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Article

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Does body fat change with car ownership rates? A longitudinal survey of gender differences

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ABSTRACT

Durable goods provide conventional proxies for household wealth, which, in turn, may increase the tendency to consume healthier food products and engage in leisure-time physical exercise. Higher car ownership levels, on the other hand, may reduce the tendency to participate in utilitarian, non-exercise-related physical activities such as walking to work and biking to do errands. Based on a recent longitudinal two-year Israeli Central Bureau of Statistics (CBS) survey, we examine the correlation between the number of cars owned by households and household members' body mass index (BMI) for adult female and male respondents below the workforce retirement age. Results indicate that projected BMI of native Israeli Jewish females and Jewish immigrants from Asian-African countries drops significantly, while compared with baseline native Jewish Israelis, the projected BMI decrease among Arab females is attenuated significantly with increased car ownership levels. These outcomes suggest that programs aimed at alleviating poverty may have the additional benefit of promoting obesity-reducing activities, particularly among the population of native Jewish Israeli females and immigrants from Asian African countries.

1. Introduction

In recent years, a general consensus has emerged in the medical profession around the characterization of obesity in western industrialized countries as a disease *per se* rather than only a risk factor for other diseases (Rosenthal et al., 2017; page 1649). Twenty percent of the articles in the 1999 special issue of JAMA on obesity, compared to 49% of news reporting on that issue, labeled obesity an epidemic (Saguy & Almeling, 2008, p. 65). Also, 81% of American respondents participating in a representative survey ranked obesity and cancer as the most serious health problems facing the nation (Rosenthal et al., 2017). Complications caused by obesity may include: spontaneous onset of labor (Hermesch Amy et al., 2016); hypertensive disorders of pregnancy (Gasse, Boutin, Demers, Chaillet, & Bujold, 2017); subclinical vascular damage (Yan et al., 2017); multimorbidity (Wikström, Lindström, Harald, Peltonen, & Laatikainen, 2015); metabolic syndrome (Yoon et al., 2015); and myeloid leukemia (Shamriz et al., 2017). Because obesity is associated with a higher risks of chronic illnesses, it is linked to significant additional health care costs (OECD, 2016). Qin and Pan (2016) estimate the obesity cost per person in China as 5.29% of the total personal medical expenditure.

A widely adopted definition of overweight is a body mass index ($BMI = \frac{WEIGHT}{HEIGHT^2} = \frac{kg}{meter^2}$) greater than or equal to 25 but lower than 30, with type I obesity defined as $30 \leq BMI < 35$ (Qin & Pan, 2016, p. 1293; OECD, 2016, p. 98 Nyberg et al. (2018); World

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Health Organization, Obesity and overweight. Key facts). Referring to the United States, Ogden et al. (2006) estimated that 66.3% of adults are overweight or obese and 17.1% of children and adolescents are overweight. In 1990 no US state had an obesity rate higher than 15%. In 2005 only six US states had obesity rates of below 20% (Menifield, Doty, & Fletcher, 2008). According to more recent estimates referring to 2011–2014, 37% of US adults and 17% of youth are obese (Ogden, Carroll, Fryar, & Flegal, 2015). Referring to other countries, according to the OECD report from 2016 (OECD, 2016, p. 4.13 Self-Reported Obesity among Adults above 15 years, 2014 (or latest year); page 99), in eight OECD European countries, namely, United Kingdom, Estonia, Turkey, Hungary, Latvia, Iceland, Ireland and Malta, BMI ≥ 30 for at least 20% of the population.

A related but not readily apparent aspect of the problem of obesity and lack of physical exercise is associated with urban economics and spatial planning. The typical suburbanization process in the 60s and 70s of the 20th century has been characterized by urban sprawl, and the predominance of car-oriented communities.¹ Based on a cross section of American cities, Brueckner and Fansler (1983); and McGareth (2005) demonstrated that total residential land area decreases with a higher percentage of households with one or more cars (see, for example, McDonald & McMillen, 2011 pages 136–137). These patterns, which are particularly prominent in US cities (e.g., Nivola, 1998; O'Sullivan, 2012, chap. 7, pp. 181–184, pp. 181–184), have been followed by a sharp increase in health problems related to prevalence of obesity rates (e.g., Zhao & Kaestner, 2010; Griffin et al., 2013).²

Another aspect of the problem is the relationship between body fat and wealth. Although empirically challenging, it is important to ascertain whether a lack of financial sources actually increases obesity. A finding that wealth reduces obesity, particularly among the poor, suggests that poverty alleviating programs may have the additional benefit of being effective obesity-reducing policies (Au & Johnston, 2015, p. 1404). According to 2005–2008 national data, for white American women, obesity rates tended to increase significantly with decreased income and lower education level (Houle, Holt, Gillespie, Freedman, & Reyes, 2009; Flegal, Carroll, Ogden, & Curtin, 2010; Pan, Freedman, Gillespie, Park, & Sherry, 2011). Preston (1975) demonstrated in a macro level that life expectancy rises with per-capita GDP, Zagorsky (2005) found a significant 12% (7%) decrease of projected net worth of white (black) women with 1-unit increase in BMI. Pan et al. (2011) demonstrate that after controlling the baseline BMI, the incidences of obesity and extreme obesity decreased significantly with increasing levels of education, from 5.1% in elementary education to 2.9% in college education. Incidences were significantly higher among young adults (6.4% for age 18–29 compared with 1.5% for age above 70), women (5.4% compared with 3.2% for men), and adults who did not participate in any leisure-time physical activity (5.1% compared with 3.7%). Finally, Datar and Chung (2015) show that BMI decreases significantly among children in a higher quintile of socioeconomic ranking.

Following Arbel, Fialkoff and Kerner (2018, 2019) the current study seeks to examine the relationship between the BMI and car ownership rates based on a new longitudinal representative survey of the Israeli population, which covers 2015–2016. Intuitively, a higher car ownership level is expected to reduce the tendency to participate in utilitarian, non-exercise physical activities such as walking to work and biking to do errands (Mettner, 2006). Consequently, a higher level of car ownership is expected to raise projected BMI. A more salient feature of increased car ownership rates, however, is its being a proxy for higher level of wealth. Following Shah, Mullainathan, & Shafir, 2012, if the number of owned cars is a proxy for wealth, projected BMI would be expected to rise with lower car ownership rates, given that scarcity changes the allocation of attention to urgent survival assignments, while neglecting other assignments, such as the consumption of healthier and more expensive food products and the engagement in leisure-time physical exercise. In sum, increasing car ownership rates may drive two offsetting forces, which operate in opposite directions either to increase or decrease BMI.³

The literature on the demand for cars indeed demonstrates that higher car ownership rates are associated with a higher level of wealth. Employing data from the Israeli housing expenditure survey carried out by the Israeli Central Bureau of Statistics (CBS), 2015, Alperovich, Deutsch, & Machnes, 1999 find that for the baseline household without cars, projected probability to purchase two cars is higher than projected probability to purchase only one car with the same rise in permanent income. Goodwin, Dargay, & Hanly, 2004 review the relevant literature and generate a meta-analysis of 69 empirical studies on UK elasticities of road traffic and fuel consumption. Their findings suggest that if real income rises by 10%, the projected number of cars is expected to increase by 4% within about a year, and by 10% in the long run (page 278).

Results of our empirical analysis indicate that for most sample groups of females, namely, native Jewish Israelis, and Jewish immigrants from Asia-Africa, the wealth effect, which drives projected BMI downward with more cars, dominates. For these groups of females, policies aimed at alleviating poverty might have the side effect of being effective obesity-reducing policies as well. For all the male groups, the pattern of reduction of participation in utilitarian non-exercise physical activities with higher car ownership rates, dominates.

Additional findings suggest that compared with native Jewish Israeli female respondents, for native Arab female respondents,

¹ This suburbanization process itself spurred the creation of urban economics as a separate discipline in economics. Mills and Hamilton (1989), for example, provide a formal proof to the statement that under realistic conditions, high income households live further from the city center than do low-income households. Baum-Snow (2007) estimated that had the US interstate highway systems not been built during the 1950s and 1960s, aggregate central city population would have increased by 8% from 1950 to 1990 – rather than declining by 17% (McDonald & McMillen, 2011, p. 318).

² On the other hand, based on a longitudinal survey carried out among movers from one neighborhood to another, Eid, Overman, Puga, & Turner, 2008 found no relationship between obesity and urban sprawl.

³ The Jewish traditional sources may describe these two offsetting forces as: “Jeshurun grew fat and kicked” (Deuteronomy 32:15) – for the reduction of participation in utilitarian non-exercise physical activities with higher car ownership rates; and “More possessions more worry” (Ethics of our Fathers, 2: 7) – for the decrease of BMI with the number of owned cars.

projected BMI drop attenuates significantly with each additional car. In that context, Prioreshi et al. (2017) and Arbel, Fialkoff, et al. (2019) and Arbel, Kerner, et al. (2019) discussed the impact of body image and cultural differences on obesity and low-weight-disorder, respectively. Prioreshi et al. (2017) discuss the traditional desirability of higher BMIs in African rural populations vs. the western preference for a normal weight silhouette among women. In line with our findings, it seems that while the body image of native Israeli females may be more influenced by western preferences, the same image of native Arab Israeli females may be more influenced by traditional preferences. This interpretation is strengthened by comparing married females to married males stratified by ethnic groups. While native Jewish Israeli married men are consistently above the cutoff line of overweight ($BMI = 25$), native Jewish Israeli married women are consistently below this cutoff line. This divergence does not exist among the sample of Arab respondents, and Jewish immigrants from American-European and Asian African countries.⁴

Finally, compared to women with at least one child but without owning a car, projected BMI of women with cars rises significantly for each additional car.⁵ In contrast to the female respondents, on the one hand, male respondents exhibit a significant rise in projected BMI with each additional car owned. On the other hand, for the male respondents, projected BMI drops significantly with gross annual income (in line with Zagorsky, 2005), but, compared to women, the magnitude of the drop is much slower.

