{c0}$ (Raudenbush and Bryk 2002; Yang and Land 2006).

To investigate the reversal hypothesis about a possible shift of the socio-demographic gradient in the overweight epidemic during the period of study, equations (3) - (6) take random period effects into account in the estimation of level-1 coefficients. A simple reparameterization of HAPC models can show that $t_{ij}$ at equation (3) - (6) corresponds to interactions between random period effects and effects of socio-demographic covariates (Rabe-Hesketh and Skrondal 2008). Because a reduced model with random effects at the intercept $a_{jk}$ lends no support to an increasing cohort effect for the overweight epidemic and very few birth cohorts are significantly associated with overweight status, this HAPC analysis considers whether the effect of socio-demographic variables vary across different time periods in lieu of cohorts. From
equation (3) to equation (6), \( \pi_i \) is the main effect of a socio-demographic indicator and \( t_{ij} \), which is assumed to be normally distributed with variance \( \tau_u \), is the random period effect on level-1 coefficient \( \beta_{ijk} \). A \( \chi^2 \) test can be conducted to compare whether a model with random period and cohort effects significantly fits data better than a corresponding reduced model without any random effects. All HAPC-CCREM models were estimated by SAS PROC GLIMMIX (Littell et al. 2006). To yield robust estimates of the cohort-specific fixed effects, birth cohorts are defined as two-year groups.\(^4\) Due to moderate sample sizes in earlier and later cohorts, individuals born before the year 1940 are grouped into the before 1940 cohort and individuals born at the year 1980 or after are grouped into the 1980 or after cohort.

3.2.7 Results

Overweight prevalence rates for the overall population and socio-demographic groups are shown in Table 6. For the overall population, the prevalence rates increase substantially at older age groups or more recent periods. While prevalence rates of overweight tend to be lower for cohorts born in more recent years, the highest overweight prevalence rates are in the cohorts born at the beginning of the Great Chinese Famine (1958-1959). With regard to the socio-demographic gradient, women have higher rates of overweight than men do over most age groups and survey waves except for age 25 to age

\(^4\) I have also tried different ways of categorizing the birth cohorts and the results are robust.
39 and the most recent two survey waves (the 2006 and 2009 waves), respectively. Likewise, although women have higher rates of overweight in earlier birth cohorts, this pattern virtually reverses itself for cohorts born after the 1960s. Despite the fact that urban residents have consistently higher prevalence rates of overweight than their rural counterparts across different age groups and survey waves, the rural-urban difference in overweight tends to diminish in more recent survey waves. For cohorts born before the 1960s, urban residents also have higher prevalence rates of overweight than rural residents but this conclusion does not hold for cohorts born after the 1960s.

Across different socio-economic groups, individuals from high-income families have greater overweight prevalence rates across all age groups and survey waves except for the youngest age group (ages 18-24). Meanwhile, these income disparities in overweight prevalence show no signs of convergence in either older age groups or more recent survey waves. Yet, individuals from low-income families largely have higher prevalence rates of overweight than these of individuals from high-income families in more recent cohorts (born after the year 1965). Although individuals with higher educational attainment have higher prevalence rates of overweight across virtually all age groups and survey waves, this pattern reverses in more recent survey waves (the 2006 and 2009 waves). Similarly, the educational disparity in overweight tends to be mixed for more recent cohorts (born after the year 1965).
Table 6: Prevalence rates of overweight for Chinese population and socio-demographic groups, CHNS 1989-2009 (N= 55,683)

<table>
<thead>
<tr>
<th>Ages</th>
<th>Overall population</th>
<th>Male</th>
<th>Female</th>
<th>Urban residents</th>
<th>Rural residents</th>
<th>High income families</th>
<th>Medium- or low-income families</th>
<th>High school or above</th>
<th>Middle school or below</th>
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<td>18-24</td>
<td>6.9%</td>
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<td>6.0%</td>
<td>8.1%</td>
<td>6.4%</td>
<td>6.7%</td>
<td>7.0%</td>
<td>7.2%</td>
<td>6.8%</td>
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<td>38.3%</td>
<td>26.0%</td>
</tr>
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</table>

Survey waves

<table>
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<tr>
<th>Year</th>
<th>Overall population</th>
<th>Male</th>
<th>Female</th>
<th>Urban residents</th>
<th>Rural residents</th>
<th>High income families</th>
<th>Medium- or low-income families</th>
<th>High school or above</th>
<th>Middle school or below</th>
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<td>1989</td>
<td>8.8%</td>
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<td>8.1%</td>
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<td>8.9%</td>
<td>8.8%</td>
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<td>16.5%</td>
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<td>Birth Cohorts</td>
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<td>Female</td>
<td>Urban residents</td>
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<td>Middle school or below</td>
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<tr>
<td>Before 1940</td>
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<td>15.6%</td>
<td>17.6%</td>
<td>16.6%</td>
<td>17.3%</td>
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<tr>
<td>1968-1969</td>
<td>15.9%</td>
<td>15.0%</td>
<td>16.7%</td>
<td>14.8%</td>
<td>16.4%</td>
<td>15.0%</td>
<td>16.2%</td>
<td>15.0%</td>
<td>16.2%</td>
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<tr>
<td>1970-1971</td>
<td>15.4%</td>
<td>16.9%</td>
<td>14.1%</td>
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<td>15.6%</td>
<td>15.5%</td>
<td>15.4%</td>
<td>15.3%</td>
<td>15.4%</td>
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<td>1972-1973</td>
<td>15.2%</td>
<td>16.7%</td>
<td>14.0%</td>
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<td>12.3%</td>
<td>15.7%</td>
<td>14.9%</td>
<td>18.8%</td>
<td>14.0%</td>
<td>11.2%</td>
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<td>1976-1977</td>
<td>17.5%</td>
<td>21.1%</td>
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<td>18.1%</td>
<td>14.8%</td>
<td>18.4%</td>
<td>19.1%</td>
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<tr>
<td>1978-1979</td>
<td>12.7%</td>
<td>15.1%</td>
<td>10.3%</td>
<td>13.1%</td>
<td>12.5%</td>
<td>8.9%</td>
<td>14.2%</td>
<td>13.0%</td>
<td>12.5%</td>
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<tr>
<td>1980 or after</td>
<td>12.6%</td>
<td>17.1%</td>
<td>8.2%</td>
<td>12.9%</td>
<td>12.5%</td>
<td>11.7%</td>
<td>13.0%</td>
<td>13.8%</td>
<td>11.6%</td>
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</table>
Results from the HAPC analysis are shown in Table 7. When only variables denoting age, birth cohorts and survey periods are included in the hierarchical model (Model 1 in Table 7), it is clear that the odds of overweight significantly increases with older age and more recent survey waves, although the positive age effect is also significantly moderated by its curvilinear trajectory. Earlier periods (the 1989, 1991, 1993 waves) are significantly associated with lower odds of overweight but recent periods (the 2004, 2006 and 2009 waves) are significantly associated with higher odds of overweight. These findings suggest that the rising overweight epidemic in China is primarily driven by age and period effects. For cohort effects, individuals who were born from 1952 to 1955 and experienced adiposity rebound during the Great Chinese Famine are significantly less likely to be overweight when they grew up, whereas children who were born during (the first two years of) the Famine (1958-1961) are significantly associated higher odds of overweight. I interpret these cohort effects as support for the critical-period hypothesis.

While these patterns of age, period and cohort effects persist across different models, there are interesting changes in the socio-demographic gradient in the overweight epidemic across the age, period, and cohort temporal dimensions (Models 2 to 6 in Table 7). As shown in Model 2, the main effect of male is significantly associated with higher odds of being overweight (odds ratio = $e^{0.9491} = 2.5834$). Yet, the positive effect of male tends to decline with older ages (odds ratio = $e^{-0.0336} = 0.9670$). While interactions between the male category and earlier survey waves (the 1989 and 1991 waves) are significantly positive, their signs reverse in more recent survey waves (the 2006 and 2009 waves) wherein the male effects are significant and negative with survey waves. In Model
3, urban residence has a positive and non-significant effect on being overweight, but its interaction with the square term of age is significantly positive (odds ratio = $e^{0.0004} = 1.0004$). With regard to the interactions between urban residence and period effects, the signs of these interactions also change from positive (only marginally significant for the 1997 wave) to significantly negative (the 2006 and 2009 waves) over the period of study. Likewise, the main effect of higher socio-economic status (either from high-income families or with higher educational attainment) on the odds of overweight is significant and positive (odds ratio for high-income families and high school is $e^{0.3443} = 1.4110$ and the odds ratio for high school and above is $e^{0.1578} = 1.1709$), whereas the interactions of the SES covariates with survey waves are significantly negative in the last survey wave. Results from the full model of the HAPC analysis are shown in Model 6. By and large, the findings remain consistent with those from Models 2-5, although the main effect of high school and above and the interaction between high-income families and the 2009 wave become non-significant. Almost all random components across Model 1-6 are statistically significant. The only exception is the random effect of income in the full model (Model 6).
Table 7 Results from logistic hierarchical age-period-cohort models of overweight prevalence in China: 1989-2009 (N=55,683)

