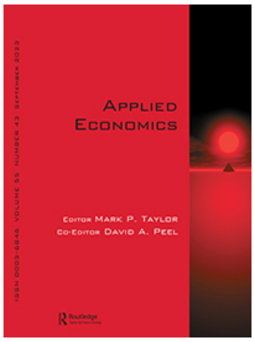

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Spousal dependence and intergenerational transmission of body mass index

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ABSTRACT

Obesity and overweight have become increasingly prevalent in developing countries like China. This paper explores the evolvement of body mass index (BMI) of the Chinese population using a nationally representative sample. Focusing on familial transmission of BMI, we model married couple's BMI jointly and explore how parents' BMI affect children's BMI. In particular, we use spousal and parental characteristics as proxy variables to account for potential omitted variables bias and explicitly model common couple effect with the correlated random-effects model for couple' BMI. Our analysis suggests strong and positive spousal dependence and intergenerational transmissions of BMI in Chinese families. The influences of spousal BMI, parental BMI and a variety of social economic characteristics are found to depend on gender, region of residence (urban versus rural) and evolve over time. We find positive effects of spousal BMI that are significant, asymmetric (greater for wife than for husband), and generally vary across regions. For grown children, we find parental BMI to be the most important predictors for children's BMI. Since families can play an essential role in preventing obesity, our results can be useful for developing health intervention programs and promoting healthy lifestyle.

KEYWORDS
Body mass index; China; Intergenerational transmission of BMI; Spousal dependence of BMI; BMI; Children's BMI; Overweight; Obesity; Parental BMI

JEL CLASSIFICATION
D12; I10; I12; I14; I1

I. Introduction

Obesity is a common risk factor associated with many chronic diseases, and its increasing prevalence has imposed tremendous financial burden on countries undergoing rapid economic development. Although there are numerous studies on the undesirable economic and health consequences of obesity in developed countries, academic research is relatively silent on its impacts on developing countries. But this does not imply it is not an important topic in these countries. According to a recent survey (Ng et al. 2014) conducted by the Institute for Health Metrics and Evaluation at the University of Washington, China has the second largest obese population (more than 62 million) in the world. According to the 2015 Report on the Nutrition and Chronic Disease Status of Chinese Residents[1], the overweight and obesity rates of Chinese adults are 30.15% and 11.9% respectively in 2014, significantly increased from 22.85% and 7.1% in 2002. Body mass index (BMI), defined as height/weight (meters/kg^2), is a common measure to classify overweight and obesity. Using nationally representative household surveys, we depict an increasing trend of obesity and overweight percentages of Chinese adults from 1991 to 2011 in Figure 1 below.

A large number of studies show that overweight and obesity are associated with family environment and genetic traits (Vogler et al. 1995; Philipson and Posner 1999; Jeffery and Rick 2002; Sacerdote 2004; Lakdawalla and Philipson 2009; Gao, Zhang, and Wu 2015; Gao and Shen et al. 2017). For example, Jeffery and Rick (2002) report that spousal correlation in BMI ranges from 0.1 to 0.2. Positive spousal correlation in BMI can be attributed to: (1) assortative matching in selection of spouse, and (2) family environment, including exercise frequency, dietary habits and household income, which are usually common and shared by couples. Using a novel copula model Gao, Zhang, and Wu (2015) find that the intergenerational BMI dependence is generally asymmetric and stronger for females. Intergenerational transmission

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Sihong Chen's contribution was made when he was a PhD student in the Department of Agricultural Economics of Texas A&M University, prior to joining Amazon and does not represent Amazon's views.

[1]http://en.nhfpc.gov.cn/.

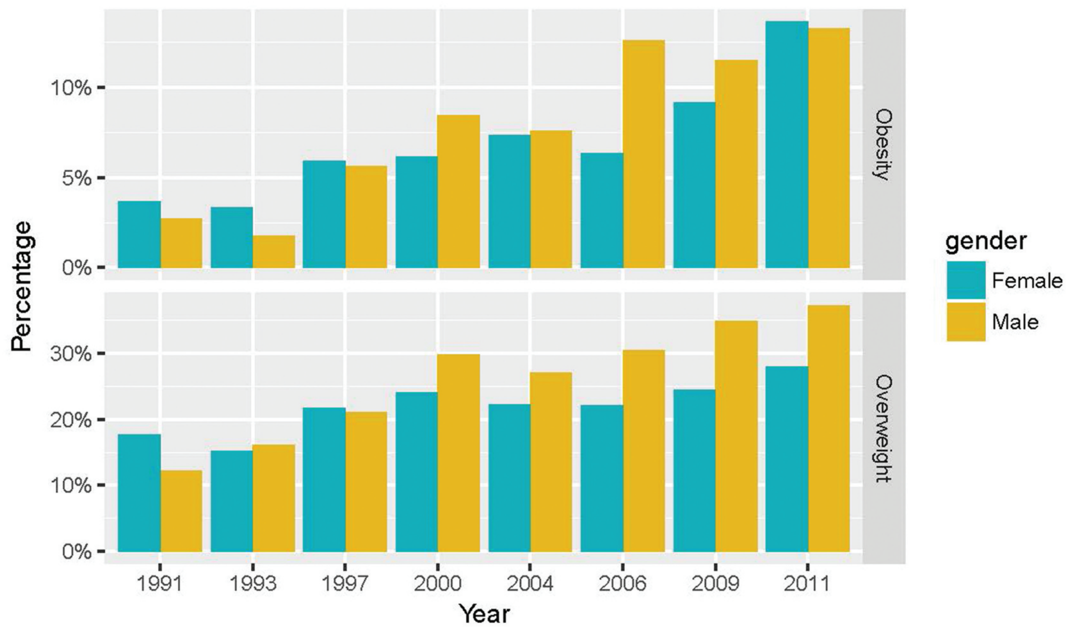

Figure 1. Percentages of overweight and obese Chinese adult over time.

of BMI arises for two reasons: (1) genetic traits, which are shared by biological parents and children; (2) family environment (where and how parents raise their children). Existing literature indicates that family environment plays an important role in both spousal and intergenerational correlation in BMI. For instance, Anderson, Butcher, and Levine (2003) suggest that if mothers work for long hours their children are more likely to be obese or overweight. Taveras et al. (2005) find that overweight and obesity are negatively related to the frequency of having family dinners.