Our findings may be of assistance to public policy planners in the fields of transportation and health. As our study indicates, future planning in these fields should account for the relationship between body fat and car ownership rates.

The remainder of this article is organized as follows. Section 2 includes the descriptive statistics. Sections 3 and 4 describe the methodology and results, respectively. Finally, Section 5 concludes and summarizes.

2. Description of sample and data

2.1. Sample and controls

The data for this study are based on the longitudinal survey carried out by the Israeli CBS in 2014–2015 and 2016. As an OECD member since 2010, Israel is required to conduct such a survey.

The sample of this survey is representative of the Israeli population, which includes all the Israeli households and persons living in non-therapeutic institutions, namely, students in dormitories, assisted living for the elderly and absorption centers for new immigrants. This definition of the Israeli population excludes prisoners, inhabitants in therapeutic institutions, such as chronic care housing for the elderly, Israeli inhabitants who remained outside the country for at least one year, foreign workers, diplomats, and Bedouins living in scattered settlements in the southern part of Israel.

The common method used to collect the data from the sampled households is face-to-face interviews at the respondents' homes via computerized questionnaires. Interviews were held with each adult household member above 17 years old, in one of three languages (Hebrew, Arabic and Russian).

Given that several studies in the field use telephone interviews (e.g., Adachi-Mejia et al., 2017; Stark et al., 2014), the face-to-face interview technique provides two main advantages: 1) unlike phone interviews, the respondent is more likely to answer the questionnaire in a non-threatening environment with a reduced tendency to avoid answers; 2) the interviewer can assess the reliability of answers, particularly regarding environmental/housing conditions, and height and weight of each household member. 3) families who are sampled by the Israeli CBS are required to cooperate by law. Consequently, high cooperation rates are achieved.

2.2. Descriptive statistics

Table 1 displays the descriptive statistics of the pooled sample. The sample includes 8866 observations covering up to two years (2015–2016) and 2488 households, where the age brackets of female (male) members were restricted to 21–62 (21–67) years old. The lower age-limit is designed to capture adults after 2–3 years of compulsory military service with the potential to receive a driving license. The upper age-limit is based on the retirement age for the workforce - 62 for women and 67 for men.

The three upper rows in Table 1 describe the sample mean, standard deviation, minimum and maximum weight in kg., height in meters and BMI calculated as $\frac{WEIGHT}{HEIGHT^2}$. As previously noted, the BMI measure is positively correlated with body fat percentage. According to the conventional medical terminology, overweight is defined as $25 \leq BMI < 30$; type I obesity, as: $30 \leq BMI < 35$ and type II obesity as $BMI \geq 35$ (e.g., Qin & Pan, 2016, p. 1293; OECD, 2016, p. 98; Nyberg et al. (2018); World Health Organization, 2019).^{6,7}

The average, minimum and maximum weight in the pooled sample is 74.36, 44.0 and 120 kg. (WEIGHT). The average, minimum and maximum height in the pooled sample is 1.70, 1.49 and 1.90 m. (HEIGHT). The average BMI in the pooled sample is 25.57 and

⁴ It should be noted in this context, that a large portion of the immigrants from European-American countries came from the European republics of Former-Soviet Union, namely, Russia, Ukraine, Lithuania and Latvia (e.g., Arbel, Fialkoff, et al. (2019) and Arbel, Kerner, et al. (2019)). Consequently, prior to immigration, they were less exposed to the Western culture.

⁵ For a comparison of the desirable housing choice in terms of projected BMI between married couple with and without children, see, for example, Arbel, Fialkoff, and Kerner (2018).

⁶ The OECD report, 2016 states that: "Obesity is a known risk factor for numerous health problems, including hypertension, high cholesterol, diabetes, cardiovascular diseases and some forms of cancer. Because obesity is associated with higher risks of chronic illnesses, it is linked to significant additional health care costs." (page 98).

⁷ Available at: <https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight> accessed at March 28, 2019.

Table 1
Descriptive statistics.

VARIABLES	Description	Obs.	Mean	STD	Min	Max
WEIGHT	Weight in kilograms	8866	74.36	15.46	44.00	120.00
HEIGHT	Height in meters	8866	1.70	0.09	1.49	1.9
BMI	Body Mass = $\frac{WEIGHT}{HEIGHT^2}$	8866	25.57	4.48	14.04	48.68
GRTOTINC > 10,000 NIS	Gross annual income of the household from all sources in NIS	8603	235,506	246,157	10,148	3,223,913
CAR	1 = own a car; 0 = otherwise	8866	79.68%	40.24%	0	1
CARNUM	Number of cars for owners of at least one car	7064	1.45	0.66	1	5
AGE	Age in years	8866	41.92	12.77	21	67
FEMALE	1 = female; 0 = male	8866	47.61%	49.95%	0	1
FAM	Number of persons in household	8866	3.75	1.96	1	25
SINGLE	1 = single; 0 = otherwise	8866	20.78%	40.57%	0	1
MARRIED	1 = married; 0 = otherwise	8866	69.02%	46.25%	0	1
DIVORCED	1 = divorced; 0 = otherwise	8866	8.61%	28.05%	0	1
WIDOW	1 = widow; 0 = otherwise	8866	1.60%	12.55%	0	1
JEWISH	1 = Jewish; 0 = otherwise	8866	72.10%	44.86%	0	1
ARAB	1 = Arab; 0 = otherwise	8866	24.02%	42.73%	0	1
OTHER_NON_JEWISH	1 = other non-Jewish; 0 = otherwise	8866	3.88%	19.31%	0	1
IMMIGRANT	1 = immigrant; 0 = native Israeli	8866	23.89%	42.64%	0	1
IMM_EUR_AMERICA	1 = immigrant from Europe or America; 0 = otherwise	8866	19.15%	39.35%	0	1
IMM_ASIA_AFRICA	1 = immigrant from Asia or Africa; 0 = otherwise	8866	4.74%	21.24%	0	1
HAS_CHILDREN	1 = Has at least one child; 0 = Otherwise	8866	65.37%	47.58%	0	1
CHILD_NUM	Number of children for households with at least one child	5796	2.47	1.45	1	11

The frequencies of households across ownership of cars are given in the following table:

CAR	Frequency
0	568 (22.83%)
1	1920 (77.17%)
Total	2488 (100.00%)

Notes: The sample includes 8866 observations \times years covering up to two years (2015–2016), and 2488 households, where the age of female (male) members was restricted to 21–62 (21–67) years old. This restriction is based on the retirement age for the workforce, which is 62 years old for female and 67 years old for male. NIS is the local Israeli currency (1 NIS \approx 0.25 US Dollars).

Relative frequencies are given in parentheses.

the standard deviation is 4.48 (BMI). Both the respective 95% and 99% confidence intervals ((25.48, 25.66) and (25.45, 25.69)) imply overweight ($25 \leq BMI < 30$) in the Israeli population. When stratified by gender, the 99% confidence interval for the mean BMI is (24.57, 24.95) for women and (26.16, 26.46) for men. The implication is that for the relevant cohorts ($20 < AGE \leq 62$ for women and $20 < AGE \leq 67$ for men), only Israeli men suffer from overweight.

Fig. 1 displays deciles of BMI stratified by gender in our sample. The BMI is calculated as $\frac{WEIGHT}{HEIGHT^2}$ where WEIGHT is measured in kilograms and HEIGHT is measured in meters. The vertical (horizontal) axis in Fig. 1 measures the BMI (the decile and mean BMI). For 12.79% (15.87%) of the female (male) participants in our representative sample of the Israeli population, $BMI \geq 30$. These frequencies are similar to those in the Netherlands – 13%; and France and Luxemburg – 15%–16%, where the OECD average is 16%. In eight OECD countries, namely, United Kingdom, Estonia, Turkey, Hungary, Latvia, Iceland, Ireland and Malta, $BMI \geq 30$ for at least 20% of the population. (OECD, 2016, p. 4.13 Self-Reported Obesity among Adults above 15 years, 2014 (or latest year); page 99).