<table>
<thead>
<tr>
<th>Fixed effects</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
<th>Model 6</th>
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<tbody>
<tr>
<td>Intercept</td>
<td>-5.2326***</td>
<td>-5.7039***</td>
<td>-5.3674***</td>
<td>-5.3358***</td>
<td>-5.3388***</td>
<td>-5.9012***</td>
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<tr>
<td>Age</td>
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<td>0.1716***</td>
<td>0.1634***</td>
<td>0.1563***</td>
<td>0.1583***</td>
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<tr>
<td>Age squared</td>
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<td>-0.0015***</td>
<td>-0.0016***</td>
<td>-0.0015***</td>
<td>-0.0015***</td>
<td>-0.0017***</td>
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<tr>
<td>Male</td>
<td>0.9491*</td>
<td>0.9167*</td>
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<tr>
<td>Male × Age</td>
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<td>-0.0336*</td>
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<tr>
<td>Male × Age squared</td>
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<td>0.0001</td>
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<tr>
<td>Urban residents</td>
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<tr>
<td>Urban residents × Age squared</td>
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<td>0.0003*</td>
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</tr>
<tr>
<td>High-income families</td>
<td>0.3443***</td>
<td>0.2701***</td>
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<tr>
<td>High school and above</td>
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<td>0.0873</td>
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<td><strong>Period effects</strong></td>
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<td>The 1989 wave</td>
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<tr>
<td>The 1989 wave × Urban residents</td>
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<td>-0.0032</td>
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<tr>
<td>The 1989 wave × High-income families</td>
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<td>-0.0013</td>
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<tr>
<td>The 1991 wave</td>
<td>-0.4141**</td>
<td>-0.2959**</td>
<td>-0.4679**</td>
<td>-0.4389**</td>
<td>-0.4120**</td>
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<tr>
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<tr>
<td>The 1991 wave × High-income families</td>
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</tr>
<tr>
<td>The 1991 wave × High school or above</td>
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<td>0.0971</td>
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<tr>
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<td>-0.2465</td>
<td>-0.3839*</td>
<td>-0.3689*</td>
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<td>0.0971</td>
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<tr>
<td>The 1997 wave</td>
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<td>-0.0487</td>
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<tr>
<td>The 1997 wave × Male</td>
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<td>The 2000 wave</td>
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<td>0.2094</td>
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<td>0.1981</td>
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<td>0.0434</td>
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<tr>
<td>The 2004 wave</td>
<td>0.3349*</td>
<td>0.2601**</td>
<td>0.3570*</td>
<td>0.3435*</td>
<td>0.3284*</td>
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<td>-0.0230</td>
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<tr>
<td>The 2004 wave × High school or above</td>
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</table>
Table 7 (continued)

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<th>Fixed effects</th>
<th>Model 1</th>
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<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
<th>Model 6</th>
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<tbody>
<tr>
<td>The 2006 wave</td>
<td>0.3635*</td>
<td>0.2171*</td>
<td>0.4407**</td>
<td>0.3921**</td>
<td>0.3807**</td>
<td>0.3107*</td>
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<tr>
<td>× Male</td>
<td>0.3164*</td>
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<td>× Urban residents</td>
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<td>× High-income families</td>
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<td>× High school or above</td>
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<tr>
<td>The 2009 wave</td>
<td>0.4490**</td>
<td>0.2637**</td>
<td>0.5565***</td>
<td>0.4844**</td>
<td>0.4773**</td>
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<tr>
<td>× Male</td>
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<td>× Urban residents</td>
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<td>× High-income families</td>
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<td>× High school or above</td>
<td>-0.1484*</td>
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**Cohort effects**

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<td>Before 1940</td>
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**Random variance components**

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<th>Model 3</th>
<th>Model 4</th>
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<tbody>
<tr>
<td>Intercept</td>
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<td>0.2064***</td>
<td>0.1765***</td>
<td>0.1644***</td>
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<td>Sex effect</td>
<td>0.1039***</td>
<td></td>
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<tr>
<td>Residence effect</td>
<td>0.0343***</td>
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<tr>
<td>Income effect</td>
<td>0.0086**</td>
<td></td>
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<tr>
<td>Education effect</td>
<td>0.0125***</td>
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<tr>
<td>Cohort effect</td>
<td>0.0088***</td>
<td>0.0089***</td>
<td>0.0084***</td>
<td>0.0086***</td>
<td>0.0080***</td>
<td>0.0082***</td>
</tr>
</tbody>
</table>

$\chi^2$ 908.83*** 979.06*** 954.48*** 920.61*** 855.82*** 997.18***

* The likelihood ratio $\chi^2$ test compares the full model with random effects with a reduced model omitting random effects.
** p<.10; * p<.05; ** p<.01; *** p<.001 (two-tailed tests)
To better understand the implications of these findings for studies of overweight prevalence in China, the partial regression coefficients and random effects estimated from the full model of the HAPC analyses were converted to predicted probabilities (expected values of prevalence rates of overweight) with the results displayed in Figure 6 to Figure 8. Figure 6 shows the age patterns of the sex and regional disparities in the overweight prevalence rates. Although males are heavier than females in early adulthood, there is a sex crossover at ages 32-34. As compared with the age trajectory for females, the male overweight prevalence rates level off and decline about five years earlier (around age 50). Likewise, the prevalence rates for rural residents level off and decline around age 50, which is almost ten years earlier than these for urban residents. Figure 7 exhibits the estimated cohort effects. Consistent with the critical-period hypothesis, the lowest level of overweight prevalence happens in the 1952-1953 birth cohorts, which consist of individuals who experienced the Famine during adiposity rebound. The overweight prevalence rates rise dramatically for the subsequent cohorts with the maximum rate for the cohorts born at the beginning of the Famine (1958-1959) when strict measures in combating the Famine and prioritizing food allocation to children and infants were presumably absent (Ashton, Hill, Piazza, and Zeitz 1984). Net of other effects, the estimated period effects shown in Figure 8 maintain steady growth over the time span of the study. Individuals who are female, from high-income families or with higher educational attainment largely have higher overweight prevalence rates over the period of study but the sex, regional and educational disparities in overweight prevalence diminish or even reverse in more recent two waves, which can be attributed to sex, regional and educational crossovers in period effects. The socio-demographic crossovers in the
overweight prevalence show support for the reversal hypothesis.

Figure 6 Predicted probabilities of overweight for Chinese population and sex & residential groups based on a hierarchical age-period-cohort model, CHNS 1989-2009: age effects

Note: The probabilities of overweight prevalence are predicted from the estimated coefficients of the full model of the HAPC analyses (Model 6 in Table 2).
Figure 7 Predicted probabilities of overweight prevalence for Chinese population based on a hierarchical age-period-cohort model, CHNS 1989-2009: cohort effects

Note: The probabilities of overweight prevalence are predicted from the estimated cohort-specific effects of the full model of the HAPC analyses (Model 6 in Table 2).
Figure 8 Predicted probabilities of overweight prevalence for Chinese population based on a hierarchical age-period-cohort model, CHNS 1989-2009: period effects.

Note: The probabilities of overweight prevalence are predicted from the estimated period-specific effects of the full model of the HAPC analyses (Model 6 in Table 2).
3.2.8 Discussion and Conclusions

The development, trends and patterns of China’s adulthood overweight prevalence have also been a focus of demographic and epidemiological studies (Cui, Huxley, Wu, and Dibley 2010; Gordon-Larsen et al. 2012; Gu et al. 2005; Luo, Mu, and Zhang 2006; Popkin 2008; Wang, Monteiro, and Popkin 2002b). As few studies have tried to elucidate the age, period and cohort effects embedded in the overweight prevalence rates and no prior study has had both the data and analytical tools to decompose these three temporal components from overall trends in prevalence rates, it remains unclear as to what they are. The primary objective of this study has been to address this unclarity.

Based on hierarchical age-period-cohort analyses of data on 55,683 adults aged 18 to 64 from eight successive waves of the China Health and Nutrition Survey from 1989 to 2009, I find that the steady increase in overweight prevalence is primarily driven by age and period effects. First, overweight prevalence increases throughout the adulthood until the early 50s after which the age trajectory levels off or declines, with the prevalence rates for male and rural residents reach their plateaus at much younger ages than their counterparts do. Second, the period effects are very strong, with a virtually monotonic increase in overweight from 1989 to 2009. Yet, sex, regional and educational disparities appear in more recent waves as the overweight prevalence rates for male, individuals from low-income families and the poorly educated are catching up with or even surpassing their peers, which is attributed to sex, regional and educational crossovers in period effects. Finally, although no generally increasing trends of cohort effects were identified, cohorts born in the beginning of the Great Chinese Famine have highest prevalence rate of overweight, whereas cohorts that experienced the Famine during
childhood adiposity rebound are significantly less likely to be overweight.