Some recent studies consider weight/height data augmented with socioeconomic variables (employment status, income, insurance, etc.), demographic information (age, gender, education, residents' area, etc.) and behavioural variables (smoking, exercise frequency, etc.) to help explain observed variations in obesity and overweight (Price, Reed, and Guido 2000; Wilson 2002; Chou, Grossman, and Saffer 2004; Classen and Hokayem 2005; Mamun et al. 2005; Abrevaya and Tang 2011; Cohen et al. 2013; Chen, Liu, and Wang 2014; Gao and Shen et al. 2017). For example, Abrevaya and Tang (2011) use a large micro dataset in the United States with information on husbands, wives and grown children to explore familial BMI relationship and determination of weight status. They find that household income affects husband's and wife's BMI differently; parental BMI and smoking behaviour serve as significant predictors for grown children's BMI. Gao and Shen et al. (2017) explore a Chinese data and find different determinants of BMI for urban and rural residents. In particular, they suggest that BMI is correlated with gender, age, labour intensity, drinking and eating habits among urban residents, and with income, number of siblings and eating habits among rural residents.

This paper attempts to analyse the increasing prevalence of obesity and overweight in China over a span of two decades. We make two primary contributions to the current literature. First, we explicitly model familial relationship of BMI in different areas of China. Although Gao and Shen et al. (2017) also consider separate models for Chinese urban and rural residents' BMI, they do not take into account spousal BMI and parental BMI in their analysis despite the abundant evidence on BMI transmission within family. Secondly, our analysis explores the dynamics of obesity and overweight determinants for Chinese in different periods. The importance of dynamics of obesity determinants is demonstrated by Philipson and Posner (1999) and Lakdawalla and Philipson (2009), who argue that agricultural and technological innovations contribute to the increase in overweight and obesity. As China has experienced a rapid economic growth and numerous agricultural innovations since early 1990s, one may naturally conjecture that the determinants of obesity might have evolved during this period. Unlike studies that rely on cross-sectional data (e.g. Abrevaya and Tang (2011) and Gao and Shen et al. (2017)), we utilize nationally representative data that span two decades since 1991. This longitudinal sample allows us to model time varying impacts of various contributing factors on BMI during the sample period.

Our results provide strong evidence on BMI transmission within family. For example, an individual's BMI is found to have a significant and positive impact on the BMI of his/her spouse, though this impact has decreased in the recent decade. Intergenerational transmission of BMI is evident: parental BMI is the most important predictor for children's BMI. We also find that individual BMI depends on socioeconomic and demographic characteristics. In particular, income effect is positive for men's BMI while employment status has a negative effect on women's BMI. However, these characteristics are not as informative for children's BMI, for whom only education attainment is found to be a negative predictor for younger women. Lastly, we identify significant education impact on couples' BMI using structural regressions with a common couple effect, suggesting that some common factors influencing both husband and wife are probably omitted.

The remainder of this paper is structured as follows. Section II briefly introduces some background information and provides summary statistics of the household survey data used in our analysis. Section III presents the models and estimation results. Specifically, section 3.1 and section 3.3 consider proxy-variable regressions for spousal BMI and children BMI, while section 3.2 investigates couple effects using correlated random-effects regressions for spousal BMI. The last section concludes.

II. Data

This study uses data from the China Health and Nutrition Survey (CHNS) that is collaborative project between Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health (NINH) at the Chinese Center for Disease Control and Prevention (CCDC). This project is designed to measure the impacts of health, nutrition and family planning policies implemented by national and local governments, and examine how the economic transformation of China affects the health and nutritional condition of the Chinese population. The survey was conducted in 12 provinces (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, Shaanxi, Shandong, Yunnan and Zhejiang) and 3 national central cities (Beijing, Chongqing and Shanghai). The initial round of survey began in 1989; detailed information pertinent to this study was collected in eight subsequent rounds in 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011. We therefore focus our analysis on these eight rounds. To capture dynamics in BMI determinants during the sample period and at the same time to avoid yearly sampling variations, we cluster our samples into the 1990s group (1991, 1993, 1997, 2000) and the 2000s group (2004, 2006, 2009, 2011).

CHNS conducts surveys at the household level, collecting information regarding individual household members such as age, education level, height, weight, employment status, smoking behaviour and health insurance coverage. Also available are some household common characteristics, such as total annual income (in RMB), child status (has child or not) and region (urban or rural). The key variable in our study, BMI, is measured as weight/height^2 (kg/m^2) in the typical way. Notice that the recommended classification of obesity and overweight is different for the Chinese population because Asians tend to have higher body fat than whites of same age and BMI (Potts 2003). In particular BMI values between 24 and 28 are classified as overweight and those greater than 28 as obese[2]

We present summary statistics of our sample in Table 1. Sample averages and standard deviation of non-indicator variables, as well as percentages of indicator variables are reported separately in the upper and lower panel of Table 1. The first two

[2]The more common cut-offs are BMI between 25 to 30 for overweight and BMI greater than 30 for obese. Our analysis is not sensitive to this alternative criterion..

Table 1. Variables and descriptive statistics.

	Married couple		Grown children	
	Female	Male	Female	Male
Non-indicator variables				
BMI	22.96	22.86	21.14	22.03
	(3.79)	(3.30)	(3.15)	(3.35)
Family income (in RMB)	30,894	30,894	29,251	35,371
	(48,970)	(48,970)	(40,180)	(64,766)
Education (in years)	6.40	8.04	9.68	9.58
	(4.32)	(3.72)	(3.60)	(3.04)
Age	43.24	45.11	23.59	27.35
	(12.17)	(12.51)	(5.44)	(7.21)
Indicator variables				
Obese (1 if BMI $\geq$ 28)	0.077	0.069	0.020	0.054
Overweight (1 if 24 $\leq$ BMI $<$ 28)	0.260	0.252	0.101	0.175
Has child	0.660	0.660	0.049	0.124
health insurance	0.479	0.516	0.534	0.573
Smoker	0.030	0.672	0.016	0.535
Employed	0.707	0.823	0.759	0.828
Urban	0.291	0.291	0.324	0.290
Married	1.000	1.000	0.132	0.492
Number of Observations	11,541	11,541	1,437	2,982

standard deviations reported in parentheses for non-indicator variables.