Further evidence reveals an alarming increase in the BMI across time. Referring to the United States, in 1990 no state had obesity rate higher than 15%. In 2005 only six US states had obesity rates of below 20% (Menifield et al., 2008). Likewise, in our sample, projected BMI of female (male) respondents with lagged BMI = 25 becomes 25.19 (25.41) in the subsequent year, a rise of $\frac{25.19}{25} = 0.76\%$ ($\frac{25.41}{25} = 1.64\%$) in just one year. For each 1 point BMI increase in 2015, projected BMI in 2016 is expected to rise significantly by 0.865 points for women and by 0.8233 points for men at the 1% significance level in just one year.⁸

Returning to Table 1, the variable GRTOTINC relates to the gross annual income of the household. This variable is measured in NIS, the local Israeli currency, where 1 NIS \approx 0.25 US Dollars. Of the total 8866 observations \times years, 8603 (97%) reported on gross annual income above 10,000 NIS. The average gross annual income above 10,000 NIS is 235,506 NIS. By comparison, the annual average salary in Israel in January 2017 is $9,543 \times 12 = 114,516$ NIS or about 28,629 US Dollars.⁹

Fig. 2 displays the distribution of GRTOTINC above 10,000 NIS and below 1,000,000 NIS. The distribution includes 8526

⁸ The reported outcomes were obtained by regressing BMI on [Lagged(BMI) – 25], so that the constant term becomes the projected BMI in subsequent year for BMI = 25 (for this model design where the constant term becomes the projected value, see, for example, Ramanathan, 2002, pp. 147–148). The regression outcomes for female respondents are: $proj(BMI) = 25.1885 + 0.8650[Lagged(BMI) - 25]$ and for male respondents: $proj(BMI) = 25.4149 + 0.8233[Lagged(BMI) - 25]$. All the coefficients are statistically significant at the 1% significance level.

⁹ See, for example, Social Security website: <https://www.btl.gov.il/Mediniyut/GeneralData/Pages/%D7%A9%D7%9B%D7%A8%20%D7%9E%D7%9E%D7%95%D7%A6%D7%A2.aspx>. accessed at March 28, 2019.

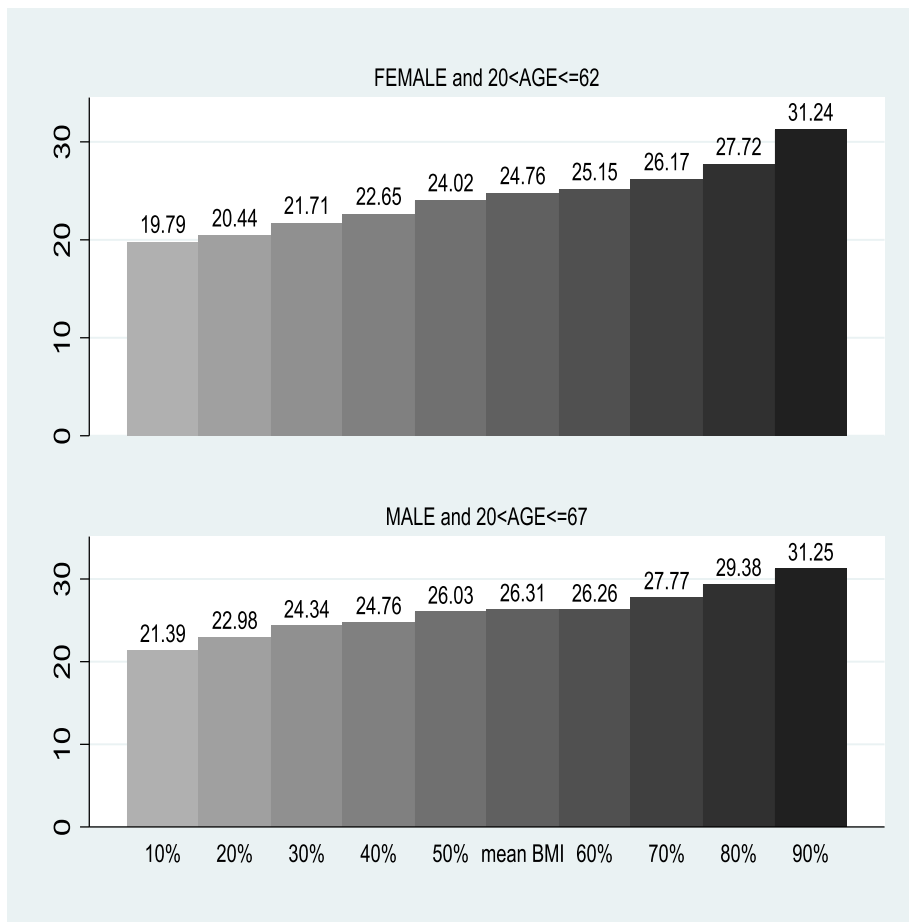


Fig. 1. Deciles of Body Mass Index (BMI) Stratified by Gender.

Notes: The figure displays the distribution of the BMI by deciles stratified by gender and based on a longitudinal survey of the Israeli Central Bureau of Statistics, which covers two years (2015 and 2016). The sample is representative and restricted to female (male) respondents whose age is 21–62 (21–67) years old. The upper limit of age is the retirement age for female and male, respectively. The BMI is calculated as $\frac{WEIGHT}{HEIGHT^2}$, where WEIGHT is measured in kilograms and HEIGHT is measured in meters. The vertical (horizontal) axis measures the BMI (the decile and mean BMI). A widely adopted definition of overweight is a BMI greater than or equal to 25, with obesity defined as BMI ≥ 30 (Qin & Pan, 2016, p. 1293). For 12.79% (15.87%) of the female (male) participants, BMI ≥ 30 .

observations \times years. Consequently, $\frac{8,526}{8,866} = 96.17\%$ of the original sample of observations \times years are included in the distribution. As is evident from the figure, the distribution is clearly skewed to the right. The gross annual income of 99% of the household in this distribution is below 100,000 NIS. The median is 169,464.5 NIS and the mean is 217,653.9 NIS. The skewness is 1.42 and the kurtosis is 5.27. The Sapiro-Wilks test for normality rejects the null hypothesis that the distribution of GRTOTINC is normal (calculated z-value of 16.717).

Referring to the variable of car ownership in Table 1, of the 8866 observations, 79.68% own at least one car (CAR). When stratified by households, of the 2488 households, 1920 households, consisting of 77.17%, own at least one car. According to the 2015 Israeli CBS report (Table 14.- Ownership of Durable Goods in Deciles of Households by Net Income Per Standard Person) 69.7% of the country's 2.413 million households owned a car.¹⁰

Referring to the number of cars per household, namely, our main explanatory variable, the sample mean of cars per household of at least one car is 1.47 and the standard deviation is 0.66 (CARNUM). A formal statistical test rejects the null hypothesis of an average of one car at the 1% significance level (t-value of 61.45 with 7063 degrees of freedom). These outcomes indicate that households that own a car, own on average more than one car.

Fig. 3 displays scatter diagrams of BMI vs. number of cars, and stratified by gender. The problem of heteroscedasticity is evident from these figures: the spread of the body mass becomes smaller with the number of cars. To examine formally the hypothesis of

¹⁰ The difference between the sample and population mean of household car ownership rates (77.17% vs. 69.7%) may be reconciled as follows. Note that our sample is restricted to 20 to 62 year-old female respondents, and 20 to 67-year-old male respondents. When these restrictions are removed, car ownership rates drop from 77.17% to 66.89%.

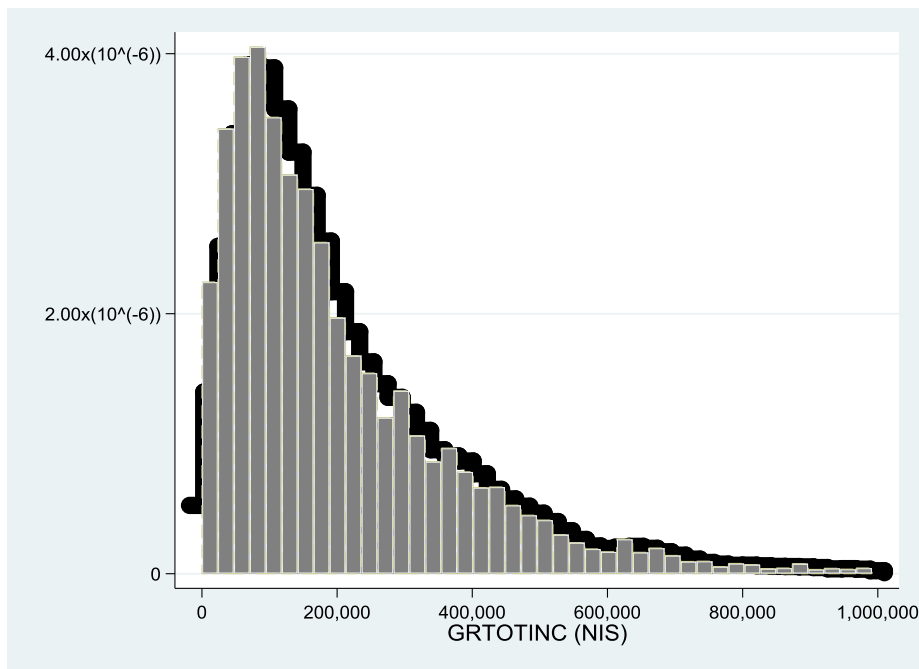


Fig. 2. Distribution of Annual Gross Income per Household Below 1 Million NIS and Above 10,000 NIS.

Notes: Here are selected statistics for that distribution.