While maternal weight during and after pregnancy may explain women’s higher overweight prevalence rates after age 30 (Gunderson, Abrams, and Selvin 2000; Moreira, Padez, Mourao-Carvalhal, and Rosado 2007), researcher should be cautious in interpreting the decline of overweight prevalence for rural residents at earlier ages as a beneficial factor to their health. Due to China’s salient rural-urban divide in health care coverage and medical resources, it is possible that such a decline in adulthood overweight prevalence at earlier ages is associated with an early onset of diseases and morbid conditions of rural residents (Banister and Zhang 2005; Zhu and Xie 2007).

The patterns and shifts of period effects across different socio-demographic groups are consistent with the reversal hypothesis on the association between SES and body weight in the course of social and economic development (Jones-Smith, Gordon-Larsen, Siddiqi, and Popkin 2011; Pampel, Denney, and Krueger 2012). As knowledge of a health risk factor becomes available, individuals with higher socio-economic status benefit first and likely the most from the proliferation of overweight-related knowledge (Smith, Sen, and Hanley 2010), which is responsible for a reverse socio-demographic gradient in China’s adulthood overweight epidemic (Jones-Smith, Gordon-Larsen, Siddiqi, and Popkin 2011).

The cohort patterns of the overweight epidemic reported here support the critical-period hypothesis. With regard to the long arm of the Great Chinese Famine, I find that the Great Chinese Famine leads to a higher probability of being overweight in adulthood, possibly mediated by toddler and maternal malnutrition and impaired development in utero (Luo, Mu, and Zhang 2006; Ravelli, Stein, and Susser 1976; Wang
et al. 2009). In particular, the life-course effect of nutritional deprivation on adulthood overweight prevalence is striking for cohorts born at the beginning of the Famine, which is consistent with the pattern of infant and childhood mortality during the Famine (Ashton, Hill, Piazza, and Zeitz 1984). By contrast, birth cohorts that were exposed to the Famine during childhood adiposity rebound have achieved the lowest overweight prevalence rates among all birth cohorts examined.

Beyond the parallels between findings reported in this study and those reported in previous research (Ashton, Hill, Piazza, and Zeitz 1984; Dietz 1994; Jones-Smith, Gordon-Larsen, Siddiqi, and Popkin 2011; Pampel, Denney, and Krueger 2012), this chapter raises a number of questions that merit additional research. First, and perhaps most important, the strong period effects identified in this study help to focus the search for causal mechanisms underlying the rise in adulthood overweight prevalence rates in China. That is, the predominance of period effects implies that this rise affected all ages and birth cohorts. And my estimates of the period effects show particularly rapid increases in the 1990s and early 2000s, a period of rapid economic development in China that was associated with rapid urbanization and associated changes towards a higher-fat and higher-carbohydrate diet and a more sedentary living and working style (Hsing 2010; Popkin 1999; Popkin 2008; Popkin and Du 2003; Zhu, Breitung, and Li 2012). A more precise allocation of dietary causal effects to sheer increases in caloric consumption versus carbohydrate/sugar proportions remains to be identified in future studies. And the decreases in caloric demand due to changes in life and work patterns also need identification and estimation. Second, the precise mechanism through which the overweight prevalence rates for rural residents and males begin to decline at earlier ages
than those of urban residents and females remains unclear. For instance, are these differences due to greater rates of physical activity or lower levels of high-fat and high-carbohydrate diets of rural residents and males? Third, the lowest overweight prevalence rate of the cohort experiencing adiposity rebound during the Famine needs further analysis and explanation. As the causal link between adiposity rebound and adulthood overweight has not been fully identified, how can adiposity rebound help to understand this cohort effect? Fourth, given that the effect of early nutritional deprivation on adulthood overweight is sensitive to the timing of exposure and even several months’ difference in the timing of exposure in utero and early infancy can have dramatically different implications on adulthood overweight prevalence (Ravelli, Stein, and Susser 1976), more refined analyses based on a much larger sample size of individuals born in the Famine and more exact timing of exposure to nutritional deprivation are needed to evaluate these cohort effects. Fifth, why the sudden increase in overweight prevalence for the 1976-1977 cohort? Is this a statistical fluke? Or is it due to some historical event such as the intersection of the beginning of the economic transformation of China with a critical stage in the young adult life course development of this cohort?

3.3 The Global Distribution of Obesity and Its Association with Human Development Index

3.3.1 The Spatial Distribution of Human Development Index and Obesity

The Human Development Index (HDI) introduced by the United Nations Development Program (hdr.undp.org) provides a comprehensive and comparable way to
measure social and economic development across countries. By creating a single statistic serving as a frame of standardized reference for development, the HDI investigates the range (the difference between a maximum and a minimum) of each dimension and then reveals where each country stands with reference to such range, expressed as a value between zero and one. The HDI consists of three components: education, life expectancy at birth and wealth. The education component of HDI includes mean years of schooling for adults aged 25 years and expected years of schooling for children of school entering age. The second component of the HDI refers to life expectancy at birth. The final component of the HDI corresponds to gross national income per capita based on purchasing power parity.

The spatial distribution of the Human Development Index (HDI) in 2010 is shown in Figure 9. Whereas low-HDI countries are largely concentrated in sub-Saharan Africa, very-high-HDI countries are located outside Africa, which include most countries in North America and Western Europe and several countries in East Asia (Japan and Korea), Latin America (Argentina and Chile) and Oceania (Australia and New Zealand).

The spatial disparity in overweight is similar to that of HDI (see Figure 10 and Figure 11). High-HDI countries located in America, Europe and Oceania appear to have higher levels of overweight, while African countries have lower prevalence of overweight. Yet, the prevalence of overweight is lower in Asian countries (Japan and Korea) with higher levels of HDI, which may point to the significance of dietary patterns and culture. With regard to the sex disparity in overweight, males have higher risk of overweight and this pattern is consistent across countries.

With regard to the spatial distribution of obesity, it is clear that the prevalence of
obesity remains high in high-HDI countries located in North America, Latin America and Oceania (see Figure 12 and Figure 13). Meanwhile, the sex disparity in obesity deserves attention. Whereas only limited countries in Western Europe show higher levels of obesity for males, most European countries have higher levels of obesity for females. It should be noted that females in general have higher levels of obesity than males do, although males have higher levels of overweight across countries (Kelly et al. 2008).

Figure 14 and 15 show the spatial distribution of Body Mass Index. Again, the spatial distribution of BMI resembles that of overweight and obesity. From Figure 10 to Figure 15, it should be noted that the spatial distribution of BMI tends to be more homogeneous for males as compared to that for females. In the next section, we investigate the association between HDI and a series of anthropometric indicators.
Figure 9 The spatial distribution of the Human Development Index (HDI) in 2010

Figure 10 The global prevalence of overweight in 2010, Male, Aged 15 and above

Data source: the WHO Global Infobase (https://apps.who.int/infobase/)
Figure 11. The global prevalence of overweight in 2010, Female, Aged 15 and above

Data source: the WHO Global Infobase (https://apps.who.int/infobase/)
Figure 12 The global prevalence of obesity in 2010, Male, Aged 15 and above

Data source: the WHO Global Infobase (https://apps.who.int/infobase/)
Figure 13 The global prevalence of obesity in 2010, Female, Aged 15 and above

Data source: the WHO Global Infobase (https://apps.who.int/infobase/)
Figure 14 The global distribution of Body Mass Index in 2010, Male, Aged 15 and above

Data source: the WHO Global Infobase (https://apps.who.int/infobase/)
Figure 15 The global distribution of Body Mass Index in 2010, Female, Aged 15 and above

Data source: the WHO Global Infobase (https://apps.who.int/infobase/)

3.3.2 The Association between Obesity and Human Development Index

In this section, I situate the discussion on the increasing prevalence of overweight/obesity in China in a global context. To test whether the fifth phase of epidemiological transition (or the age of obesity and inactivity) exists, it is important to investigate the association between socio-economic development and the prevalence of overweight/obesity. If there were a positive association between human development and the obesity/overweight prevalence, we would expect that the obesity epidemic magnifies and perpetuates itself as a country, such as China, climbs its economic ladder.

Figure 16 shows the scatterplots between overweight prevalence and the Human Development Index. Both scatterplots lend some support to a positive association between the Human Development Index and the overweight prevalence. In particular, the Pearson correlation coefficients between male/female overweight prevalence and the Human Development Index are 0.728 and 0.475, respectively. This sex difference in correlation coefficients is in line with the observation that there are more variations in the spatial distribution of female overweight prevalence.