columns of Table 1 report information of married couples during the sample period. On average, wives have slightly higher BMI and less education than husbands. Roughly 25% of couples are obese or overweight in our sample. Two thirds of couples in our sample have at least one child and about half of them have health insurance. In the couple sample, 67% of men are smokers while only 3% of women smoke frequently; men have higher employment rate than women (82.3% v.s. 70.7%). Around 30% of the couples come from urban areas. China uses a residence registration system called 'hukou', which classifies people as rural or urban residents, to restrict free migration and determine eligibility to local resources such as public education, medical care and pension plan. For example, school-age children from rural areas do not have access to public schools in urban areas, even if they have been living in the urban areas. We are interested to learn whether China's economic transformation had affected overall health condition of people with urban or rural hukou differently, given that generally urban areas have benefited more from the transformation during the sample period. For this purpose, we conduct our analysis for urban and rural areas separably.

The last two columns of Table 1 report summary statistics for grown children who live in the same household with their parents. In our investigation of intergenerational BMI transmission from parents, we focus our analysis on children with complete information on both parents in the survey. In our sample there are 1,437 grown daughters and 2,982 grown sons who lived with their parents. On average, female children have lower BMI than male children. This could be partially explained by their younger age (23.59 v.s. 27.35). Unlike their parents, male and female children have the same level of average education. Only 7.5% of female children are obese or overweight, in contrast to 15.9% for male children. Not surprisingly more men are smokers than women (53.5% v.s. 1.6%); nonetheless, the prevalence of smoking is lower than that among their parents. Employment rates are 75.9% and 82.8% for female and male respectively. The employment gender gap among growth children is smaller than that of their parents (6.9% v.s. 11.6%), probably reflecting an increasing status of younger women in China's labour market. There are more married men than married women in the grown children sample (49.2% v.s. 13.2%). This is due to the fact that in China married daughters are considerably less likely to live in the same household with their parents than married sons.

III. Models and results

Following Abrevaya and Tang (2011), we employ proxy-variable regressions and correlated random-effects models to account for potential endogeneity and examine familial relationship of BMI. Section 3.1 examines impacts of demographic and economic characteristics and spousal BMI on individual BMI. Particularly we include spousal information to control for potential endogeneity due to omitted variables in the determinants of BMI. Section 3.2 investigates spousal BMI regressions that allow for correlated random effects to address endogeneity concern. We explore intergenerational BMI transmission between parents and grown children in section 3.3.

Spousal BMI regressions with proxy variables

We consider the following models for wife's and husband's BMI:

$$\mathrm{BMI}_w = x'_w\beta_w + \alpha_w + \in_w \tag{1}$$

$$\mathrm{BMI}_h = x'_h\beta_h + \alpha_h + \in_h \tag{2}$$

where subscript w denotes wife and h husband. On the right-hand side of both equations, x is a vector of observed individual variables, α represents an unobserved factor that may correlate with both BMI and x, and $\in$ is an idiosyncratic error term satisfying $E(x' \in) = 0$. We assume different coefficients in equation (1) and (2) to allow for different marginal effects of x_w and x_h on wife's and husband's BMI. We include the unobserved α to account for the fact that some likely contributing factors such as exercise or eating habits are not available from the survey and these omitted variables are possibly correlated with some covariates in x. Due to the presence of unobserved α, regressing BMI on x using the ordinary least squares (OLS) produces inconsistent results. To mitigate endogeneity bias, we employ spousal information as proxy variables for the omitted term α in the regressions. Especially we use spousal covariates x_{spouse} such as spouse's education, employment status and smoking behaviour as proxies for α and incorporate them as additional covariates.

We consider three model specifications to analyse determinants of individual BMI and present the corresponding results in Tables 2, 3 and 4. Model 1 includes only individual characteristics as covariates with no spousal information. Model 2 considers both spousal BMI and individual characteristics to explain variations in BMI. The last model employs individual characteristics and additional spousal information as proxy for omitted variables in the regression. We include province dummies in all three models and report robust standard errors clustered at the couple level. As we discussed earlier we have four subsamples (1990s/2000s groups and urban/rural groups) for each model, and we shall use years × region to denote a specific group for notational simplicity in the following discussion.

Relationship between individual BMI and spousal BMI

Regression results reported in Tables 3 and 4 suggest significant influence of spousal BMI on that of the other half. Husband's BMI has a larger impact on wife's BMI across all groups and models. This asymmetry is most pronounced in the 2000s × urban group where husband's impact is twice as large as wife's impact, though their magnitudes have decreased over time. Overall these impacts vary over time and across regions. Comparing results across different regions from the same period, we find larger spousal impacts in the rural group after year 2000. For instance in model 2 for the 2000s group, the marginal effect of spousal's BMI in the rural sample is considerably larger than its urban counterpart (0.103 v.s. 0.064 for wife's BMI and 0.098 v.s. 0.032 for husband's BMI). Similar findings are reported in model 3 wherein more individual and spousal characteristics are included.

Relationship between individual BMI and characteristics

In models 1, 2 and 3 we investigate how individual characteristics can explain their own BMI with and without spousal BMI. Coefficients of age and age square are significantly positive and negative in all models, suggesting that BMI tends to increase with age at a decreasing rate. Smoking turns out to be a strong predictor for male BMI except for the 2000s × urban group. This is not uncommon since nicotine is known to contribute to weight loss. No significant results are observed on female BMI. This is plausibly due to lack of variation in the smoking variable for the female sample, wherein only 3% are smokers.

Income is found to be a positive predictor of husbands' BMI, and its impact seems to decline over time. Since nutrition demand is higher for men than women, it is not unexpected to see

Table 2. Regression results for couple BMI in Model 1.