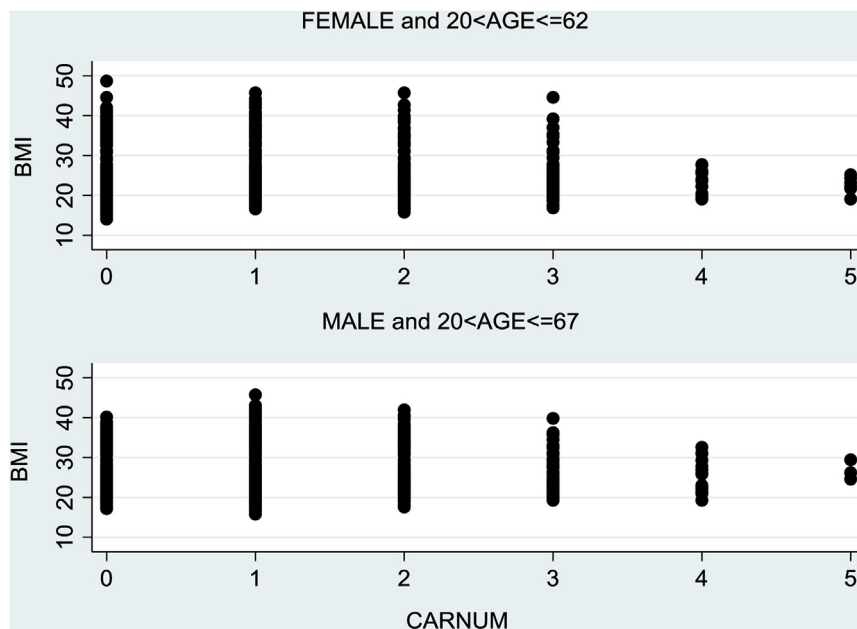


Fig. 3. Scatter Diagram Body Mass Index (BMI) vs. Number of Cars.

Notes: The figure displays scatter diagrams of BMI vs. number of cars, and stratified by gender. To examine formally the hypothesis of heteroscedasticity, we run the White statistical test (e.g. [White, 1980](#); [Green, 2012](#): 322–325; [Johnston & Dinardo, 1997](#), pp. 166–174). Results of this test suggest that heteroscedasticity is supported empirically (calculated chi-squared values of 50.23, and 25.55 compared with the critical chi-squared values with two degrees of freedom of 5.99 for the 1% significance level and 9.21 for the 1% significance level).

heteroscedasticity, we run the White statistical test (e.g. [White, 1980](#); [Greene, 2012](#): 322–325; [Johnston & Dinardo, 1997](#), pp. 166–174). The test is carried out by: 1) regressing BMI on CARNUM and CARNUM_SQ. 2) Generating and squaring the residuals. 3) Regressing the squared residuals on CARNUM and CARNUM_SQ. 4) Calculating the LM test statistics of NR^2 where N is the number of observations and R^2 is the R-squared obtained in the auxiliary regression in step 3. 5) Compare the calculated statistics with critical

Table 2

Pearson correlation matrix for the pooled sample.

	ln(BMI)	GROTOTINC	CARNUM	AGE	HAS_CHILDREN
ln(BMI)	1.000 8866				
GROTOTINC	−0.0591*** 8866	1.000 8866			
CARNUM	−0.0449*** 8866	0.3757*** 8866	1.000 8866		
AGE	0.2924*** 8866	0.0592*** 8866	0.0483*** 8866	1.000 8866	
HAS_CHILDREN	−0.0438*** 8866	0.1112*** 8866	0.1159*** 8866	−0.2195*** 8866	1.000 8866

Notes: *** significantly different from zero correlation at the 1% significance level.

chi-square statistics with two degrees of freedom (5.99 for the 1% significance level and 9.21 for the 1% significance level). Rejection of the null hypothesis supports heteroscedasticity. Results of this test suggest that heteroscedasticity is supported empirically (calculated chi-squared values of 50.23, and 25.55). Consequently, in subsequent sections we employ robust standard errors, which correct heteroscedasticity (e.g., Green, 2012 pages 388–392).

Other explanatory control variables include a series of socio-demographic characteristics: age; family status (single, married, divorced, widowed); religion (Jewish, Arab, other); immigrant status and country of origin (Europe-America and Asia-Africa); whether the individual has at least one child; and the number of children. The average age is 41.92 and the standard deviation is 12.77 (AGE). Of the 8866 observations, 20.78% are single (SINGLE), 69.02% are married (MARRIED), 8.61% are divorced (DIVORCED), and 1.60% are widow (WIDOW). Of the 8866 observations, 72.10% are Jewish (JEWISH), 24.02% are Arab (ARAB), and 3.88% are others (OTHER_NON_JEWISH). 23.89% are immigrants (IMMIGRANTS), where for 19.15% the continent of origin is Europe or America (IMM_EUR_AMERICA), and for the continent of origin is Asia or Africa (IMM_ASIA_AFRICA).

2.3. Pearson correlation matrix

Table 2 reports the Pearson Correlations between the variables ln(BMI), GROTOTINC, CARNUM, AGE and HAS_CHILDREN. All the reported correlations refer to 8866 observationsyears, and are significantly different from zero correlation at the 1% significance level.

The ln(BMI) variable is positively and significantly correlated with AGE (29.24%) and negatively and significantly correlated with GROTOTINC (−5.91%), CARNUM (−4.49%), and HAS_CHILDREN (−4.38%). The implication from the positive correlation between ln(BMI) and AGE is the rise in the BMI with AGE.

The GROTOTINC variable is positively and significantly correlated with CARNUM (37.57%), AGE (5.92%), and HAS_CHILDREN (11.12%). The positive correlation between GROTOTINC and CARNUM indicates that households with more cars are also wealthier. Interestingly, the positive correlation between GROTOTINC and HAS_CHILDREN indicates that compared with households with no children, households with at least one are also wealthier.

The CARNUM variable is positively and significantly correlated with AGE (4.83%) and positively and significantly correlated with HAS_CHILDREN (11.59%). The latter correlation indicates that households with children need more cars. Finally, the AGE variable is negatively and significantly correlated with HAS_CHILDREN (−21.95%), implying a lower probability of having more children with age.

3. Methodology

Consider the following longitudinal model,¹¹ consisting of two structural equations and include the number of cars as a proxy for wealth:

$$\ln(BMI) = \alpha_{0,K} + \alpha_{1,K}GROTOTINC \cdot 10^{-6} + \alpha_{2,K}CARNUM + \alpha_{4,K}AGE + \alpha_{5,K}MARRIED + \alpha_{7,K}DIVORCED + \alpha_{8,K}WIDOW + \alpha_{9,K}ARAB + \alpha_{11,K}OTHER_NON_JEWISH + \alpha_{12,K}IMM_EUR_AMERICA + \alpha_{14,K}IMM_ASIA_AFRICA + \alpha_{16,K}HAS_CHILDREN + HFE \cdot \vec{\delta} + u_{1,K} \quad (1)$$

$$\alpha_{j,K} = \gamma_{j,K} \text{ for } j = 0,1,4,5,7,8,9,11,12,14,16 \quad (1a)$$

$$\alpha_{2,K} = \gamma_{2,K} + \gamma_{3,K}CARNUM + \gamma_{6,K}MARRIED + \gamma_{10,K}ARAB + \gamma_{13,K}IMM_EUR_AMERICA + \gamma_{15,K}ASIA_AFRICA + \gamma_{17,K}HAS_CHILDREN \quad (1b)$$

¹¹ For convenience, we display the variables without the index i for observation and t for time.

where $K = (FEMALE, MALE)$, namely, the models are applied separately to female and male respondents and covers up to two years (2015 and 2016); $\ln(BMI)$ is the natural logarithm of body mass index¹²; $GRTOTINC \cdot 10^{-6}$ is the gross annual income in millions of NIS; $CARNUM$ is the number of cars owned by the household; AGE is the age of each individual in years; $MARRIED$, $DIVORCED$, $WIDOW$ describe family status and the base category of $SINGLE$; $ARAB$, $OTHER_NON_JEWISH$ capture the difference between each religion and the base category of $JEWISH$; $IMM_EUR_AMERICA$ and IMM_ASIA_AFRICA cover the difference among immigrants stratified by the continent of origin and the base category of native Israelis; $HAS_CHILDREN$ distinguishes individuals with at least one child and the base category of individuals without children; $\alpha_{j,K}$ for $j = 0, 1, 4, 5, 7, 8, 9, 11, 12, 14, 16$ and $\gamma_{j,K}$ for $j = 0, 1, 2, \dots, 16, 17$ are parameters, HFE is a matrix of households individual effect dummies, $\vec{\delta}$ is a column vector of the corresponding coefficients, and $u_{i,K}$ is the column vector whose elements are the classical random disturbance terms.

Substituting and rearranging terms yields the following model with interaction variables:

$$\begin{aligned} \ln(BMI) = & \gamma_{0,K} + \gamma_{1,K} GRTOTINC \cdot 10^{-6} + \gamma_{2,K} CARNUM + \gamma_{3,K} CARNUM_SQ + \gamma_{4,K} AGE + \gamma_{5,K} MARRIED + \gamma_{6,K} CARNUM \\ & \cdot MARRIED + \gamma_{7,K} DIVORCED + \gamma_{8,K} WIDOW + \gamma_{9,K} ARAB + \gamma_{10,K} CARNUM \cdot ARAB + \gamma_{11,K} OTHER_NON_JEWISH \\ & + \gamma_{12,K} IMM_EUR_AMERICA + \gamma_{13,K} CARNUM \cdot IMM_EUR_AMERICA + \gamma_{14,K} IMM_ASIA_AFRICA + \gamma_{15,K} CARNUM \\ & \cdot IMM_ASIA_AFRICA + \gamma_{16,K} HAS_CHILDREN + \gamma_{17,K} CARNUM \cdot HAS_CHILDREN + HFE \cdot \vec{\delta} + u_{i,K} \end{aligned} \quad (2)$$

where the random-effect full model contains 17 variables and 18 parameters including the constant term, as well as $CARNUM_SQ$, namely $CARNUM$ raised to the power of two. This enables a non-monotonic variation with the number of cars. The interaction term model, which permits the parameter to change with explanatory variables, is conventional in the literature (e.g., Ramanathan, 2002, pp. 241–242; Greene, 2012, pp. 201–202). The objective is to study the change of the parameter of selected explanatory variables with the number of cars.

