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Dietary transition and its relationship with socio-economic status and peri-urban obesity in India

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Abstract

In 2015-16, India was the seventh-largest economy in the world and had more than 200 million people at risk for obesity. Overconsumption of calories from processed foods, an outcome of a country's dietary transition, is known to be an important mechanism that drives risks for obesity. Testing the relationship between processed foods, socio-economic status and obesity has not been possible thus far due to the limited availability of relevant micro-level data. In this paper, we use novel cross-sectional data from a primary socio-economic survey conducted in the rural-urban interface of Bangalore, a mega-city in India, to explore the role of dietary transition in obesity. We show that calories from semi- and ultra-processed foods are positively associated with the prevalence of obesity (Body Mass Index, BMI, ≥25) among women. Households in the lower-income group are at higher risk of obesity due to excess consumption of calories from semi-processed foods while ultra-processed foods are associated with obesity among higher income groups. We also find that excess consumption of semi-processed food calories is strongly associated with an increase in the prevalence of obesity among women who meet their recommended dietary allowance for calories. This suggests that there is a threshold effect before which consumption of calories from processed foods may improve BMI. Furthermore, in line with the literature, we show that labor-intensive physical activities seem to alleviate the effect of calories on obesity. The strength of the association between semi-processed foods and obesity reduces with occupations association with greater physical activity. Our study highlights how diet-related transitions during economic growth and urbanization impact different economic groups & the dual burden of malnutrition. Our results call for strategic interventions, that are focused on reducing obesity in India, to work on moderating the consumption of semi-processed foods among peri-urban households.

Keywords: Obesity, dietary transition, structural transformation, rural-urban interface, urbanization, India.

1. Introduction

Transition in the food consumption patterns towards energy-dense, fatty, salty foods, and sweetened beverages is one of the widely attributed factors for the shift in the nutritional problems from undernutrition to overnutrition, especially in low- and middle-income countries (LMICs) (Popkin et al., 2012; Popkin, 2009, 2001; Shetty, 2002). Transformations in the global food systems from fresh markets to modern retail chains have increased the ease of access to processed and packaged foods and beverages (Pingali, 2007; Popkin, 2017, 2014; Reardon et al., 2003; Zhou et al., 2015). Furthermore, rising off-farm wages have increased the opportunity cost of preparing food at home leading to higher consumption of processed foods and frequent dining out practices (Kennedy and Reardon, 1994; Regmi and Dyck, 2001). Processed foods are the outcomes of different levels of industrial processing. Many industrial production processes make them highly palatable and less satiating, which eventually leads to their overconsumption (Fardet, 2016; Monteiro et al., 2013). Combined with the reduction in physical activity due to the changing work-effort during structural transformation (ST),[1] excess calories from overconsumption increases body fat and hence the body mass index (BMI) (Hill et al., 2012). This increase in body weight often leads to greater obesity and incidence of non-communicable diseases (NCDs) in otherwise nutrition insecure populations (Ford et al., 2017; Popkin et al., 2012; Popkin, 2006).

In India, there has been a rapid increase in the prevalence of obesity in the last decade (NFHS-5, 2019-20). Aiyar et al. (2021) show that much of this increase can be attributed to the spillover effect of ST from the nearby urban centers. Dang et al. (2019) find that changing work effort due to occupation transitions towards less physically demanding activities is correlated with obesity. However, due to the lack of detailed dietary data, these authors also acknowledge that they cannot explore the role of dietary transition in the prevalence of obesity. Other studies such as Meenakshi (2016), Subramanian et al. (2009), and Subramanian et al. (2011) show that the income-obesity gradient has been tilting away from the higher socio-economic status group but, they too, do not explore the role played by diets.

In this paper, we estimate the association between processed food consumption and obesity in fast-growing peri-urban areas. The dietary patterns of urban people are distinctly different from their rural counterparts especially in the consumption of processed foods (Bren d'Amour et al., 2020; Cockx et

[1] ST reallocates the workforce and economic output share from labor-intensive (e.g. agriculture) to capital-intensive (e.g. industry and service) activities (Herrendorf et al. 2014). Such a change in occupational patterns reduces the energy expended in work (Monda et al. 2008). Along with these changes in work-effort in the labor force, ST comes to be associated with greater urbanization and greater dietary diversity (Rahman and Mishra 2020). The latter is also associated with an increase in access to processed food items and an increase in risk for obesity (Pingali and Khwaja 2004; Popkin 2001; Popkin et al. 2012; Shetty 2013).