Figure 17 shows the scatterplots between the obesity prevalence and the Human Development Index. Again, a positive association between the HDI and the obesity prevalence is suggested for both males and females. The Pearson correlation coefficients are 0.569 and 0.440 for males and females, respectively. Figure 18 repeats the patterns shown in Figure 16 and 17. There is a positive association between the HDI and BMI across countries and this association tends to be more pronounced for males than that for females.
Figure 16 The association between overweight prevalence and the Human Development Index
Figure 17 The association between obesity prevalence and the Human Development Index.
Figure 18 The association between Body Mass Index and the Human Development Index

3.4 Discussion and Conclusions

To study childhood overweight/obesity in a comparative perspective, this chapter investigates the temporal trends of adulthood overweight in China and the global distribution of overweight/obesity. The most interesting finding is that adulthood overweight and childhood overweight show different temporal patterns. While the
previous chapter finds that the rising prevalence of childhood overweight in China is primarily driven by cohort effects, results of this chapter show that adulthood overweight in China is related to salient period effects. As Chinese children grow up in a more obesogenic environment, such cohort effects embedded in childhood overweight point to the severity of the obesity epidemic in China because more obese younger generations will eventually replace older generations if the cohort component continues into the future. I interpret the salient cohort effects of childhood overweight in China as evidence for the fifth phase of epidemiological transition, while the period increases driving adulthood overweight point to the significance of social and economic development in shaping health burdens.

While this dissertation project primarily deals with the temporal patterns of overweight and obesity issues, the spatial dimension of the overweight/obesity epidemic deserves attention. The global distribution of overweight/obesity prevalence also supports the fifth phase of epidemiological transition because a positive association exists between the HDI and a series of anthropometric measures. In other words, the overweight/obesity epidemic is in tandem with social and economic development. Moreover, this positive association is consistent across different sex groups. Such association also tends to be stronger for males than that for females, although it remains less clear why there is less heterogeneity in the spatial distribution of anthropometric measures related to males.
4. The Non-Medical Costs of Childhood Overweight and Obesity

4.1 Introduction

In previous chapters, I have investigated the temporal and spatial patterns of childhood overweight and obesity. Although the medical consequences of childhood overweight and obesity have been systematically investigated by existing research (Anderson and Butcher 2006; Dallman, Pecoraro, Akana, La Fleur, Gomez, Houshyar, Bell, Bhatnagar, Laugero, and Manalo 2003; Deckelbaum and Williams 2001; Flegal, Graubard, Williamson, and Gail 2005; Young, Dean, Flett, and Wood-Steiman 2000), few studies try to link temporal patterns of childhood obesity to behavioral and psychosocial outcomes. Yet, it has been shown that the consequences of childhood obesity are not restricted to physical health. For example, a systematic review has demonstrated that both higher and lower levels of depression were found among the obese (Friedman and Brownell 1995). Meanwhile, a recent study finds that children who are obese are more likely to be bullied, regardless of a number of potential socio-demographic, social, and academic confounders (Lumeng, Forrest, Appugliese, Kaciroti, Corwyn, and Bradley 2010). A comprehensive review on the association between childhood obesity and school performance has also demonstrated that poorer academic performance is associated with childhood obesity (Taras and Potts-Datema 2005). This chapter thus deals with these non-medical consequences of childhood obesity using latent trajectory models.
4.2 The Non-Medical Consequences: mental disorder, self-esteem, personality and delinquency

Research on etiology of obesity on depression is a long-standing and complicated area for medical sociologists, demographers and psychologists (Atlantis and Baker 2008; Simon 1963). Given that both obesity and depression are associated with physical health (such as coronary heart disease and hypertension), debates about the obesity-depression relation are escalated by increasing prevalence of both obesity and depression all over the world. One pioneering research (Crisp and McGuiness 1976) found that obesity negatively related to levels of anxiety (in men and women) and depression (in men). A follow-up research also suggested this negative relation between obesity and depression among younger middle class women, though high levels of anxiety were observed for massively obese younger women\(^5\) (Crisp, Queenan, Sittampalin, and Harris 1980). Contrary to this ‘jolly fat’ hypothesis, a research based on the First National Health and Nutrition Examination Survey (NHANES I) found that higher BMI among women was weakly associated with higher levels of depression and the finding remained robust after controlling for age, education and smoking (Istvan, Zavela, and Weidner 1992). Using a representative sample, a positive relation between overweight and depression among the more educated was found (Ross 1994).

Existing literature (Carpenter, Hasin, Allison, and Faith 2000; Onyike, Crum, Lee, Lyketsos, and Eaton 2003; Roberts, Kaplan, Shema, and Strawbridge 2000) suggest that the obesity-depression is sensitive to the definition of obesity and relative body weight (e.g., continuous versus categorical variable). For example, Onyike and

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\(^5\) Massively obesity was defined as 50% or more above average weight for height and often becoming increasingly obese in that research.
his colleagues (2003) argued that the continuous treatment of BMI required a linear assumption underlying the obesity-depression relation. Although the association between obesity in general and depression is not fully established in existing research, extreme or massive obesity has been regarded as an important risk factor for depression, which highlights heterogeneity across the obese population in terms of the obesity-depression relation (Onyike et al. 2003). After controlling physical health conditions, familial depression and demographic risk factors, it is found that extreme obesity was associated with higher levels of depression across sex and race groups (Dong, Sanchez, and Price 2004). Based on the Third National Health and Nutrition Examination Survey (1988-1994), researchers found that the association between class 3 obesity (BMI ≥ 40) and past-month depression remained robust after age, education, physical health, dieting, medicine, marital status, smoking, alcohol and substance use were controlled (Onyike et al. 2003).

It has also been argued that the psychological impact of obesity should be stronger in a group where being overweight and obese is rare, abnormal, or unacceptable (Roberts, Deleger, Strawbridge, and Kaplan 2003; Ross 1994). Therefore, obesity can have differential effect across different SES, sex and race/ethnicity groups. The moderating effect of SES is indicated by existing research. Children in higher SES schools were more likely to stigmatize the obese as ‘lazy’ or ‘greedy’ than children in lower SES schools (Wardle, Volz, and Golding 1995). Meanwhile, high-income women on average deemed 11 lbs. as the weight gain needed for taking actions and the corresponding weight gain is 20 lbs. for low-income women in the US (Jeffery and French 1996). More explicitly, Ross (1994) found significant moderating effect of education in the obesity-depression relation, i.e., being overweight was associated with higher levels of depression only among those
with a college degree, but was irrelevant of depression among those with lower educational attainment. From the reflected self-appraisal perspective, Ross (1994) found that being overweight was much more depressing for well-educated than for individuals with lower educational attainment.

The obesity-depression relation can be moderated by children’s sex and race through body image distortion and body image dissatisfaction (Friedman and Brownell 1995; Klesges, Haddock, Stein, Klesges, Eck, and Hanson 1992). For instance, it is found that Black females hold thicker body size ideals, which is more consistent with their perceived body size (Rucker and Cash 1992). Obesity is associated with more stigma for females than for males (Wadden and Stunkard 1985). Compared with adolescent White girls, it is less likely for adolescent Black girls to want to lose weights (Rosen and Gross 1987). Because weight is an essential component of appearance, which is treasured more for women than men (Wardle, Williamson, Johnson, and Edwards 2006), obesity was found to have more adverse effect on women’ mental health (Atlantis and Baker 2008; Carpenter, Hasin, Allison, and Faith 2000). For instance, a research using data from the third wave of NHANES (1998-1994) found that obesity was associated with past-month depression for women but not for men (Onyike et al. 2003), although a study using data from two large school-based surveys in UK failed to find evidence that mental health of adolescent girls was more vulnerable to obesity (Wardle, Williamson, Johnson, and Edwards 2006).

Physiological and genetic pathways linking obesity and mental disorder also deserve attention, although an examination on these pathways is out of the scope of this paper. Intake of carbohydrates can affect both body weight and depression through central serontologic activity (Lieberman, Wurtman, and Chew 1986;
Rosenthal, Genhart, Jacobsen, Skwerer, and Wehr 1987; Wurtman and Wurtman 1989). On the other hand, reduced physical activity can increase depression via levels of endorphins, regulation of norepinephrine, physical fitness and self-esteem (Lobstein, Mosbacher, and Ismail 1983; Ross and Hayes 1988).

Genetic research on the etiology of depression has shown that the serotonin system, which serves as the target of selective serotonin reuptake-inhibitor drugs (SSRIs), provided a plausible source of candidate genes for depression. For instance, the effect of life stress was found to be moderated by a polymorphism in the 5-HTT gene and its associated differential serotonergic response to stress (Caspi, Sugden, Moffitt, Taylor, Craig, Harrington, McClay, Mill, Martin, and Braithwaite 2003). Although this gene-by-environment interaction was largely falsified by a follow-up analysis (Risch, Herrell, Lehner, Liang, Eaves, Hoh, Griem, Kovacs, Ott, and Merikangas 2009), research on genetic profiles regarding serotonin system remains promising for the obesity-depression relation. In addition, several medical studies have found that leptin, a hormone secreted by adipose tissue, and its receptor are associated with both body weight regulation and depression (Friedman and Halaas 1998; Lu 2007).