This feature of the model may be demonstrated by deriving $\ln(BMI)$ with respect to the number of cars:

$$\begin{aligned} \frac{\partial \ln(BMI)}{\partial CARNUM} = & \gamma_{2,K} + 2\gamma_{3,K} CARNUM + \gamma_{6,K} MARRIED + \gamma_{10,K} ARAB + \gamma_{13,K} IMM_EUR_AMERICA + \gamma_{15,K} IMM_ASIA_AFRICA \\ & + \gamma_{17,K} HAS_CHILDREN \end{aligned} \quad (2a)$$

4. Results

Table 3 displays the regression outcomes obtained from equation (2). Regression results are based on a panel dataset, which covers two years (2015 and 2016). The pooled sample includes 8866 observations \times years (4221 females \times years – columns (1)–(2) and 4645 males \times years – columns (3)–(4)) who are members of 2057 and 2179 households. The dependent variable is $\ln(BMI)$, the natural logarithm of the variable BMI (Body Mass Index), which is calculated as $\frac{WEIGHT}{HEIGHT^2}$, where weight is measured in kilograms and height is measured in meters. Based on the results of the F-test according to which Household Fixed-Effect (HFE) coef. $(\vec{\delta}) \neq \vec{0}$, we run a random-effect panel regression, namely, we include the individuals fixed-effect dummies for heterogeneity (a further discussion on panel data analysis is given in Johnston & Dinardo, 1997, pp. 390–395). The VIF is an average measure for collinearity, where a measure of above 10 implies high collinearity. Robust standard errors are given in parentheses, * significant at the 10% significance level. ** significant at the 5% significance level, *** significant at the 1% significance level.

According to columns (1)–(2) in Table 3, projected BMI of female respondents is expected to rise significantly by 0.48%–0.51% with each additional year of age, and by 2.29% with a shift from a family status of single to married. Both estimates are statistically significant at the 1% significance level. Compared with Jewish female respondents, Arab female respondents with no car exhibit projected BMI, which is higher significantly by 6.85%–7.14% (significant at the 1% significance level). Compared with native Jewish Israeli female respondents, Jewish female immigrants with no car whose country of birth is Europe and America exhibit projected BMI, which is higher significantly by 2.75%–3.87% (significant at the 1% significance level). Compared with women without children and cars, projected BMI of women with at least one child and without a car drops significantly by 2.25%–2.41% (significant at the 5% significance level).

Referring to car ownership rates, and columns (1)–(2) in Table 3, for the baseline Jewish female respondents, projected BMI decreases significantly (at the 1% significance level) by 3.37%–3.68% for each additional car, ($CARNUM = 0, 1, 2, 3, 4, 5$). For Arab female respondents, projected BMI drop is attenuated significantly by 1.37%–1.56% for each additional car (significant at the 10%–5% levels). For female immigrants whose continent of birth is Asia or Africa, projected BMI decrease is intensified significantly by 3.38%–4.21% for each additional car (significant at the 5% significance level). Finally, compared with women with at least one child but who don't own a car, projected BMI of women with cars rises significantly by 2.18%–2.23% for each additional car (significant at the 1% significance level).

Columns (3)–(4) in Table 3 refer to the group of adult men below the retirement age. According to the results, projected BMI of male respondents is expected to drop significantly by 1.71%–2.02% for additional annual gross income of 1 Million NIS (significant at

¹² An inherent feature of this semi-logarithmic model is the coefficients of the explanatory variables reflecting percent for each unit of change in the independent variable (e.g., Ramanathan, 2002, pp. 234–236).

Table 3

Regression analysis: Car ownership stratified by gender.

Variables	(1) Full ln(BMI)	(2) Step-wise ln(BMI)	(3) Full ln(BMI)	(4) Step-wise ln(BMI)
Constant	2.9873*** (0.0184)	2.9973*** (0.0174)	3.0991*** (0.0154)	3.1219*** (0.0121)
GRTOTINC× 10 ⁻⁶	−0.0034 (0.0097)	−	−0.0202*** (0.0073)	−0.0171** (0.0072)
CARNUM	−0.0337*** (0.0098)	−0.0368*** (0.0060)	0.0199** (0.0085)	−
CARNUM_SQ	0.0010 (0.0024)	−	−0.0028 (0.0021)	−
AGE	0.0051*** (0.0004)	0.0048*** (0.0003)	0.0025*** (0.0003)	0.0024*** (0.0003)
MARRIED	0.0198 (0.0143)	0.0229*** (0.0081)	0.0568*** (0.0123)	0.0429*** (0.0069)
MARRIED×CARNUM	−0.0061 (0.0080)	−	−0.0119 (0.0074)	−
DIVORCED	−0.0262 (0.0164)	−	0.0069 (0.0110)	−
WIDOW	−0.0197 (0.0294)	−	0.0297 (0.0334)	−
ARAB	0.0714*** (0.0122)	0.0685*** (0.0116)	0.0301*** (0.0113)	0.0273*** (0.0078)
ARAB×CARNUM	0.0137* (0.0080)	0.0156** (0.0075)	−0.0057 (0.0076)	−
OTHER_NON_JEWISH	0.0063 (0.0131)	−	−0.0078 (0.0127)	−
IMM_EUR_AMERICA	0.0387*** (0.0150)	0.0275*** (0.0100)	0.0214 (0.0141)	0.0211** (0.0107)
IMM_EUR_AMERICA×CARNUM	−0.0089 (0.0094)	−	−0.0010 (0.0087)	−
IMM_ASIA_AFRICA	0.0127 (0.0279)	−	−0.0271 (0.0182)	−
IMM_ASIA_AFRICA×CARNUM	−0.0421** (0.0191)	−0.0338** (0.0141)	0.0033 (0.0118)	−
HAS_CHILDREN	−0.0225** (0.0108)	−0.0241** (0.0106)	0.0068 (0.0095)	−
HAS_CHILDREN×CARNUM	0.0223*** (0.0071)	0.0218*** (0.0068)	−0.0026 (0.0058)	−
Gender and Cohort	FEMALE20-62	FEMALE20-62	MALE20-67	MALE20-67
Observations	4221	4221	4645	4645
R-squared	0.168	0.168	0.0894	0.0875
Number of hhid	2057	2057	2179	2179
chi-squared-statistic	396.4***	389.3***	196***	180.1***
F statistics that all HFE coef. ($\vec{\delta}$)= $\vec{0}$	6.80***	6.78***	7.08***	7.11***
VIF	3.53	2.67	3.84	2.18

Notes: The random-effect regression outcomes are based on a panel dataset, which covers two years (2015 and 2016). The pooled sample includes 8866 observations× years (4221 females×years – columns (1)–(2) and 4645 males×years – columns (3)–(4)) who are members of 2057 and 2179 households. The dependent variable is ln(BMI), the natural logarithm of the variable BMI (Body Mass Index). The VIF is an average measure for collinearity, where a measure of above 10 implies high collinearity. Robust standard errors are given in parentheses. * significant at the 10% significance level. ** significant at the 5% significance level. *** significant at the 1% significance level.

the 5%–1% levels). Interestingly, and in contrast to the female respondents, male respondents exhibit a significant 1.99% rise in projected BMI (significant at the 5% significance level) with each additional car ($CARNUM = 0,1,2,3,4,5$). Like the women respondents, projected BMI of male respondents is expected to rise significantly by 0.24%–0.25% with each additional year of age, and by 4.29%–5.68% with a shift from a family status of single to married. Both estimates are statistically significant at the 1% significance level. Compared with Jewish male respondents, Arab male respondents exhibit projected BMI, which is higher significantly by 2.73%–3.01% (significant at the 1% significance level). Compared with native Israeli Jewish male respondents, Jewish male immigrants whose country of origin is Europe and America, exhibit projected BMI, which is higher significantly by 2.11% (significant at the 5% significance level).