	Dependent variable = wife BMI				Dependent variable = husband BMI			
Years & Region	1990s	1990s	2000s	2000s	1990s	1990s	2000s	2000s
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Income	0.233*	0.424***	− .061	− .010	0.501***	0.385***	0.162*	0.127*
	(0.133)	(0.060)	(0.187)	(0.070)	(0.120)	(0.052)	(0.093)	(0.067)
Child	× .292	λ_w.238*	*.056	0.187	*.261	− .198	0.118	0.190
	(0.218)	(0.127)	(0.266)	(0.127)	(0.209)	(0.131)	(0.197)	(0.117)
Health insurance	− .032	0.218*	0.092	0.435***	0.073	0.180	− .032	0.521***
	(0.090)	(0.118)	(0.331)	(0.115)	(0.111)	(0.122)	(0.205)	(0.113)
Smoker	0.143	^{2}.268	− .259	β_{smoker}.180	− 0.321.435**	λ_{edu} = 0.033.338***	***.149	− .361***
	(0.659)	(0.313)	(0.196)	(0.188)	(0.221)	(0.113)	(0.169)	(0.112)
Education	0.035	0.022	***.088**	− .012	0.022	0.037**	− .021	0.101***
	(0.039)	(0.019)	(0.041)	(0.022)	(0.032)	(0.019)	(0.031)	(0.021)
Age	0.316***	0.252***	0.150	0.334***	0.219***	0.167***	0.130***	0.194***
	(0.064)	(0.034)	(0.098)	(0.036)	(0.055)	(0.031)	(0.047)	(0.033)
Age^2	**.003***	−0.003***	−0.001	−0.003***	−0.002***	−0.002***	−0.001***	−0.002***
	(0.001)	(0.0004)	(0.001)	(0.0004)	(0.001)	(0.0004)	(0.0005)	(0.0003)
Employed	−0.485*	−0.968***	−0.669**	−0.566***	−0.347	−0.907***	0.142	−0.758***
	(0.265)	(0.189)	(0.284)	(0.136)	(0.308)	(0.210)	(0.236)	(0.170)
Observations	1,391	4,011	1,969	4,170	1,391	4,011	1,969	4,170
Adjusted R^2	0.144	0.117	0.061	0.101	0.125	0.122	0.047	0.123

∗, ∗∗, ∗ ∗ ∗ denote statistical significance at the 10%, 5% and 1% levels respectively. Robust standard errors clustered at the couple level are reported in parentheses. Province dummies are included in all models.

Table 3. Regression results for couple BMI in Model 2.

	Dependent variable = wife BMI				Dependent variable = husband BMI			
Years & Region	1990s	1990s	2000s	2000s	1990s	1990s	2000s	2000s
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Spousal BMI	0.155***	0.151***	0.064*	0.103***	0.141***	0.117***	0.032*	0.098***
	(0.036)	(0.025)	(0.034)	(0.025)	(0.033)	(0.020)	(0.017)	(0.022)
Income	0.157	0.371***	−0.074	−0.024	0.471***	0.334***	0.166*	0.129*
	(0.133)	(0.060)	(0.186)	(0.070)	(0.121)	(0.052)	(0.093)	(0.066)
Child	−0.249	−0.207	−0.062	0.171	−0.219	−0.170	0.118	0.171
	(0.214)	(0.128)	(0.265)	(0.127)	(0.204)	(0.131)	(0.196)	(0.116)
Health insurance	−0.018	0.201*	0.107	0.384***	0.078	0.146	−0.043	0.480***
	(0.091)	(0.110)	(0.326)	(0.114)	(0.111)	(0.114)	(0.204)	(0.111)
Smoker	0.219	−0.221	−0.240	−0.146	−0.432*	−0.336***	−0.144	−0.364***
	(0.639)	(0.313)	(0.194)	(0.191)	(0.221)	(0.113)	(0.169)	(0.112)
Education	0.029	0.011	−0.088**	−0.019	0.015	0.036**	−0.018	0.101***
	(0.038)	(0.019)	(0.041)	(0.022)	(0.031)	(0.018)	(0.031)	(0.021)
Age	0.285***	0.227***	0.141	0.317***	0.170***	0.140***	0.129***	0.165***
	(0.064)	(0.034)	(0.097)	(0.037)	(0.056)	(0.031)	(0.047)	(0.034)
Age^2	−0.002***	−0.002***	−0.001	−0.003***	−0.002***	−0.001***	−0.001***	−0.002***
	(0.001)	(0.0004)	(0.001)	(0.0004)	(0.001)	(0.0004)	(0.0005)	(0.0004)
Employed	−0.394	−0.885***	−0.649**	−0.518***	−0.298	−0.785***	0.133	−0.728***
	(0.260)	(0.187)	(0.281)	(0.135)	(0.299)	(0.209)	(0.236)	(0.168)
Observations	1,391	4,011	1,969	4,170	1,391	4,011	1,969	4,170
Adjusted R^2	0.162	0.132	0.063	0.110	0.143	0.137	0.049	0.132

*, **, * * * denote statistical significance at the 10%, 5% and 1% levels respectively. Robust standard errors clustered at the couple level are reported in parentheses. Province dummies are included in all models.

Table 4. Regression results for couple BMI in Model 3.