al., 2018; Popkin, 2001). In India, fast-paced urbanization, improved infrastructure, and the emergence of small towns have blurred the boundaries between rural and urban areas, leading to the creation of complex rural-urban interfaces (Denis et al., 2012; Pingali et al., 2019). Facilitated by access to economic opportunities and a higher opportunity cost of time spent on cooking food at home, there is a growing demand for processed foods among urban consumers (Bairagi et al., 2020; Drewnowski and Popkin, 1997; Rao et al., 2006). The diverse food markets in urban areas cater to such increased demand (Demmler et al., 2018; Reardon et al., 2003). Thus, analyzing the peri-urban experiences provides an opportunity to measure how ST in these peri-urban areas affects obesity through the dietary transition to greater consumption of processed foods. To this end, we utilize a unique cross-sectional primary survey that collected socio-economic, diet, and nutrition-related information of women living in the rural-urban interface of the mega-city of Bangalore (India). Using the NOVA classification system (Monteiro, 2009), we model how different levels of industrial processing of foods consumed affect the prevalence of obesity in the rural-urban interface.

We make three contributions to the literature. First, accounting for different levels of food processing is important to understand the diet correlates of obesity. Literature, mainly from high-income countries, shows that the excess consumption of ultra-processed foods such as sweetened beverages, ready-to-eat meals, and fast-foods increases obesity (Asfaw, 2011; Monteiro et al., 2018; Poti et al., 2017). Studies for LMICs show that increased intake of calorie sweeteners, edible oil, and animal food is associated with obesity prevalence (Misra et al., 2011; Popkin et al., 2012; Popkin, 2009; Popkin and Gordon-Larsen, 2004; Shetty, 2002). In India too, the consumption of ultra-processed foods such as sweetened beverages and processed snacks is on the rise. In our study, we use the NOVA classification to disentangle the effects of calories consumed from semi-processed foods as opposed to ultra-processed foods on obesity. We show that consumption of semi-processed foods matters more than ultra-processed foods for obesity prevalence, especially among lower-income groups. At higher income levels, the relationship between ultra-processed food and obesity becomes evident. This suggests that obesity growth in peri-urban areas, which are in the middle of their ST, first becomes linked with the consumption of semi-processed foods. Hence, identifying household drivers for the consumption of these semi-processed foods may provide key clues for preventing the obesity epidemic from reaching lower-income groups in LMICs. We provide some exploratory evidence that ration card holders, who procure subsidized semi-processed foods, are at greater risk from this dietary relationship with obesity. This suggests that there is a need for the reform of how food is distributed through the urban public distribution system (PDS).

Second, many countries provide recommended dietary allowance (RDA) guidelines for individuals to lead a healthy life. Most countries do not account for the role of processed foods in contributing calories to meet these RDAs.[2] For example, if an individual's calorie consumption is lower than his/her RDA, consumption of processed calories could result in weight gain. But this would reduce extreme thinness (BMI<18.5) without affecting the risks for obesity. On the other extreme, for an individual consuming more calories than his/her RDA, overconsumption of processed calories will increase the propensity for obesity. Thus, when studying the role of processed foods, we propose that it is important to distinguish obesity risks based on an individual's baseline ability to meet their specific RDA. We provide some evidence that the effect of processed food calories on obesity is stronger for individuals who consume more calories than their RDA. This indicates that there is a threshold effect in the relationship between processed food consumption and obesity during the ST process which may also be driven by overconsumption.

Finally, it is well known that more physical activity is crucial to reduce the risk of obesity caused by excess calorie consumption (Dang et al., 2019; Monda et al., 2008; Popkin, 2009). We add supporting evidence that the effects of excess consumption of semi-processed foods on obesity prevalence can be somewhat alleviated by greater physical activity. Obesity in women engaged in relatively labor-intensive physical activities exhibits a weaker relationship with the consumption of semi-processed food.

The rest of the paper is structured as follows. We discuss the recent trends in the diet transition and obesity in India in the section. 2. Then, in section 3, we discuss our study area and sampling technique, and describe the data and elaborate on the sample characteristics. Section 4 explains the empirical method employed and section 5 discusses the results. Lastly, we summarize our findings and draw conclusions in section 6.

2.Background

2.1. Changing diets and the role of processed foods in India

Pingali and Khwaja (2004) identify two distinct stages in dietary transition associated with ST in India. The first stage marks the income-induced shift from the consumption of a few traditional cereals such as rice and wheat towards a diversified diet, leading to improved diet quality. In the second stage, the influence of urbanization and globalization results in the excess consumption of sugar, oil, sweetened beverages, fast and convenient foods. Excess consumption of such food items, as discussed before, is associated with an increase in the prevalence of obesity.