Figs. 4–8 simulate projected ln(BMI) vs. Number of Cars for adult married females and males below retirement age. Projected values were obtained from a random-effect panel regressions that include all the interaction terms between CARNUM, FEMALE, MARRIED, AGE and GRTOTINC. All the figures provide a direct comparison between projected BMI of females and males, and give the 95% confidence interval of each projection. The upper (lower) figures exhibit the projection for each gender separately (the projected difference across gender). Fig. 4 refers to the pooled sample of 4366 adult Jewish Israeli married females (males) whose cohort is 21–62 (21–67) year-old. The upper bound of 62 (67) year old is the retirement age for female (male). As is evident from the

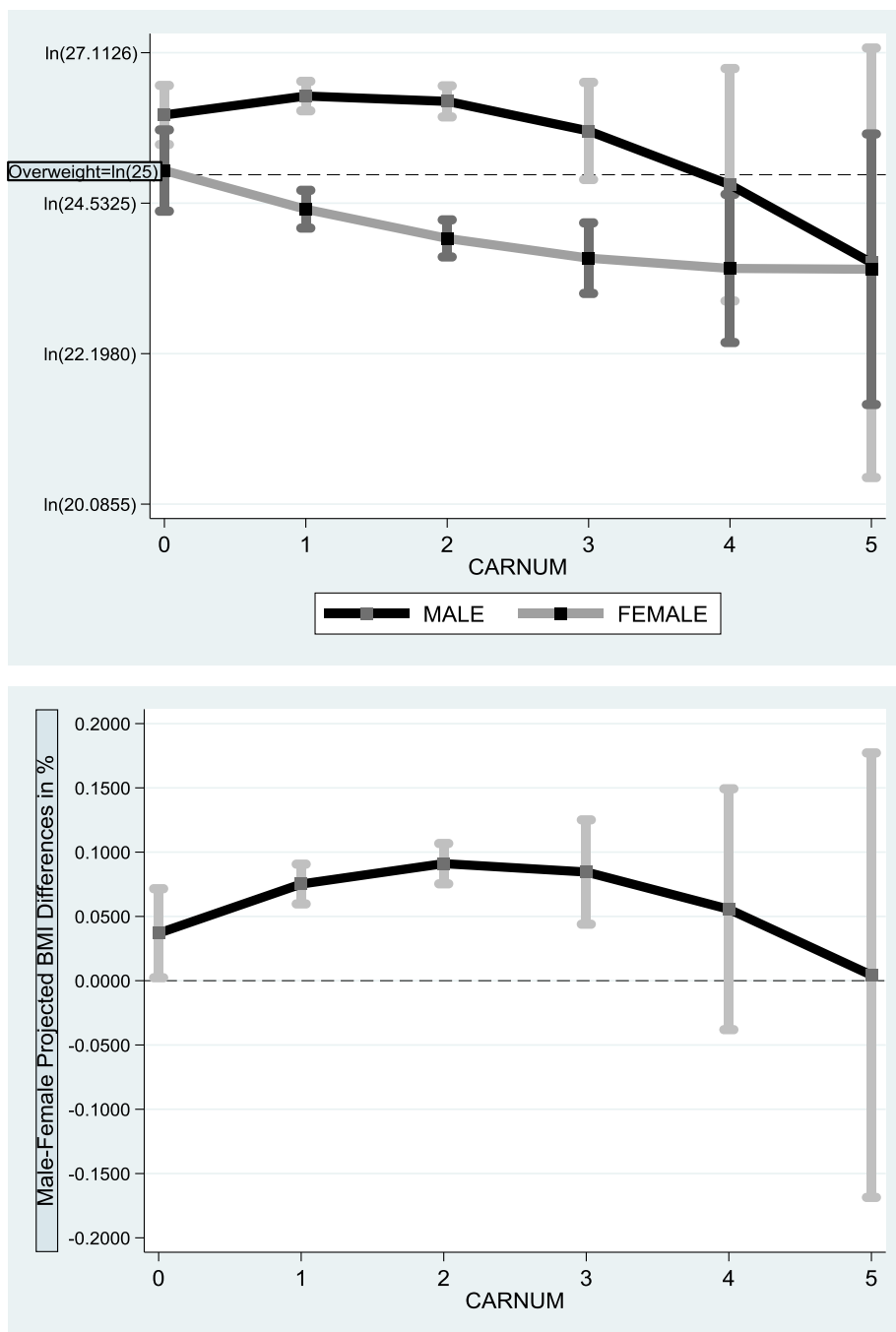


Fig. 4. Projected Body Mass Index (BMI) vs. Number of Cars for the Pooled Sample of Married Jewish Israelis Stratified by Gender

Notes: The figure refers to the pooled sample of 4366 adult Jewish Israeli married females (males) whose cohort is 21–62 (21–67) year-old. The upper bound of 62 (67) year old is the retirement age for females (males). Projected values of $\ln(\text{BMI})$ were obtained from a random-effect model that includes all the interaction terms between CARNUM, FEMALE, MARRIED, AGE and GRTOTINC. For each projection, the figure displays the 95% confidence interval.

upper figure, for both genders, the 95% spread around the projection increases with the number of cars. While men suffer from overweight, as they are above the cutoff line of $\text{BMI} = 25$, women are below the overweight cutoff line. The pace of projected BMI decline with the number of cars is steeper for married women. This result is consistent with the regression outcomes, according to which for the female respondents, projected BMI drops significantly with the number of cars, while for the male respondents projected BMI drops significantly with gross annual income, but the magnitude of the drop is much more gradual. Finally, the lower figure shows that for the pooled sample, up to three cars, namely, for $\text{CARNUM} = 0, 1, 2, 3$, gender differences of projected BMI are

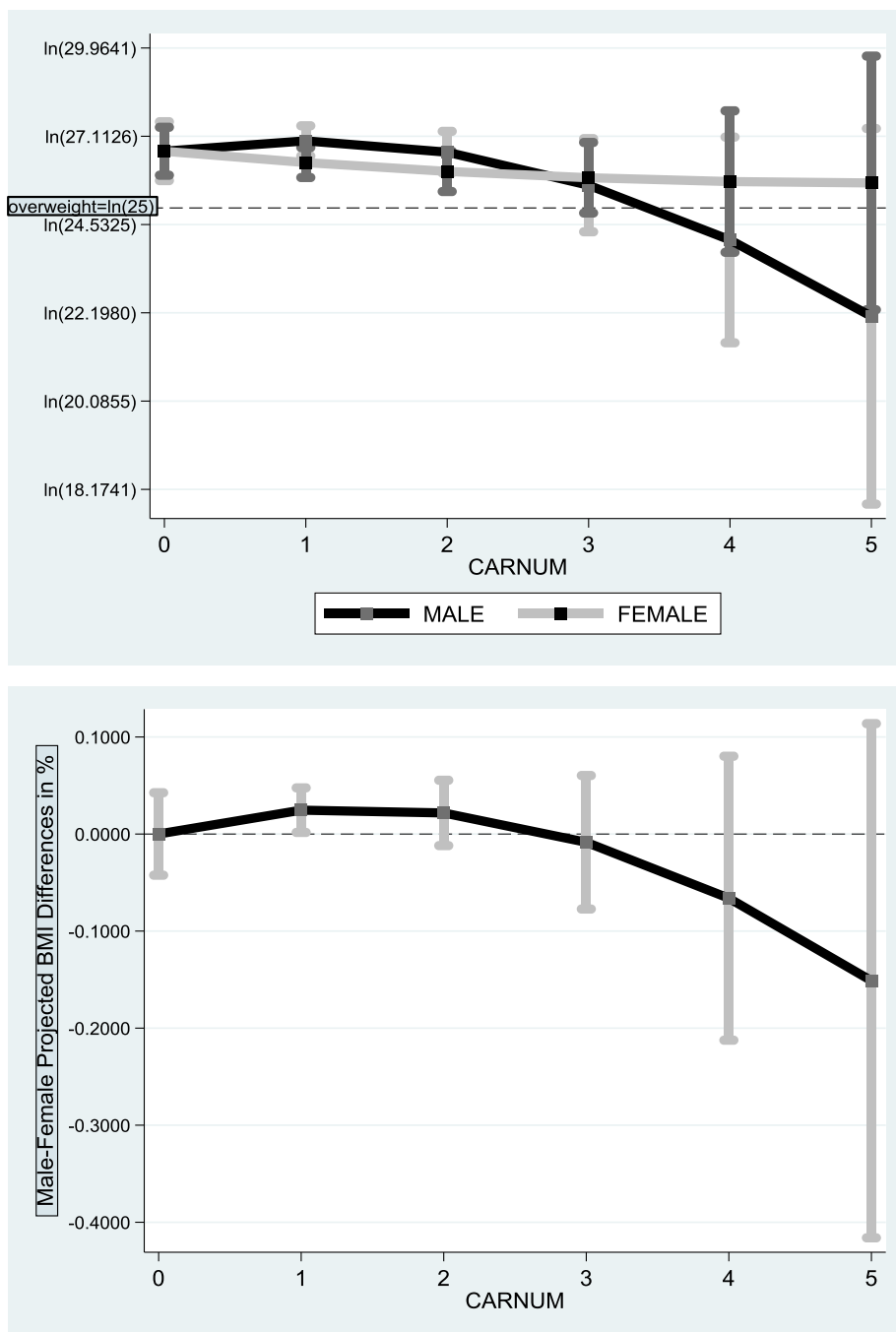


Fig. 5. Projected Body Mass Index (BMI) vs. Number of Cars for Married Arab Females and Males.

Notes: The figure refers to the pooled sample of 1551 adult Arab Israeli married females (males) whose cohort is 21–62 (21–67) year-old. The upper bound of 62 (67) year old is the retirement age for females (males). Projected values of $\ln(\text{BMI})$ were obtained from a random-effect model that includes all the interaction terms between CARNUM, FEMALE, MARRIED, AGE and GRTOTINC. For each projection, the figure displays the 95% confidence interval.

statistically significant.

Fig. 5 refers to the pooled sample of 1551 adult Arab Israeli married females (males) whose cohort is 21–62 (21–67) year-old. Interestingly, and unlike the pooled sample of married Jewish Israelis, for CARNUM = 0,1,2,3, both genders suffer from overweight, as they are above the cutoff line of BMI = 25. Moreover, based on the lower graph, and in contrast to the Jewish Israeli respondents, no significant projected BMI gender differences is found among the Arab Israeli respondents.