Although there is a dearth of literature linking trajectories of childhood obesity to personality, a few studies find that obesity does have implications on personality. For example, a study consisting of 83 morbidly obese patients compared personality changes before and after gastric banding surgeries (Larsen and Torgersen 1989). Before the treatment, they found that these patients reported higher scores on the Oral cluster traits (self-doubt, insecurity, dependence, sensitivity, compliance and emotional instability). After the treatment, there were a significant decrease in scores on the Oral cluster traits and a significant increase in scores on the Obsessive traits.
(parsimony and orderliness). These patients also became less neurotic and showed better control of their situation after the treatment. For children aged 10 years old in Nanjing, China, a study found that severely obese children had significantly higher scores on psychoticism (Li 1995). Yet, a study based on Swedish obese patients (aged 37-57) provided no evidence of a general obese personality profile. Even though this research team found that there were significant differences between obese patients and reference subjects on nearly all personality traits, the sizes of effects are small and can be explained by items tapping condition-specific symptoms, e.g., problems with sweating and breathing (indicators of anxiety) (Rydén, Sullivan, Torgerson, Karlsson, Lindroos, and Taft 2003). Finally, a recent study showed that weight gain across the adult life span is associated with higher scores in impulsivity and lower scores in agreeableness (Sutin, Ferrucci, Zonderman, and Terracciano 2011).

There are still debates on whether childhood obesity is associated with lower self-esteem. Based on a total of 1,520 children (aged 9 to 10) born to mothers in the National Longitudinal Survey of Youth, a four-year longitudinal study found that obese boys, obese Hispanic girls and obese white girls tended to report decreasing lower levels of self-esteem. Moreover, such decreasing levels of self-esteem can be explained by sadness, loneliness, and nervousness (Strauss 2000). Yet, another study based on 851 4th to 12th graders suggested that the association between childhood obesity and self-esteem is weak: only 1% of the variance in self-esteem score is explained by BMI (Kaplan and Wadden 1986). Using the 1996 National Longitudinal Study of Adolescent Health (Add Health), it is shown that a significant deleterious impact of overweight and obesity on self-esteem is only restricted to the youngest adolescents (ages 12-14) (Swallen, Reither, Haas, and Meier 2005).

While there are a few studies suggesting obese children or adolescents are
more likely to engage in delinquent behaviors, obese children and adolescents are more likely to be bullied and physically abused by peers. For example, a study based on 821 six graders suggested that obese children were more likely to be bullied, even if a series of socio-demographic, social, and academic covariates were accounted for (Lumeng et al. 2010). Likewise, a study based on 5,749 boys and girls (11-16 years old) showed that overweight and obese youth were more likely to be the targets of bullying victimization (Janssen, Craig, Boyce, and Pickett 2004). This conclusion held for both relational (e.g., withdrawing friendship or spreading rumors) and overt victimization (e.g., physical attack or name-calling) but did not hold for sexual harassment. On the other hand, 15- to 16-year-olds were more likely to perpetrate bullying than their normal-weight classmates. Furthermore, a study does suggest that concurrent child overweight is significantly associated with behavioral problems (e.g., antisocial behaviors, conflicts with peers) (Lumeng, Gannon, Cabral, Frank, and Zuckerman 2003). This conclusion is supported by another study on 4,718 preschool children in Bavaria, which revealed that obese children tended to report problems in peer relations (Boneberger, Von Kries, Milde-Busch, Bolte, Rochat, and Ruckinger 2009).

4.3 Data: The National Longitudinal Study of Adolescent Health

The National Longitudinal Study of Adolescent (or Add Health) is administered by the Carolina Population Center at the University of North Carolina. This survey was proposed to evaluate health, psychological and behavioral outcomes of adolescents and a series of questions pertaining to their social, economic and demographic background. Since the first wave of the Add Health collected during
September 1994 through December 1995, three waves of data were collected: wave II during April through August 1996, wave III during August 2001 through April 2002 and wave IV from 2007 to 2009. The primary sampling unit for the Add Health was the school, and the research team designed the survey in a way that the sample was representative of US private and public schools regarding a series of demographic and geographic factors, such as spatial regions of the country, rural/urban areas, types of school, ethnicity, and school size. The wave I of the Add Health consisted of a representative sample of 18,924 participants and oversampled non-Hispanic Blacks, Hispanics, Asian Americans, and Native Americans to ensure a representative sample. All measures included in this research were retrieved from in-home interview. The Add Health possesses two key features that made this analysis possible. First, it tracks a several cohorts of children/adolescents over time and thus provides repetitive anthropometric measures. Second, the Add Health, especially the more recent waves, included a variety of measures related to mental disorder, juvenile delinquency, personality and self-esteem, which allows this chapter to investigate the non-medical implications of childhood overweight.

4.4 Method: Latent Trajectory Models

Because this research tries to investigate whether an unobserved latent source of temporal variations exists in age trajectories of obesity, depression, perceived intelligence, juvenile delinquency and personality traits, finite mixture regression models are employed in the current study to investigate population heterogeneity (Hamil-Luker, Land, and Blau 2004; Jones, Nagin, and Roeder 2001; Land, McCall, and Nagin 1996; Nagin and Land 1993; Nagin 1999). Traditional ways of modeling
age trajectories, such as growth-curve models, assume that individuals deviate from a population-level trajectory. Yet, it is possible that several heterogeneous growth trajectories at the population level exist due to an unobserved latent source. Instead of assuming only one overall growth trajectory, finite mixture regression models thus provide a more flexible and reasonable way of modeling (latent) trajectories. Using finite mixtures of proper statistical distributions, this method for modeling group-based growth trajectories employs multinomial modeling to detect separate clusters of individual trajectories related to personal characteristics.

Considering that growth trajectories $P(Z_i | Age_i)$ represent the development of an outcome over a period or an age interval of study, the statistical distribution of trajectories based on a finite mixture of groups $K$ could be written as follows:

$$P(Z_i | Age_i) = \sum_{k=1}^{K} \pi^k \cdot P(Z_i | Age_i, k; \beta^k)$$

where $\pi^k$ denotes the probability associated with the membership of group $k$ and the patterns of group-specific trajectories are given by $\beta^k$. For a given trajectory of group $k$, the conditional probability $P(Z_i | Age_i, k; \beta^k)$ follows sequential realizations over periods:

$$P(Z_i | Age_i, k; \beta^k) = \prod_{t=1}^{T} p(z_{it} | age_{it}, k; \beta^k).$$

The estimation of latent trajectories are implemented by a Stata plugin, -traj- (Jones and Nagin 2013). This program supports normal distribution, censored normal distribution, Poisson distribution, Zero-inflated Poisson distribution and Logistic
distribution. For dichotomous outcomes (obesity and depression), logistic distributions are employed in the estimation of latent trajectories. Censored normal distributions are employed for continuous variables (perceived intelligence and juvenile delinquency).

4.5 Measures

For outcome variables of this study, obesity status before age 18 is determined by a popular international BMI standard for childhood obesity (Cole, Bellizzi, Flegal, and Dietz 2000) and adulthood obesity is determined if the respondent’s BMI is above 30. The depression status is specified as follows. First, respondents were asked to evaluate whether the following symptoms appeared during the last past week based on an abridged CES-D scale:

1. You were bothered by things that usually don’t bother you

2. You felt that you could not shake off the blues, even with help from your family and your friends.

3. You felt that you were just as good as other people

4. You had trouble keeping your mind on what you were doing

5. You felt depressed

6. You felt that you were too tired to do things
7. You enjoyed life

8. You felt sad.

9. You felt that people disliked you.

Except for question 7, the respondent scored 0, 1, 2 and 3 if he/she responded never or rarely, sometimes, a lot of the time and most of the time or all of the time, respectively. Scores for the question 7 were reversely coded. Then a respondent is deemed as depressed if his/her score is equal to or above 10 (Santor and Coyne 1997). An auxiliary analysis shows that subsequent conclusions are not modified if depressive symptoms are modeled as a continuous variable instead of a dichotomous status.

Because self-esteem was not consistently measured at the Add Health, perceived intelligent was used as a proxy measure in this study given that this item has been included in a popular self-esteem scale (Heatherton and Polivy 1991). Throughout the four waves of survey, respondents were asked “Compared with other people your age, how intelligent are you?” and response categories were moderately below average, slightly below average, about average, slightly above average, moderately above average, and extremely above average.

Four measures of juvenile delinquency are constantly measured across all four waves of the Add Health:

1. In the past 12 months, how often did you take part in a fight where a group of your friends was against another group?
2. In the past 12 months, how often did you deliberately damage property that didn’t belong to you?

3. In the past 12 months, how often did you steal something worth more than $50?

4. How often did you steal something worth less than $50?

Response categories were the same for the four questions: never, 1 or 2 times, 3 or 4 times, and 5 or more times. These four categories were assigned 0, 1, 2 and 3 points respectively, and the sum of scores across four questions was used as a continuous measure for juvenile delinquency.