Studies on urban diets in India have identified changing dietary patterns towards processed foods. Daniel et al. (2011) find that dietary patterns in two large cities in India, Mumbai (West India) and Trivandrum (South India), are characterized by excess consumption of fried snacks and sweets. Satija

[2] There are three exceptions - Brazil (Brazilian Ministry of Health 2015); Ecuador (Ministerio de Salud Publica del Ecuador 2018); Peru (Ministerio de Salud del Perú 2018); Uruguay (Ministerio de Salud del Uruguay 2016).

et al. (2015) show that two of the three dietary patterns among factory workers in India are associated with a higher intake of snacks. Rathi et al. (2017) find that during a 24-hour dietary recall, at least half of adolescents living in a city in India—Kolkata—consume three or more servings of energy-dense snacks and beverages. Using large longitudinal data on purchased consumer goods, Law et al. (2019) find an increasing trend in the purchase of sweet and salty snacks, edible oils, and other processed foods among urban households. Among these dietary patterns, the ones that are rich in sugar, salt, oil, and animal food are found to be positively associated with the incidence of obesity (Daniel et al., 2011; Green et al., 2016; Satija et al., 2015).

However, it is not clear from these studies whether obesity results from the excess consumption of semi-processed foods like sugar, salt, oil, and animal food, or whether it is caused by the excess consumption of ultra-processed foods. Why should this matter? First, semi-processed foods are likely to be consumed in greater quantity in a diet at lower income levels since they may be more affordable. In India sugar is made available at a relatively stable and low price by the PDS while sweetened beverages are available through the market. Thus, among lower-income groups, increased income associated with urban growth may enable individuals to purchase and consume more semi-processed foods such as sugar (than ultra-processed sweetened beverages). Hence, even though ultra-processed foods may be more calorie-dense and satiating than semi-processed foods, if semi-processed foods account for a larger share of an individual's consumption, they will correspondingly make a larger contribution to his/her risk of obesity. Second, there may be a high opportunity cost of time associated with cooking among higher-income groups. Hence, they may prefer to consume ultra-processed foods to save time. At lower or moderate-income levels, however, this opportunity cost of time may not be as high. Thus, individuals in the lower-income group may choose to consume more semi-processed foods relative to ultra-processed foods. This could also explain why the obesity-enhancing effects of semi-processed foods may be stronger than the effects of ultra-processed foods at lower-income levels. In this paper, we account for such differences in the level of food processing while estimating the relationship between processed foods and obesity.

2.2. Obesity in India's rural-urban interface

Indian urbanization is distinct from other countries in two ways. First, the emergence of the fast-growing small towns has been the major driver of urban population growth in the recent decade (Denis et al., 2012). These small towns further fuel the living standards and nutritional outcomes of people in nearby rural areas (Aiyar et al., 2021; Gibson et al., 2017; Rao et al., 2006). Second, India's urbanization patterns can be represented by polycentric patterns. That is, the urban effects extend from the big city to surrounding small towns which then spill over into the rural areas (Steinhübel and Cramon-Taubadel, 2020). In the rural-urban interface, it is common to see households diversify their livelihood strategies to the off-farm sector even while at least one member is still engaged on the farm

(Steinhübel and Cramon-Taubadel, 2020). The resulting increased income from livelihood diversification allows for the simultaneous diversification of diet and an increased frequency of eating out (Pingali, 2007; Rahman and Mishra, 2020).

Pingali and Khwaja (2004) propose that the speed of shift from the first stage to the second stage of diet transition depends on the speed of urbanization of the location. An urban environment improves both access and affordability of diverse foods. Furthermore, the urbanization spill-over effects in such regions, catalyzed by access to better infrastructure and transportation facilities, reduce engagement in labor-intensive activities as the lifestyle becomes more sedentary. In combination with the increased calorie intake through dietary transition, reduced physical activities create an imbalance between calorie consumption and expenditure. This increases the prevalence of obesity in rural-interface regions.

The spillover effects of ST from the nearby urban centers provide easy access to processed foods, sedentary activities, and lifestyle changes. Hence, people living in the rural-urban interface are likely to be at a higher risk for obesity than their counterparts living in rural areas (Aiyar et al., 2021). Our study, thus, provides explorative evidence on how dietary transition to processed foods leads to greater obesity in the face of rapid urbanization in the rural-urban interface of Bangalore.