Figs. 6–8 stratify the pooled sample of 4366 Jewish Israeli respondents, described in Fig. 4, to three separate groups: 1) 3105

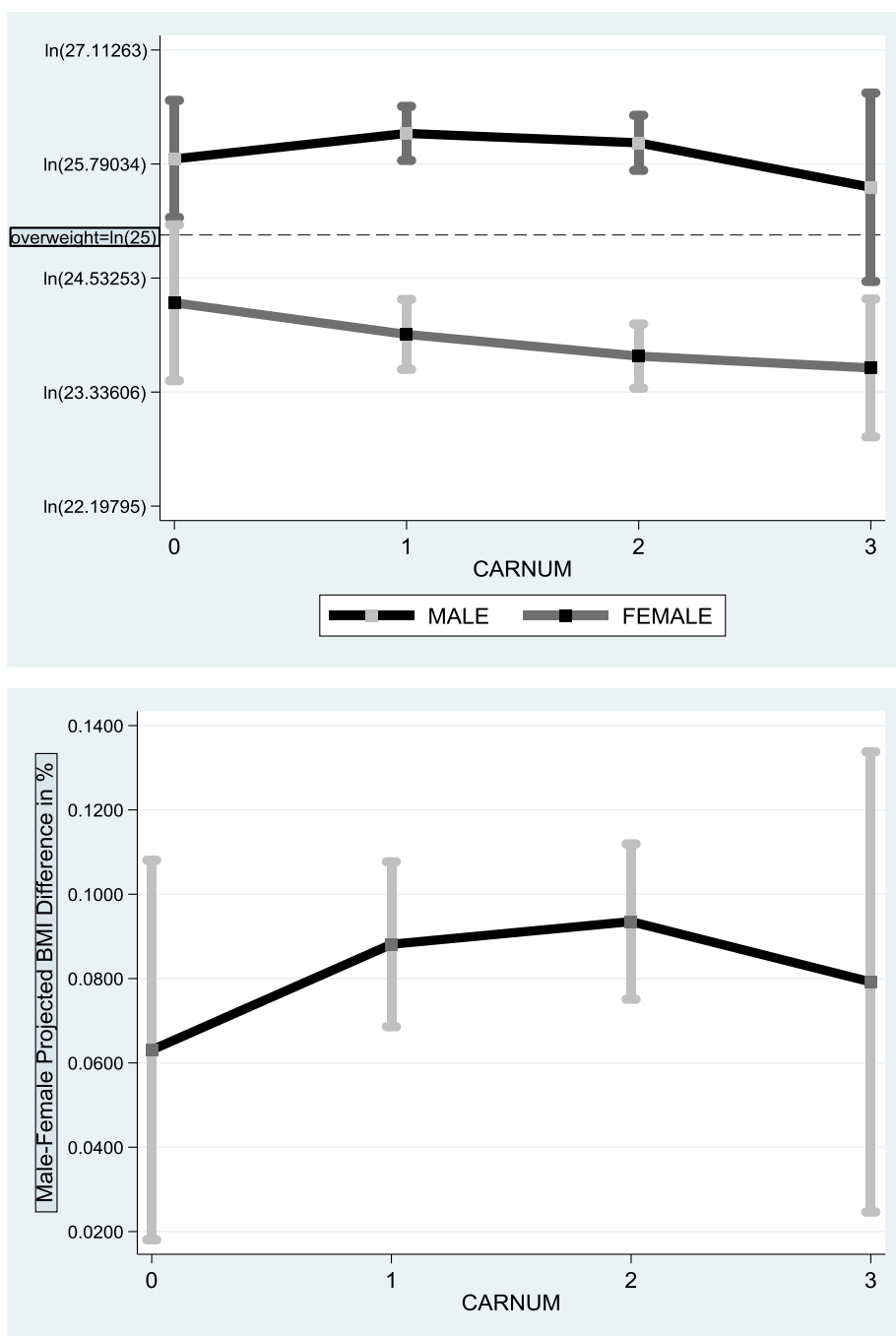


Fig. 6. Projected Body Mass Index (BMI) vs. Number of Cars for Married Jewish Native Israelis, Stratified by Gender.

Notes: The figure refers to 3105 adult Jewish native Israeli married females (males) whose cohort is 21–62 (21–67) year-old. The upper bound of 62 (67) year old is the retirement age for females (males). Projected values of $\ln(\text{BMI})$ were obtained from a random-effect model that includes all the interaction terms between CARNUM, FEMALE, MARRIED, AGE and GRTOTINC. For each projection, the figure displays the 95% confidence interval.

native Jewish Israelis; 2) 983 Jewish immigrants from Europe and America; 3) 278 Jewish immigrants from Asia and Africa. Results show that gender division above and below the cutoff line of $\text{BMI} = 25$ is preserved among the native Israeli Jewish respondents, and for CARNUM = 0,1,2,3, male-female BMI differences are statistically significant. However, for both samples of immigrants, no significant projected BMI gender differences are found with respect to the cutoff line of overweight. For the European-American immigrants, where CARNUM = 0,1, both genders are above the cutoff line of overweight, namely $\text{BMI} = 25$. For CARNUM = 1,2,3, male-female projected BMI differences are statistically significant. For the Asian-African immigrants, on the one hand the projected

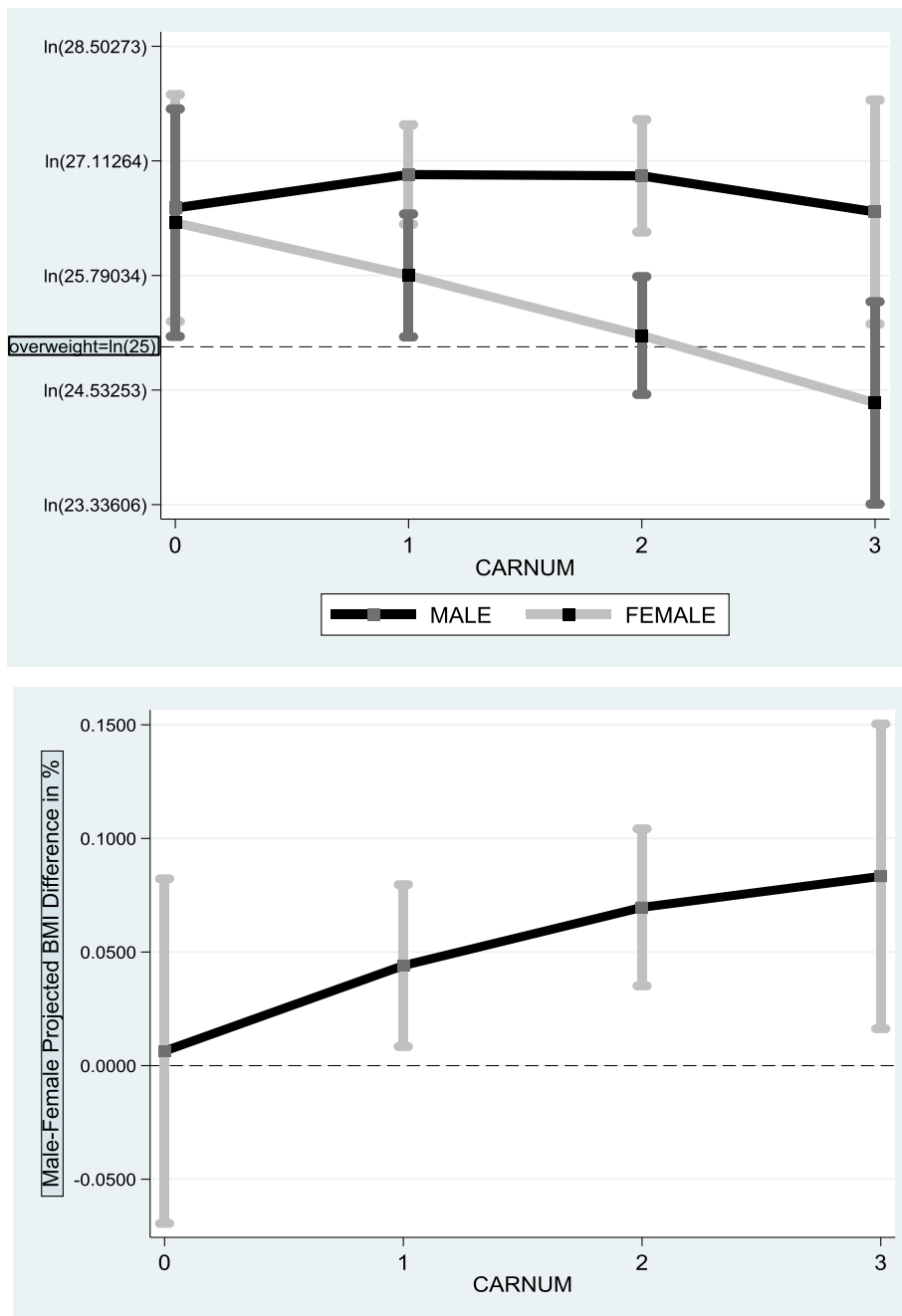


Fig. 7. Projected Body Mass Index (BMI) vs. Number of Cars for Married Jewish Immigrant from American-European Countries Stratified by Gender. **Notes:** The figure refers to 983 adult Jewish Israeli married females (males) who immigrated from American-European countries, and whose cohort is 21–62 (21–67) year-old. The upper bound of 62 (67) year old is the retirement age for females (males). Projected values of ln(BMI) were obtained from a random-effect model that includes all the interaction terms between CARNUM, FEMALE, MARRIED, AGE and GRTOTINC. For each projection, the figure displays the 95% confidence interval.