The big five personality traits were only collected at the fourth wave of the Add Health, which consists of the following five dimensions:

1. Extraversion: sociability and being outgoing
2. Agreeableness: being compassionate and cooperative
3. Conscientiousness: a tendency to be self-disciplined, organized, accountable, dependable and responsible
4. Neuroticism: propensity for experiencing negative and unpleasant feelings, such as depression, anger and anxiety
5. Imagination (or openness to experience): intellectual curiosity, creativity and appreciation for art, adventure and novel ideas.

Because each dimension was measured by four items with scores ranging from 1 to 5 (e.g., strongly disagree, disagree, neither agree nor disagree, agree, strongly agree), the overall score of each dimension ranged from 1 to 20. Some items have been
reverse coded such that a higher score is associated with a higher load in one personality trait.

Besides age, the latent trajectory regression models also consider several time-stable covariates. Female is a dichotomous variable denoting a respondent’s sex. The race variable consists of four categories: Caucasian (as the reference category), African American, Asian, and Native American and others. The analyses also consider whether a respondent and his/her mother were born in the U.S. and whether a mother is college educated.

4.6 Results

Descriptive statistics of the sample are shown in Table 8. The increase in age is consistent with time periods of different waves of the Add Health. Less than one half of the respondents are female. Over one half of respondents are Caucasians and about 20% of them are African Americans. Asians and Native Americans and others account for around 7% and 12% of the population studied across the four waves of survey. Most of these interviewees and their mothers are born in the United States. About one quarter of respondents’ mothers are college educated.

The prevalence rates of obesity are increasing dramatically with age. They almost quadruple from 8.5% at age 15/16 to 32.6% at age 28/29. The rates of depression are relatively stable throughout adolescence and early adulthood, ranging from 21.7% to 28.3%. On average, a respondent believes that he/she is slightly intelligent above average and this finding is persistent across survey waves. The
delinquency score reduces from 0.911 to 0.158 over the period of study but there is a salient variance associated with juvenile delinquency. Respondents also tend to achieve higher scores in extraversion, agreeableness, conscientiousness and imagination but have lower scores in neuroticism.

Table 8 Descriptive statistics of the sample studied, Add Health, 1994-2009

<table>
<thead>
<tr>
<th></th>
<th>Wave I</th>
<th>Wave II</th>
<th>Wave III</th>
<th>Wave IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=18,411</td>
<td>N=12,937</td>
<td>N=13,942</td>
<td>N=14,427</td>
</tr>
<tr>
<td>Age</td>
<td>Mean</td>
<td>S.D.</td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td></td>
<td>15.734</td>
<td>1.726</td>
<td>16.301</td>
<td>1.608</td>
</tr>
<tr>
<td>Female</td>
<td>0.496</td>
<td>0.496</td>
<td>0.478</td>
<td>0.474</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>0.572</td>
<td>0.583</td>
<td>0.578</td>
<td>0.590</td>
</tr>
<tr>
<td>African American</td>
<td>0.221</td>
<td>0.217</td>
<td>0.218</td>
<td>0.222</td>
</tr>
<tr>
<td>Asian</td>
<td>0.080</td>
<td>0.077</td>
<td>0.082</td>
<td>0.069</td>
</tr>
<tr>
<td>Native American et al.</td>
<td>0.127</td>
<td>0.123</td>
<td>0.122</td>
<td>0.119</td>
</tr>
<tr>
<td>Born in the U.S.</td>
<td>0.908</td>
<td>0.916</td>
<td>0.918</td>
<td>0.924</td>
</tr>
<tr>
<td>Mother college educated</td>
<td>0.253</td>
<td>0.264</td>
<td>0.263</td>
<td>0.259</td>
</tr>
<tr>
<td>Mother born in the U.S.</td>
<td>0.817</td>
<td>0.823</td>
<td>0.824</td>
<td>0.836</td>
</tr>
<tr>
<td>Obesity</td>
<td>0.085</td>
<td>0.092</td>
<td>0.205</td>
<td>0.326</td>
</tr>
<tr>
<td>Depression</td>
<td>0.275</td>
<td>0.283</td>
<td>0.217</td>
<td>0.264</td>
</tr>
<tr>
<td>Perceived intelligence</td>
<td>3.871</td>
<td>1.092</td>
<td>3.955</td>
<td>1.085</td>
</tr>
<tr>
<td>Delinquency</td>
<td>0.911</td>
<td>1.638</td>
<td>0.742</td>
<td>1.487</td>
</tr>
<tr>
<td>Extraversion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agreeableness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conscientiousness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neuroticism</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imagination</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
To determine the proper number of latent trajectories of childhood obesity, this study first investigates changes in the Bayesian Information Criterion (BIC) across models, which is an approximation to the log of Bayes factors (Jones, Nagin, and Roeder 2001). According to suggestions given by Jones, Nagin, and Roeder (2001), the following equation holds to determine the optimal number of latent trajectories and the change in $2 \ln(B_{10})$, where $B_{10}$ is the Bayes factor, should be less than 2 between finite mixture regression models with the optimal number of trajectories and a successive number of latent trajectories.

$$2 \ln(B_{10}) \approx 2(\Delta \text{BIC})$$

Results from Table 9 suggested that a finite mixture regression model containing four latent trajectories fits the data better than other alternative models. Therefore, this study considers four heterogeneous latent trajectories embedded in the age increase in childhood obesity.

<table>
<thead>
<tr>
<th>Number of trajectories</th>
<th>BIC</th>
<th>Null Model</th>
<th>$2 \ln(B_{10})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-28750.07</td>
<td>1</td>
<td>11655.3</td>
</tr>
<tr>
<td>2</td>
<td>-22922.42</td>
<td>2</td>
<td>838.26</td>
</tr>
<tr>
<td>3</td>
<td>-22503.29</td>
<td>3</td>
<td>201.96</td>
</tr>
<tr>
<td>4</td>
<td>-22402.31</td>
<td>4</td>
<td>-56.28</td>
</tr>
</tbody>
</table>

Notes: results are based on mixture models without considering demographic and socioeconomic covariates.
Results of a finite mixture regression model with four trajectories are shown in Figure 19. Based on the shape and patterns of different growth trajectories, we could label these four types of trajectories as follows:

1. Mild obesity: these respondents have lower probabilities of obesity throughout adolescence and obesity probabilities increase mildly during adulthood. Over one third (39.5%) of the sample studied show this pattern;
2. Non obesity: these respondents are not obese throughout adolescence and early adulthood. About one half of respondents belong to this group;
3. Acute obesity: the probabilities of obesity increase dramatically from adolescence to early adulthood. Less than 10% of respondents show this type growth trajectory;
4. Chronic obesity: the probabilities of obesity stay high throughout adolescence and early adulthood. More than 10% of respondents belong to this group.

Given that the finite mixture analysis of obesity does not take time-stable covariates, such as sex, place of birth, and race, into account, further analyses are conducted with time-stable covariates.
As shown in Table 10, when mild obesity is regarded as the reference group for the multinomial finite mixture regression analysis, African Americans and Native Americans and others are significantly less likely to be in the non-obesity group, as compared to Caucasians, whereas respondents with college-educated mothers are more likely to be in this group. Females are less likely to be in the acute-obesity group but more likely to be in the chronic obesity group. African Americans and individuals born in the United States are more likely to be chronically obese. Figure 19 shows new latent trajectories of obesity after considering time-stable covariates. The shape, trends and patterns of four trajectories are virtually identical to these in Figure 18, although their proportions in the overall sample vary slightly. Next, we assign each individual to his/her corresponding group and use these distinct trajectories to predict behavioral and psychosocial outcomes.
Table 10 A finite mixture analysis of obesity in the United States, Add Health, 1994-2009

<table>
<thead>
<tr>
<th></th>
<th>Non obesity Coefficients</th>
<th>Acute obesity Coefficients</th>
<th>Chronic Obesity Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.307</td>
<td>-2.288***</td>
<td>-1.866***</td>
</tr>
<tr>
<td>Female</td>
<td>0.115</td>
<td>-0.581***</td>
<td>0.216*</td>
</tr>
<tr>
<td>Race (Caucasian as reference)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>-0.380**</td>
<td>0.244</td>
<td>0.252*</td>
</tr>
<tr>
<td>Asian</td>
<td>0.262</td>
<td>0.369</td>
<td>-0.397</td>
</tr>
<tr>
<td>Native American et al.</td>
<td>-0.500**</td>
<td>0.135</td>
<td>-0.079</td>
</tr>
<tr>
<td>Born in the U.S.</td>
<td>0.034</td>
<td>0.791</td>
<td>0.586*</td>
</tr>
<tr>
<td>College-educated mother</td>
<td>0.473***</td>
<td>-0.063</td>
<td>-0.134</td>
</tr>
<tr>
<td>Mother born in the U.S.</td>
<td>-0.135</td>
<td>0.330</td>
<td>-0.121</td>
</tr>
</tbody>
</table>

**BIC: -22285.87**  
**AIC: -22128.96**

Note: *Mild obesity is the reference group.  
Ψ p<.10; * p<.05; ** p<.01; *** p<.001 (two-tailed tests)

Figure 20 Age trajectories of obesity estimated by finite mixture regression models with time-stable covariates, Add Health, 1994-2009

Table 11 shows the effect of time-stable covariates and obesity trajectories on personality traits and we focus on the net association between obesity trajectories and personality traits. When non-obesity group is set as reference, other obesity...
trajectories exert no significant effects on extraversion (the effect of chronic obesity is marginally significant). Either acute obesity, or mild obesity or chronic obesity is significantly associated with lower levels of agreeableness and conscientiousness but higher levels of neuroticism. Mild obesity is associated with significantly lower level of imagination.