	Dependent variable = wife BMI				Dependent variable = husband BMI			
Years & Region	1990s	1990s	2000s	2000s	1990s	1990s	2000s	2000s
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Spousal BMI	0.154***	0.149***	0.062*	0.104***	0.137***	0.112***	0.030*	0.096***
	(0.036)	(0.025)	(0.034)	(0.025)	(0.032)	(0.020)	(0.017)	(0.023)
Spouse education	0.039	−0.015	−0.064*	−0.017	0.010	0.070***	0.005	0.025
	(0.039)	(0.023)	(0.037)	(0.026)	(0.035)	(0.018)	(0.034)	(0.023)
Spouse employed	−0.124	−0.576*	0.239	−0.095	−0.580**	−0.201	−0.352*	−0.241*
	(0.321)	(0.299)	(0.267)	(0.191)	(0.239)	(0.171)	(0.195)	(0.135)
Income	0.142	0.377***	−0.060	−0.014	0.476***	0.292***	0.180*	0.125*
	(0.135)	(0.061)	(0.183)	(0.071)	(0.123)	(0.052)	(0.094)	(0.066)
Child	−0.246	−0.214*	−0.060	0.162	−0.216	−0.162	0.097	0.171
	(0.213)	(0.128)	(0.265)	(0.126)	(0.203)	(0.130)	(0.198)	(0.117)
Health insurance	−0.025	0.190*	0.109	0.387***	0.085	0.109	−0.038	0.472***
	(0.091)	(0.109)	(0.327)	(0.114)	(0.113)	(0.107)	(0.206)	(0.111)
Smoker & non-smoker	1.060	0.282	−0.112*	0.134	−0.414*	−0.319***	−0.148	−0.366***
	(0.936)	(0.602)	(0.065)	(0.262)	(0.227)	(0.113)	(0.170)	(0.112)
Smoker & smoker	−0.182	−0.300	−0.923	−0.231	−0.042*	−0.687***	−0.641	−0.700***
	(0.730)	(0.361)	(0.819)	(0.222)	(0.555)	(0.266)	(0.893)	(0.183)
Non-smoker & smoker	0.078	0.064	−0.213	0.056	−0.200	0.169	−0.233***	−0.322
	(0.218)	(0.124)	(0.239)	(0.108)	(0.659)	(0.834)	(0.044)	(0.292)
Education	0.009	0.015	−0.063	−0.015	0.009	0.011	−0.017	0.089***
	(0.042)	(0.021)	(0.043)	(0.025)	(0.032)	(0.019)	(0.035)	(0.023)
Age	0.291***	0.237***	0.138	0.318***	0.175***	0.156***	0.127***	0.174***
	(0.064)	(0.035)	(0.101)	(0.037)	(0.056)	(0.032)	(0.047)	(0.034)
Age^2	−0.002***	−0.003***	−0.001	−0.003***	−0.002***	−0.002***	−0.001***	−0.002***
	(0.001)	(0.0004)	(0.001)	(0.0004)	(0.001)	(0.0004)	(0.0005)	(0.0004)
Employed	−0.358	−0.681***	−0.688**	−0.492***	−0.075	−0.623***	0.209	−0.600***
	(0.263)	(0.213)	(0.285)	(0.141)	(0.313)	(0.235)	(0.233)	(0.180)
Observations	1,391	4,011	1,969	4,170	1,391	4,011	1,969	4,170
Adjusted R^2	0.162	0.134	0.062	0.109	0.146	0.144	0.049	0.134

*, **, * * * denote statistical significance at the 10%, 5% and 1% levels respectively. Robust standard errors clustered at the couple level are reported in parentheses. The second entry in smoking categories indicates if the spouse is a smoker, and the omitted smoking category in model 4 is both non-smokers. Province dummies are included in all models.

a positive impact of increased income on male BMI during early stage of economic development. As China went through further economic transformation, nutritious food became more readily available. Correspondingly, we observe in our analysis diminished income effect for male BMI in the 2000s. For women, significant income effect is only observed for the 1990s × urban group. We note that income effect on male BMI also varies regions. For example in model 1 coefficients of income are 0.501 and 0.385 for male from the urban and rural areas in the 1990s; they are reduced to 0.162 and 0.127 in the 2000s. Similar findings appear in models 2 and 3.

Employment status is a useful predictor of BMI for some groups. Men in the rural area are more likely to have lower BMI if they are employed, while this employment effect is not significant in the urban area, probably reflecting the fact that jobs for men in the country tend to be more labour intensive than those in the cities. Women in all but the 1990s × urban group are also likely to have lower BMI if they are employed.

Relationship between individual BMI and spousal characteristics

What if spousal characteristics, other than BMI, are used as proxy for omitted determinants of individual BMI? To answer this question we include additional spousal information such as education, employment status and smoking in model 3. We also include an interaction term between couples' smoking indicators, treating the category of non-smoking husband and wife as the baseline in the model. Spousal education is a significant predictor for female BMI (–0.064) in the 2000s × urban group and for male BMI (0.070) in the 1990s × rural group. Interestingly though the magnitudes are close they show opposite signs, suggesting that spousal education probably proxies for different latent components in the omitted term α. Spouse's employment status is also a useful predictor for male BMI except for the 1990s × rural group. In particular, it is suggested that the husband tends to have lower BMI if his wife is employed. One plausible reason for this finding is that in Chinese households, wives are typically responsible for most of house keeping and meal preparation. If the wife is employed, she would have less time for meal preparation and at the same time the husband might have an increased share of house keeping, both of which might have a negative effect on husband's BMI.

Spouse's smoking seems to be a complement of own smoking for men, as the coefficients of double-smokers are at least 100% higher than those of smoking husband and non-smoking wife. We conjecture that this interaction term proxies for some unobserved factors such as health awareness or living environment. These terms are significant for female BMI only in one group (2000s × urban). Again this is probably due to the fact that only 3% of wives are smokers in our sample. Overall we find that incorporating spousal information as proxy variables tends to improve the prediction of husband's BMI, as is evident from higher adjusted R-squares in those regressions.

Spousal BMI regressions with correlated random effects

In this subsection we employ the correlated random-effcts (CRE) model (Chamberlain 1982) to account for potential dependence between unobserved common factors of spousal BMI and observable individual characteristics x. Specifically we consider the following models for wife's and husband's BMI:

$$\mathrm{BMI}_w = x_w\beta_w + \alpha + \in_w \tag{3}$$

$$\mathrm{BMI}_h = x_h\beta_h + \alpha + \in_h \tag{4}$$

where $\alpha = \alpha_w = \alpha_h$ is a common component for wife and husband, which we shall term the 'couple effect'. Chamberlain (1982) treats α as a linear projection onto the observed regressors x such that:

$$\alpha = \phi + x_w\lambda_w + x_h\lambda_h + \nu \tag{5}$$

where ϕ is the intercept and ν is an error term uncorrelated with x_w and x_h by construction of linear projection. An important advantage of the CRE estimator is that λ_w and λ_h directly show which of the observable variables x are correlated with the unobserved common component α. Combining equations (3) and (4) with projection in (5), we obtain

$$\mathrm{BMI}_w = \phi + x_w\beta_w + x_h\lambda_h + x_w\lambda_w + (\nu + \in_w) \quad (6)$$

$$\mathrm{BMI}_h = \phi + x_h\beta_h + x_h\lambda_h + x_w\lambda_w + (\nu + \in_h) \quad (7)$$

We estimate equation (6) and (7) using the pooled OLS regression as suggested by Wooldridge (2010). Notice that CRE model cannot identify couple effects λ for variables that are shared by husband and wife (income and child indicator in our case). Therefore we should interpret the coefficients β of these shared variables as the overall effects that are measured by $\beta + \lambda$ for non-shared variables. Estimation results of CRE models are reported in Tables 5 and 6 for samples in different years and areas. Specifically Table 5 presents results for 1990s sample and Table 6 results for 2000s sample. For comparison between OLS model and CRE model, below we shall frequently refer back to the results of couple model 1 in Table 2 from section 3.1.