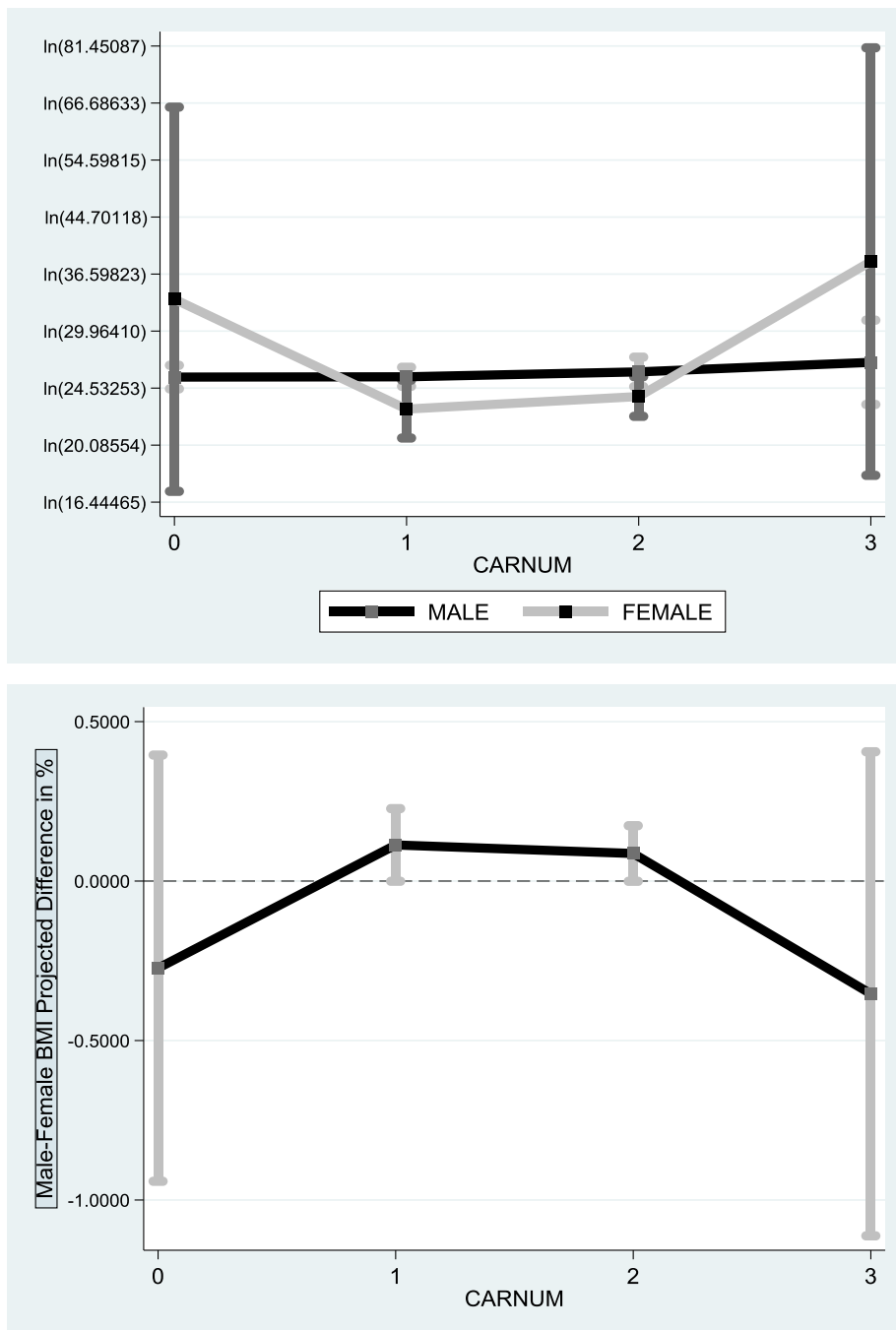


Fig. 8. Projected Body Mass Index (BMI) vs. Number of Cars for Married Jewish Immigrant from Asian-African Countries Stratified by Gender.
Notes: The figure refers to 278 adult Jewish Israeli married females (males) who immigrated from Asian-African countries, and whose cohort is 21–62 (21–67) year-old. The upper bound of 62 (67) year old is the retirement age for females (males). Projected values of $\ln(\text{BMI})$ were obtained from a random-effect model that includes all the interaction terms between CARNUM, FEMALE, MARRIED, AGE and GRTOTINC. For each projection, the figure displays the 95% confidence interval.

BMI of married females with no car or three cars is higher than that of married males. On the other hand, the spread around the projection is particularly high for married females.

5. Summary and conclusions

The current study seeks to examine the relationship between the BMI and car ownership rates based on a new longitudinal

representative survey of the Israeli population, which covers 2015–2016.¹³ We examine the BMI of respondents after the 2–3 years of compulsory military service with the potential to receive a driving license. Consequently, the sample was restricted to above 20 year-old adult respondents and below the retirement age of 62 for female respondents and 67 for male respondents.

Intuitively, a higher car ownership level is expected to reduce the tendency to participate in utilitarian non-exercise physical activities such as walking to work and biking to do errands (Mettner, 2006). Consequently, availability of more cars is expected to raise projected BMI. A more salient feature of increased car ownership rates, however, is being a proxy for higher level of wealth. Following Shah et al., 2012, if the number of owned cars is a proxy for wealth, projected BMI is expected to rise with lower car ownership rates, given that scarcity change the allocation of attention to urgent survival assignments, while neglecting other assignments, such as consume healthier and more expensive food products and engagement in leisure-time physical exercise.

Results indicate that for most sample groups of females, namely, native Jewish Israelis, and Jewish immigrants from Asia-Africa, the wealth effect, which drives projected BMI downward with more cars, dominates. For all the male groups, the force of reduction of participation in utilitarian non-exercise physical activities with higher car ownership rates, dominates.

Additional findings suggest that compared with native Jewish Israeli female respondents, for native Arab female respondents, the projected BMI drop is attenuated significantly with each additional car owned. In that context, Prioreschi et al. (2017) and Arbel, Fialkoff, et al. (2019) and Arbel, Kerner, et al. (2019) discussed the impact of body image and cultural differences on obesity and low-weight-disorder, respectively.¹⁴ Prioreschi et al. (2017) discuss the traditional desirability of higher BMIs in African rural populations vs. the western preference for a normal weight silhouette among women.¹⁵ In line with our findings, it seems that while the body image of native Israeli females may be more influenced by western preferences, the same image of native Arab Israeli females may be more influenced by traditional preferences. This interpretation is strengthened by comparing married females to married males stratified by ethnic groups. While native Jewish Israeli married men are consistently above the cutoff line of overweight (BMI = 25), native Jewish Israeli married women are consistently below this cutoff line. This departure does not exist among the sample of Arab respondents, and Jewish immigrants from American-European and Asian African countries.¹⁶

Finally, compared to women with at least one child but who don't own a car, projected BMI of women with cars rises significantly for each additional car.¹⁷ In contrast to the female respondents, on the one hand, male respondents exhibit a significant rise in projected BMI with each additional car. On the other hand, for the male respondents, projected BMI drops significantly with gross annual income (in line with Zagorsky, 2005), but, compared to women, the magnitude of the drop is much more gradual.

The outcomes of our study may have an interesting public policy implication. They enable the identification of population groups for whom poverty alleviating programs may have the additional benefit of being effective obesity-reducing policies. (Au & Johnston, 2015). According to the results, such policies are anticipated to have this side-effect among the population of Jewish females. Moreover, our findings may be of assistance to public policy planners in the fields of transportation and health. As our study demonstrates, future planning in these fields should account for the relationship between body fat and car ownership rates.

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¹³ It follows from most of the literature on urban sprawl, that obesity may be explained by car ownership, but not vice versa. On the other hand, Eid et al., 2008 found no relationship between obesity and urban sprawl.

¹⁴ Referring to low-weight disorder and anorexia, Arbel, Fialkoff, et al. (2019) and Arbel, Kerner, et al. (2019) demonstrated that: “Interestingly, for female cohort of 10–20 years, projected probability to suffer from BMI ≤ 18 rises significantly from 4.4157% to 16.6627% with reported good health conditions. This outcome might be interpreted as self-denial of young female respondents regarding their realistic health conditions, which is closer to the definition of anorexia nervosa.” (Introduction, page 3, first paragraph).

¹⁵ Referring to rural and urban South Africa, Prioreschi et al. (2017) states in the discussion section that: “This suggests that although westernisation may have influenced body image satisfaction and eating attitudes in young South African women towards a preference for a normal weight silhouette, traditional desirability of higher BMIs in African populations continue to have greater influence over rural compared to urban perceptions.” (page 10, end of first paragraph).

¹⁶ It should be noted in this context, that a large portion of the immigrants from European-American countries came from the European republics of Former-Soviet Union, namely, Russia, Ukraine, Lithuania and Latvia (e.g., Arbel, Fialkoff, et al. (2019) and Arbel, Kerner, et al. (2019)). Consequently, prior to immigration, they were less exposed to the Western culture.

¹⁷ For a comparison of the desirable housing choice in terms of projected BMI between married couples with and without children, see, for example, Arbel et al. (2018).

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