Table 11 A regression analysis of personality traits in the United States, Add Health, 1994-2009

<table>
<thead>
<tr>
<th></th>
<th>Extraversion</th>
<th>Agreeableness</th>
<th>Conscientiousness</th>
<th>Neuroticism</th>
<th>Imagination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.063***</td>
<td>-0.003</td>
<td>0.038**</td>
<td>0.020**</td>
<td>-0.079***</td>
</tr>
<tr>
<td>Female</td>
<td>-0.235***</td>
<td>-1.282***</td>
<td>-0.480***</td>
<td>-1.048***</td>
<td>0.566***</td>
</tr>
<tr>
<td>Race (Caucasian as ref.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>-0.423***</td>
<td>-0.203***</td>
<td>0.352***</td>
<td>0.206***</td>
<td>0.016</td>
</tr>
<tr>
<td>Asian</td>
<td>-0.370**</td>
<td>-0.034</td>
<td>-0.023</td>
<td>-0.014</td>
<td>-0.256**</td>
</tr>
<tr>
<td>Native American et al.</td>
<td>-0.038</td>
<td>-0.264***</td>
<td>-0.015</td>
<td>0.212**</td>
<td>0.004</td>
</tr>
<tr>
<td>Born in the U.S.</td>
<td>0.219*</td>
<td>0.206*</td>
<td>-0.018</td>
<td>-0.067</td>
<td>0.111</td>
</tr>
<tr>
<td>College-educated mother</td>
<td>0.245***</td>
<td>0.541***</td>
<td>0.011</td>
<td>-0.561***</td>
<td>0.721***</td>
</tr>
<tr>
<td>Mother born in the U.S.</td>
<td>-0.180*</td>
<td>0.007</td>
<td>-0.226***</td>
<td>0.050</td>
<td>-0.013</td>
</tr>
<tr>
<td>Acute obesity a</td>
<td>0.080</td>
<td>-0.150*</td>
<td>-0.572***</td>
<td>0.299***</td>
<td>-0.125*</td>
</tr>
<tr>
<td>Mild obesity a</td>
<td>0.024</td>
<td>-0.161**</td>
<td>-0.372***</td>
<td>0.154**</td>
<td>-0.114*</td>
</tr>
<tr>
<td>Chronic obesity a</td>
<td>-0.159*</td>
<td>-0.237***</td>
<td>-0.668***</td>
<td>0.332***</td>
<td>-0.112</td>
</tr>
<tr>
<td>Constant</td>
<td>15.140***</td>
<td>15.738***</td>
<td>14.072***</td>
<td>10.369***</td>
<td>16.277***</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.78%</td>
<td>8.20%</td>
<td>1.85%</td>
<td>5.01%</td>
<td>3.49%</td>
</tr>
</tbody>
</table>

Note: *Non-obesity is the reference group.
** p<.10; * p<.05; ** p<.01; *** p<.001 (two-tailed tests)

Figure 21 shows heterogeneity in growth trajectories of depression. There are also four types of growth trajectories for depression, as suggested by changes in BIC. Chronic depression means persistently higher levels of depression probabilities across adolescence and early adulthood. About 30% respondents belong to this group. Individuals (roughly 5% of the sample) in the acute-depression group show sudden increase in depression probabilities during early adulthood. The probabilities of depression for the non-depression group including most respondents not only stay at a low level throughout adolescence but slightly decrease during adulthood. In contrast,
depressive symptoms of the relapse group (7.3% of the sample) show improvement in early adulthood but increase afterwards. When chronic depression is set as the reference group, females are more likely to be in the acute-depression or non-depression groups (see Table 12). Both African Americans and Native Americans and others are significantly less likely to be in the non-depression group. US-born individuals tend to be in the acute-depression group. Mother’s college education has protective effect such that these respondents with college-educated mothers are significantly more likely to be in the non-depression group. For growth trajectories of obesity, the membership of chronic obesity is significantly and negatively associated with chronic depression.

Table 12 A finite mixture analysis of depression in the United States, Add Health, 1994-2009

<table>
<thead>
<tr>
<th></th>
<th>Acute depression</th>
<th>Non-depression</th>
<th>Relapse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficients</td>
<td>Coefficients</td>
<td>Coefficients</td>
</tr>
<tr>
<td>Constant</td>
<td>-8.912***</td>
<td>0.695**</td>
<td>-1.790***</td>
</tr>
<tr>
<td>Female</td>
<td>0.497*</td>
<td>0.749***</td>
<td>-0.369???</td>
</tr>
<tr>
<td>Race (Caucasian as reference)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>0.186</td>
<td>-0.836***</td>
<td>-0.108</td>
</tr>
<tr>
<td>Asian</td>
<td>0.576</td>
<td>-0.101</td>
<td>0.005</td>
</tr>
<tr>
<td>Native American et al.</td>
<td>0.198</td>
<td>-0.329*</td>
<td>-0.107</td>
</tr>
<tr>
<td>Born in the U.S.</td>
<td>7.223***</td>
<td>0.034</td>
<td>0.675</td>
</tr>
<tr>
<td>College-educated mother</td>
<td>-0.799*</td>
<td>0.230*</td>
<td>-0.457??</td>
</tr>
<tr>
<td>Mother born in the U.S.</td>
<td>-0.155</td>
<td>-0.055</td>
<td>0.126</td>
</tr>
<tr>
<td>Acute obesity</td>
<td>-0.590</td>
<td>-0.219</td>
<td>-0.523</td>
</tr>
<tr>
<td>Mild obesity</td>
<td>-0.201</td>
<td>-0.078</td>
<td>-0.196</td>
</tr>
<tr>
<td>Chronic obesity</td>
<td>-0.252</td>
<td>-0.370**</td>
<td>-0.279</td>
</tr>
<tr>
<td>BIC</td>
<td>-36631.92</td>
<td>AIC</td>
<td>-36439.67</td>
</tr>
</tbody>
</table>

Note: *Chronic depression is the reference group.

b Non-obesity is the reference group.

?? p<.10; * p<.05; ** p<.01; *** p<.001 (two-tailed tests)
Next, we investigate the association between perceived intelligence and obesity trajectories. Figure 22 shows four types of growth trajectories of perceived intelligence. In figure 22, very few respondents believe that they are less intelligent than others (2.6%), while most of them find themselves either as intelligent as others (58.2%) or slightly/moderately more intelligent than others (43.6%). About 5% of the respondents suggest that they are extremely intelligent as compared with their peers. If the less-intelligent group is deemed as the reference group, African Americans, as compared to Caucasians, are more likely to identify themselves as talents. Results from a finite mixture regression analysis (see Table 13) show that respondents with college-educated mothers are significantly more likely to be in a group other than the reference group (less intelligent). There is no significant relationship between obesity
trajectories and perceived intelligence.