Relationship between BMI and smoking

Results of the CRE model for the 1990s groups are similar to those in couple model 1. The coefficients for β_{smoker} in the husband equation are negative and their magnitudes are close to those in couple model 1 (− 0.435 v.s. − 0.435 for urban area, − 0.306 v.s. − 0.338 for rural area), while their couple effects λ_{smoker} are not statistically significant. This result implies that smoking does not have an indirect impact on husband's BMI through the shared couple effect. CRE models also suggest no significant direct effect (β_{smoker}) or indirect effect (λ_{smoker}) on wife's BMI for the 1990s group, which is consistent with the findings in couple model 1. Interestingly we find evidence of couple effects for women in the 2000s group, where λ_{smoker} are − 0.326 and − 0.321 for the urban and rural areas respectively. Both coefficients are significant at least at the 10% level, while neither β_{smoker} in couple model 1 nor CRE model is statistically significant. This discrepancy suggests that ignoring common couple effects might lead to an upward bias in the estimate of smoking effect on women's BMI, as a negative λ_{smoker} implies there may exist omitted variables in the couple effect α that are negatively correlated with smoking. Therefore although smoking does not have a direct impact on women's BMI in our analysis, it can exert influence through couple effects via living environment, health awareness, exercise and eating habits, etc.

Relationship between BMI and education

Education is of great interest in our study since it is potentially correlated with many unobservables in the common effect α. Before we proceed to the discussion of education effect we want to emphasize that income effects in couple model 1 and CRE model are close in magnitude in all four subsamples, therefore we have similar control for income in both models and the following analysis of education impacts on BMI should work through channels other than income. We first discuss the results for men in the urban area. For the 1990s group, β_{edu} is insignificant in couple model 1 and CRE model, but the couple effect λ_{edu}, estimated at 0.048, is marginally significant at the 10% level. For the 2000s group, education again exhibits little direct impact on BMI, while λ_{edu} is estimated at − 0.052 with a 10% significance level. It appears that education of men living in the cities is correlated with couple effect α in a time-varying manner. One plausible explanation for this apparent sign switch in education impacts is that better educated people in the cities are generally more health conscious and tend to adopt healthy diet and life style; the benefits of healthy habits are initially manifested by higher BMI in the early stage of economic development, followed by lower BMI under a more advanced economy. We also note that after controlling for couple effect men in the 1990s × rural group do not have a significant overall education effect (β_{edu}+λ_{edu}) in CRE model, while β_{edu} is 0.037 and significant at the 5% level in couple model 1. This difference suggests that estimate of couple model 1 might be biased upward due to omitted variables.

Couple effects through education are also found for women, which appear to decrease in the rural area over time. For the 1990s × rural group, β_{edu} of couple model 1 is insignificant, but in the CRE model $\beta_{\text{edu}} = -0.048$ and $\lambda_{\text{edu}} = 0.075$, both of which are significant at least at the 5% level. Results for the 2000s × rural group are similar ($\beta_{\text{edu}} = -0.049$ and $\lambda_{\text{edu}} = 0.033$). Couple effect λ_{edu} decreases by 56% from 1990s to 2000s though

Table 5. CRE model BMI regression results for couples in urban and rural area during 1990s.

Models	1990s urban couples				1990s rural couples			
	β estimates		λ estimates		β estimates		λ estimates	
Variables	Husband	Wife	Husband	Wife	Husband	Wife	Husband	Wife
Male	1.862				1.667*			
	(1.905)				(0.973)			
Income	0.461***	0.248**			0.328***	0.440***		
	(0.101)	(0.112)			(0.047)	(0.053)		
Child	−0.313*	−0.268			−0.199*	−0.246**		
	(0.182)	(0.188)			(0.108)	(0.110)		
Health insurance	0.216	0.204	0.007	−0.235**	−0.166	−0.045	0.362**	−0.075
	(0.166)	(0.145)	(0.109)	(0.106)	(0.236)	(0.230)	(0.177)	(0.151)
Smoker	−0.435*	0.608	−0.005	−0.422	−0.306**	0.066	−0.021	−0.338
	(0.247)	(0.720)	(0.177)	(0.423)	(0.134)	(0.352)	(0.099)	(0.227)
Education	−0.040	−0.006	0.048*	0.021	0.017	−0.048**	−0.005	0.075***
	(0.038)	(0.040)	(0.028)	(0.027)	(0.022)	(0.019)	(0.017)	(0.013)
Age	−0.194	−0.091	0.374***	0.054	0.017	0.090	0.146**	0.027
	(0.131)	(0.139)	(0.100)	(0.093)	(0.080)	(0.084)	(0.059)	(0.057)
Age^2	0.001	0.0004	−0.003***	0.00005	−0.001	−0.002*	−0.001	−0.0003
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Employed	0.115	0.193	−0.179	−0.597***	−0.087	−0.406	−0.620**	−0.289*
	(0.430)	(0.312)	(0.312)	(0.217)	(0.346)	(0.250)	(0.267)	(0.157)

*, **, * * * denote statistical significance at the 10%, 5% and 1% levels respectively. Robust standard errors are in parentheses. Province dummies are included in all regressions.

Table 6. CRE model BMI regression results for couples in urban and rural area during 2000s.