Figure 22: Age trajectories of depression estimated by finite mixture regression models with time-stable covariates, Add Health, 1994-2009

Table 13: A finite mixture analysis of perceived intelligence in the United States, Add Health, 1994-2009

<table>
<thead>
<tr>
<th></th>
<th>Ordinary (^a) Coefficients</th>
<th>Smart (^a) Coefficients</th>
<th>Talent (^a) Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2.810(^{***})</td>
<td>1.903(^{***})</td>
<td>-0.361</td>
</tr>
<tr>
<td>Female</td>
<td>-0.333(^p)</td>
<td>-0.284</td>
<td>-0.050</td>
</tr>
<tr>
<td>Race (Caucasian as reference)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>-0.183</td>
<td>0.008</td>
<td>0.710(^{**})</td>
</tr>
<tr>
<td>Asian</td>
<td>0.767</td>
<td>0.751</td>
<td>0.023</td>
</tr>
<tr>
<td>Native American et al.</td>
<td>0.411</td>
<td>0.164</td>
<td>-0.007</td>
</tr>
<tr>
<td>Born in the U.S.</td>
<td>0.058</td>
<td>0.484</td>
<td>0.395</td>
</tr>
<tr>
<td>College-educated mother</td>
<td>0.810(^*)</td>
<td>1.731(^{***})</td>
<td>2.107(^{***})</td>
</tr>
<tr>
<td>Mother born in the U.S.</td>
<td>0.345</td>
<td>0.378</td>
<td>0.174</td>
</tr>
<tr>
<td>Acute obesity(^b)</td>
<td>0.107</td>
<td>-0.040</td>
<td>0.041</td>
</tr>
<tr>
<td>Mild obesity(^b)</td>
<td>0.024</td>
<td>-0.205</td>
<td>-0.036</td>
</tr>
<tr>
<td>Chronic obesity(^b)</td>
<td>-0.186</td>
<td>-0.180</td>
<td>-0.383</td>
</tr>
</tbody>
</table>

BIC: -92792.18  AIC: -92596.02

Note: \(^a\) The less intelligent is the reference group.
\(^b\) Non-obesity is the reference group.
\(^p\) \(p<.10\); \(^*\) \(p<.05\); \(^{**}\) \(p<.01\); \(^{***}\) \(p<.001\) (two-tailed tests)

For the age trajectories of juvenile delinquency, an overall decrease in
intensities of delinquency is observed from adolescence to early adulthood. Conformists who have never engaged in any delinquent behaviors account for about one third of the sample. Troublemakers contribute to 40.4% of the sample and they report delinquent behaviors throughout the age interval studied, although intensities of delinquency reduce slightly in adulthood. Naughty youth (29.3% of the sample) only report few delinquent behaviors during adolescence. Delinquents report much higher delinquency intensities than others do and they also engage in delinquent behaviors in adulthood. Table 14 shows full results from the finite mixture analysis. When conformists are set as the reference group, children with acute obesity are less likely to be in either naughty youth group or delinquent group, while the membership of mild obesity is also negatively associated with the odds of becoming delinquents.

Figure 23 Age trajectories of depression estimated by finite mixture regression models with time-stable covariates, Add Health, 1994-2009
Table 14 A finite mixture analyses of juvenile delinquency in the United States, Add Health, 1994-2009

<table>
<thead>
<tr>
<th></th>
<th>Troublemaker Coefficients</th>
<th>Naughty Youth Coefficients</th>
<th>Delinquent Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-1.283***</td>
<td>-0.433*</td>
<td>-4.426***</td>
</tr>
<tr>
<td>Female</td>
<td>1.563***</td>
<td>-0.152</td>
<td>2.133***</td>
</tr>
<tr>
<td>Race (Caucasian as reference)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>0.164</td>
<td>-0.087</td>
<td>-0.112</td>
</tr>
<tr>
<td>Asian</td>
<td>0.448*</td>
<td>0.145</td>
<td>0.868**</td>
</tr>
<tr>
<td>Native American et al.</td>
<td>0.571***</td>
<td>0.780***</td>
<td>1.183***</td>
</tr>
<tr>
<td>Born in the U.S.</td>
<td>0.344*</td>
<td>0.592***</td>
<td>1.436***</td>
</tr>
<tr>
<td>College-educated mother</td>
<td>-0.067</td>
<td>-0.573***</td>
<td>-0.140</td>
</tr>
<tr>
<td>Mother born in the U.S.</td>
<td>0.281*</td>
<td>-0.080</td>
<td>0.127</td>
</tr>
<tr>
<td>Acute obesity b</td>
<td>-0.050</td>
<td>-0.430*</td>
<td>-0.538*</td>
</tr>
<tr>
<td>Mild obesity b</td>
<td>-0.098</td>
<td>-0.112</td>
<td>-0.334*</td>
</tr>
<tr>
<td>Chronic obesity b</td>
<td>-0.014</td>
<td>-0.329*</td>
<td>-0.369</td>
</tr>
</tbody>
</table>

BIC -64062.14 AIC -63865.98

Note: * The conformist is the reference group.
** Non-obesity is the reference group.
Ψ p<.10; * p<.05; ** p<.01; *** p<.001 (two-tailed tests)

4.7 Summary

This chapter mainly deals with non-medical costs of childhood obesity. Finite mixture regression models allow scholars to identify heterogeneity in growth trajectories of obesity, which can be further used to predict behavioral and psychosocial outcomes. Based on changes in BIC between finite mixture regression models with successive number of latent trajectories, four distinct types of age trajectories in obesity are identified: non-obesity, mild obesity, acute obesity and chronic obesity. Growth trajectories of obesity of most respondents interviewed in the Add Health belong to the first two groups. When mild obesity is set as the reference, females, African Americans and US-born individuals are more likely to be in the chronic-obesity group. Further analyses show that either acute obesity or mild obesity or chronic obesity is significantly associated with higher levels of neuroticism but lower levels of agreeableness or conscientiousness. For growth trajectories of depression, individuals from the chronic-obesity group are less likely to be in the non-depression group. No significant patterns between perceived intelligence and
obesity trajectories are observed. Individuals from acute-obesity or mild-obesity groups are significantly less likely to be delinquents.

5. Discussion and Conclusions

Motivated by the question whether there is a fifth phase of the Epidemiologic Transition related to obesity and inactivity, this project investigates the temporal patterns and consequences of (childhood) overweight and obesity, especially in the United States and the People’s Republic of China. Based on eight waves of China Health and Nutrition Survey, the first part of empirical analyses investigates age, period, and cohort effects of childhood overweight in China. I find that there is a strong cohort effect driving the rising prevalence of childhood overweight. Meanwhile, results from the growth-curve models show that childhood overweight and underweight in China are related such that characteristics associated with higher prevalence rates of overweight (e.g., northern China and high-income families) are also associated with lower prevalence rates of underweight.

The second part situates the discussion on childhood obesity in China in a broader context. It compares the temporal patterns of childhood overweight and these of adulthood overweight in China. This chapter shows that there is a salient cohort component embedded in the rise of childhood and adolescent overweight in China. In contrast, such cohort component is largely absent for adulthood overweight, whose increase is mainly dominated by period effects. Yet, adulthood obesity of birth cohorts experiencing the great famine during childhood or adolescence shows the imprint of famine depending on their timing of exposure. This chapter also investigates the association between human development index and obesity prevalence across
countries. Findings suggest a positive relationship between HDI indices and prevalence rates of obesity/overweight across countries.

Using multiple waves of survey data from the Add Health study, the third piece of empirical analyses examine the (latent) trajectory of childhood obesity in the United States. The last part of empirical analyses also discusses how differential patterns of latent trajectories of adolescent obesity are associated with a series of behavioral and psychosocial outcomes, such as depressive symptoms, delinquency, perceived intelligence and personality. Four distinct growth trajectories are identified: non-obesity, mild obesity, acute obesity and chronic obesity. As compared with the non-obesity trajectory, other obesity trajectories are significantly associated with higher levels of neuroticism but lower levels of agreeableness or conscientiousness. Individuals from the chronic-obesity group are less likely to appear in the non-depression group. Individuals from acute-obesity or mild-obesity groups are also significantly less likely to be delinquents.

What can scholars learn from this project about the global epidemic of obesity and its non-medical costs? This study suggests that vicious cycles triggered by obesity, especially childhood obesity, could operate in two ways. On one hand, as the cohort component in the rise of obesity is not only manifested in the developed countries (Reither, Hauser, and Yang 2009) but also in a developing country, as revealed in the current study, more obese younger generations will eventually replace older generations and set a stage for the fifth stage of the Epidemiological Transition if the cohort component continues into the future. Meanwhile, this study does suggest that children are more vulnerable to an obesogenic environment because the cohort effect of adulthood overweight/obesity is much less salient than that of childhood and adolescent overweight/obesity. On the other hand, the behavioral and psychosocial
consequences of obesity deserve serious attention. Results from finite mixture regression analyses suggest that obese children and youth are less likely to escape from depressive symptoms and have higher levels of neuroticism, although they are less likely to be delinquents. So the message here is that obese children and youth are not dangerous but less happy. These important characteristics of individuals with differential trajectories of obesity call for further investigation.
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Biography

Qiang Fu was born in 1983 in Taiyuan, China. He received a bachelor degree in Computer Science from Jinan University (Guangzhou, China) and a master degree in Demography from Peking University (Beijing, China). He was admitted to the Department of Sociology at Duke University as a Ph.D. student in 2008 and received his master degree in Sociology in 2010 (preliminary exams include demography and medical sociology). He was awarded the China Research Program Fellowship from the Lincoln Institute of Land Policy and a PARISS fellowship from the Social Science Research Institute at Duke University. Since the summer of 2009 he has also conducted field research on homeowners associations and neighborhood governance in urban China. His work has appeared in journals such as Urban Studies, Sociology of Health and Illness, Social Science Research, Environment and Planning A, International Journal of Urban and Regional Research, Chinese Sociological Review, American Behavioral Scientist, Asian Population Studies and Child Indicators Research. His book chapters are also published by Springer and Routledge.