Models	2000s urban couples				2000s rural couples			
	β estimates		λ estimates		β estimates		λ estimates	
Variables	Husband	Wife	Husband	Wife	Husband	Wife	Husband	Wife
Male	−0.674				0.900			
	(3.793)				(1.179)			
Income	0.150*	−0.011			0.133**	−0.021		
	(0.084)	(0.157)			(0.060)	(0.060)		
Child	−0.025	0.073			0.201**	0.165		
	(0.181)	(0.218)			(0.100)	(0.106)		
Health insurance	−0.340	0.341	0.458	−0.380	0.046	−0.035	0.198	0.304
	(0.500)	(0.635)	(0.447)	(0.237)	(0.309)	(0.303)	(0.225)	(0.207)
Smoker	0.014	0.088	−0.188	−0.326*	−0.410***	0.110	0.028	−0.321***
	(0.274)	(0.257)	(0.228)	(0.181)	(0.124)	(0.195)	(0.086)	(0.118)
Education	0.027	−0.067	−0.052*	−0.0001	0.094***	−0.049**	−0.004	0.033*
	(0.041)	(0.052)	(0.030)	(0.028)	(0.026)	(0.025)	(0.020)	(0.017)
Age	0.576	0.568*	−0.501	0.058	0.269***	0.395***	−0.089	0.019
	(0.427)	(0.332)	(0.419)	(0.091)	(0.100)	(0.096)	(0.073)	(0.065)
Age^2	−0.007	−0.006	0.006	−0.0004	−0.004***	−0.005***	0.001*	0.0003
	(0.005)	(0.004)	(0.005)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Employed	−0.100	−0.466	0.310	−0.325*	−0.532**	−0.161	−0.086	−0.323***
	(0.349)	(0.310)	(0.293)	(0.183)	(0.231)	(0.173)	(0.167)	(0.120)

*, **, *** denote statistical significance at the 10%, 5% and 1% levels respectively. Robust standard errors are in parentheses. Province dummies are included in all regressions.

it remains statistically significant. The evolvement of λ_{edu} suggests that the association between education and omitted variables has changed over time. For the women in 2000s × urban group, β_{edu} of couple model 1 is -0.088 and significant at the 5% level, but the CRE model shows that both β_{edu} and λ_{edu} are not significant, implying that β_{edu} is biased downward when couple effect is not taken into account.

BMI regressions for grown children

In this section we analyse grown children's BMI. We are especially interested in intergenerational transmission of BMI from parents to children. Compared to the parents sample studied in section 3.1 and 3.2, grown children in our sample are on the average better educated and more likely to be employed and have insurance. We examine daughter's BMI and son's BMI separably to allow for gender-specific impacts of various contributing factors. With parental characteristics as proxies to account for omitted variable issues, our estimation strategy is similar to those in section 3.1. Particularly we consider two models: (1) linear regression of children BMI on parental BMI and individual characteristics. (2) incorporating additional parental characteristics as proxy variables. We report estimation results for these models in Tables 7 and 8 respectively.

Our results suggest that parental BMI is a strong predictor of children BMI. Father's BMI in general has a greater impact except for children in the 1990s × urban group. We note the parental BMI impact depends on the gender of children and varies across areas. For daughters living in the urban area BMI effects of mother and father have increased over time (from 0.089 to 0.154 and from 0.066 to 0.400 respectively) in model 2. At the same time these effects have declined for daughters in the rural area. For sons living either in urban or rural area, the BMI impact of father is highly significant (at 1% level) and has increased over time (from 0.161 to 0.225 for the urban group and from 0.263 to 0.404 for the rural group) in model 2, while the BMI impact of mother has increased only for sons in the rural group. Similar patterns are observed in model 1. The overall results indicate that genetic traits shared by parents and children play a critical role in intergenerational BMI transmission.

We find negative and significant education effect for daughters' BMI except for those in the 2000s × rural group. This negative effect is stronger for the urban groups in both models. Notice that in section 3.1 we do not have similar results

Table 7. Regression results for growth children BMI in Model 1.

	Dependent variable = daughter BMI				Dependent variable = son BMI			
Years & Region	1990s	1990s	2000s	2000s	1990s	1990s	2000s	2000s
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Mother BMI	0.069	0.121***	0.150*	0.101*	0.170***	0.149***	0.133***	0.150***
	(0.043)	(0.031)	(0.080)	(0.059)	(0.034)	(0.018)	(0.045)	(0.035)
Father BMI	0.084**	0.163***	0.399***	0.104**	0.152***	0.268***	0.224***	0.390***
	(0.039)	(0.036)	(0.134)	(0.049)	(0.038)	(0.032)	(0.041)	(0.054)
Income	0.222	0.087	0.554*	0.417**	0.281	−0.104	0.251	0.035
	(0.183)	(0.116)	(0.337)	(0.205)	(0.173)	(0.072)	(0.198)	(0.127)
Child	0.692	−0.139	−0.071	−0.051	−0.333	0.073	−0.026	−0.339
	(1.000)	(0.740)	(0.700)	(0.856)	(0.506)	(0.272)	(0.472)	(0.266)
Health insurance	0.516***	−0.568**	0.363	−0.054	0.212**	0.382**	0.313	0.225
	(0.137)	(0.280)	(0.552)	(0.379)	(0.107)	(0.163)	(0.363)	(0.223)
Smoker	−0.627	1.336**	−0.549	−0.617**	0.084	0.070	−0.014	−0.795***
	(1.283)	(0.641)	(1.578)	(0.639)	(0.256)	(0.129)	(0.365)	(0.229)
Education	−0.224***	−0.145***	−0.149**	−0.112	−0.058	0.050**	0.032	0.048
	(0.055)	(0.031)	(0.074)	(0.084)	(0.052)	(0.024)	(0.067)	(0.036)
Age	0.062	−0.005	−0.247	−0.196	0.183*	0.225**	0.551***	0.515***
	(0.181)	(0.136)	(0.309)	(0.222)	(0.099)	(0.099)	(0.130)	(0.092)
Age^2	0.0004	0.001	0.005	0.006	−0.001	−0.002	−0.007***	−0.006***
	(0.003)	(0.002)	(0.005)	(0.005)	(0.001)	(0.002)	(0.002)	(0.001)
Employed	−0.632	0.142	−0.187	−0.229	0.779**	0.237	0.319	−0.049
	(0.394)	(0.285)	(0.585)	(0.339)	(0.350)	(0.245)	(0.452)	(0.284)
Married	−0.293	0.604	1.273**	0.333	−0.136	0.241	0.645	0.118
	(0.705)	(0.557)	(0.634)	(0.799)	(0.341)	(0.169)	(0.449)	(0.282)
Observations	240	647	225	325	429	1,128	437	988
Adjusted R^2	0.098	0.108	0.091	0.069	0.223	0.239	0.175	0.223

*, **, * * * denote statistical significance at the 10%, 5% and 1% levels respectively. Robust standard errors are in parentheses. Province dummies are included in all regressions.

Table 8. Regression results for growth children BMI in Model 2.

	Dependent variable = daughter BMI				Dependent variable = son BMI			
Years & Region	1990s	1990s	2000s	2000s	1990s	1990s	2000s	2000s
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Mother BMI	0.089**	0.131***	0.154*	0.110*	0.178***	0.141***	0.133***	0.153***
	(0.044)	(0.032)	(0.080)	(0.059)	(0.034)	(0.019)	(0.046)	(0.034)
Mother smoker	−0.406	0.255	0.358	−0.386	−0.165	−0.140	0.576	−0.514
	(0.559)	(0.463)	(2.385)	(0.836)	(0.480)	(0.368)	(0.862)	(0.480)
Mother education	−0.090**	−0.022	0.010	0.096**	−0.004	−0.021	−0.033	0.040
	(0.044)	(0.028)	(0.078)	(0.049)	(0.040)	(0.026)	(0.045)	(0.033)
Mother employed	0.396	0.201	−0.737	0.223	−0.081	−0.289	−0.233**	−0.022
	(0.328)	(0.284)	(0.872)	(0.355)	(0.258)	(0.208)	(0.479)	(0.260)
Father BMI	0.066*	0.177***	0.400***	0.102**	0.161***	0.263***	0.225***	0.404***
	(0.039)	(0.036)	(0.136)	(0.047)	(0.038)	(0.032)	(0.039)	(0.054)
Father smoker	−0.549*	0.216	−0.007	−0.029	0.121	−0.090	−0.012	0.482**
	(0.330)	(0.209)	(0.341)	(0.173)	(0.252)	(0.152)	(0.298)	(0.212)
Father education	0.008	−0.090***	−0.061	−0.031	−0.067*	−0.003	0.008	−0.058
	(0.038)	(0.028)	(0.103)	(0.058)	(0.034)	(0.022)	(0.044)	(0.040)
Father employed	−0.096	0.282	1.086	−0.281	−0.283	−0.313	0.312	0.345
	(0.328)	(0.464)	(0.701)	(0.425)	(0.286)	(0.281)	(0.405)	(0.283)
Income	0.223	0.119	0.540	0.411**	0.350**	−0.095	0.290	0.003
	(0.190)	(0.116)	(0.410)	(0.200)	(0.170)	(0.073)	(0.205)	(0.126)
Child	0.817	−0.208	−0.123	−0.027	−0.374	0.087	−0.043	−0.401
	(0.958)	(0.754)	(0.699)	(0.858)	(0.510)	(0.271)	(0.472)	(0.265)
Health insurance	0.507***	−0.557**	0.520	−0.103	0.194*	0.332**	0.368	0.238
	(0.129)	(0.279)	(0.603)	(0.385)	(0.107)	(0.163)	(0.364)	(0.222)
Smoker	−0.417	1.307**	−0.046	−0.115*	0.025	0.086	−0.086	−0.797***
	(1.360)	(0.652)	(1.484)	(0.665)	(0.256)	(0.130)	(0.372)	(0.228)
Education	−0.153**	−0.101***	−0.147*	−0.143	−0.011	0.057**	0.032	0.058
	(0.062)	(0.035)	(0.087)	(0.089)	(0.055)	(0.023)	(0.066)	(0.036)
Age	0.086	−0.015	−0.230	−0.200	0.116	0.213**	0.473***	0.544***
	(0.175)	(0.133)	(0.283)	(0.225)	(0.102)	(0.101)	(0.133)	(0.092)
Age^2	−0.0004	0.002	0.005	0.006	−0.0002	−0.002	−0.007***	−0.007***
	(0.003)	(0.002)	(0.004)	(0.005)	(0.001)	(0.002)	(0.002)	(0.001)
Employed	−0.550	−0.028	−0.162	−0.151	0.782**	0.373	0.207	−0.159
	(0.381)	(0.296)	(0.637)	(0.345)	(0.346)	(0.248)	(0.448)	(0.296)
Married	−0.449	0.597	1.416**	0.400	−0.163	0.216	0.606	0.201
	(0.714)	(0.549)	(0.658)	(0.786)	(0.344)	(0.168)	(0.434)	(0.287)
Observations	240	647	225	325	429	1,128	437	988
Adjusted R^2	0.106	0.124	0.076	0.062	0.226	0.241	0.178	0.227

∗, ∗∗, ∗ ∗ ∗ denote statistical significance at the 10%, 5% and 1% levels respectively. Robust standard errors are in parentheses. Province dummies are included in all regressions.

from spousal BMI models, even though their sample sizes are 6 to 10 times larger than the children sample. Considering that income and employment status have been controlled in our models, this result suggests that young educated women in the cities probably are more health conscious and more likely to control their weights via healthy diet and life style. Positive education effect is also found for sons in the 1990s × rural group, significant at the 5% level.

Comparing model 1 and 2 suggests that incorporating additional parental information as proxy variables does not necessarily produce better models. For example, adjusted R-squares in model 1 are only slightly smaller than those in model 2 for daughters in the 1990s group, while for those in the 2000s group these values are higher in model 1 where only parental BMI is used as proxy variable. Similar patterns are observed for sons' regressions. Recall that in the couples' models above, incorporating additional spousal information generally improves the performance. We conjecture that the lack of improvement in the regressions on children's BMI is because the common living environment, proxies by spousal characteristics, is the main reason behind the dependence in a couple's BMI; in contrast, generic linkage is the vastly dominant factor in intergenerational BMI transmission.

IV. Conclusion

This paper uses a nationally representative household survey of China to study familial relationship in BMI between 1991 through 2011. We find positive effects of spousal BMI that are significant, asymmetric (greater for wife than for husband) and generally vary across regions and over time. Income is found to be a strong positive predictor for husband's BMI, while employment has a significant and negative impact on wife's BMI. Similar to Abrevaya and Tang (2011) we find significant couple effect shared by wife and husband for education level in the correlated random-effects models. For grown children, we find parental BMI to be the most important predictors for children's BMI. Education attainment is shown to have a negative impact on daughters' BMI. Since families can play an essential role in preventing obesity, our results can be useful for developing health intervention programs and promoting healthy lifestyle.

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