2.3. Bangalore

With a population of 9.6 million (Directorate of Census Operations Karnataka, 2011), Bangalore is a rapidly urbanizing mega-city situated in the southern state of Karnataka. It is expected that Bangalore's population will rise to 20.3 million by 2031 (Bharadwaj, 2017). Bangalore along with several small towns located within a roughly 40-kilometer radius provides many opportunities for engaging in intensive agriculture and employment in the off-farm sector (Directorate of Census Operations Karnataka, 2011; Steinhübel and Cramon-Taubadel, 2020). Several highways connecting these urban centers have led to a rise in urbanization in the entire region (Directorate of Census Operations Karnataka, 2011). Bangalore exerts a rapidly growing demand for diverse food items from nearby peri-urban and rural areas and serves as a central hub from where the food is distributed. During the time data was gathered, the obesity rate among women in Bangalore increased from 32 percent (2015-16) to 40.1 percent (2019-20) (NFHS-5, 2019-20). Several modern retail stores and fast-food centers have emerged in Bangalore during the same time. The rapid rise in access to food markets reflects the growing demand for convenience and processed foods (Demmler et al., 2018). Besides, the Government of Karnataka provides subsidized ration for semi-processed foods such as oil, sugar, etc. for disadvantaged families at relatively low prices (Government of Karnataka, 2013).[3]

[3] The Government of Karnataka categorizes households as priority and non-priority groups based on certain eligibility criteria to define the economic status of the household (Government of Karnataka 2013). Priority

3. Study area, sampling, and data description

3.1. Study area and sampling design

Our study area, set in the rural-urban interface of Bangalore, consists of two research transects (see Figure 1). The first transect extends outwards and towards the north and the second extends towards the southwest part (two polygons in Figure 1). These transects are surrounded by several small towns. Improved access to Bangalore city and small towns offer incentives for households to engage in commercialized agricultural operations and off-farm employment across this region (Steinhübel and Cramon-Taubadel, 2020). Thus, the livelihood strategies of the households located in the rural-urban interface region are mostly a composite of farm and off-farm employment. Such diversifications in the livelihood strategies of the households increase their average income (Haggblade et al., 2010). Increased income enables the households to purchase food items from a wide range of food outlets, from mom & pop stores to hypermarkets existing in the region. All these stores sell food ranging from fresh to semi-processed to ultra-processed foods. A variety of fast-food outlets also exist within these transects and in surrounding small towns, creating easier access to semi- and ultra-processed food items. Furthermore, improvements in infrastructure, transport facilities, access to off-farm employment in this region have made a more sedentary lifestyle possible for many local inhabitants. Hence, the rural-urban interface of Bangalore, a space influenced by urbanization, globalized diet, sedentary activities, and lifestyle changes, provides an ideal setting to explore how calories from processed foods translate into obesity.

For our empirical analysis, we use the data from a socio-economic survey of 1275 households conducted between December 2016 and May 2017 in the rural-urban interface of Bangalore. We applied a two-stage stratified random sampling method to ensure that the sample households represent the urbanization pattern in this area. In the first stage, all the villages in each transect were divided into three strata (urban, peri-urban, and rural) using the "Survey Stratification Index (SSI)" (Hoffmann et al., 2017). Then, in each of these strata, sample villages were randomly selected proportional to their size (in total 61 villages). In the second stage, households were randomly selected in each village again proportional to their size using the village household list maintained by the publicly run village kinder gardens.

households hold Anthyodaya Anna Yojana (AAY) card or Below Poverty Line (BPL) card. In addition to subsidized staples such as rice and wheat, the households with AAY and BPL cards are entitled to receive sugar, oil, gram, and other region-specific food items (Government of Karnataka 2013). Non-priority households, who do not meet the criteria of living in poverty, are not eligible for subsidized food under PDS. However, if they feel that they are food insecure, they can register for an Above Poverty Line (APL) card to receive a small quantity of subsidized grains such as rice.

Information on socioeconomic, demographic, livelihood characteristics, etc. of sample households was collected using a comprehensive questionnaire. The caregiver of the family was interviewed to collect the information on household food consumption up to 14-days before the interview.[4] Anthropometric measurements such as height and weight were taken for all the women living in these sample households, except for pregnant and nursing women. We concentrate on obesity among women because women are disproportionately affected by obesity in India (NFHS-5, 2019-20). Besides, women are usually the main caregivers in Indian society. Increased opportunities for them to work outside the home have implications not just for their own health but also for the care they can provide to the family (Kennedy and Reardon, 1994; Regmi and Dyck, 2001). Additionally, the nutrition of women is found to be directly correlated with the nutritional status of other members within the household (Harttgen et al., 2013).

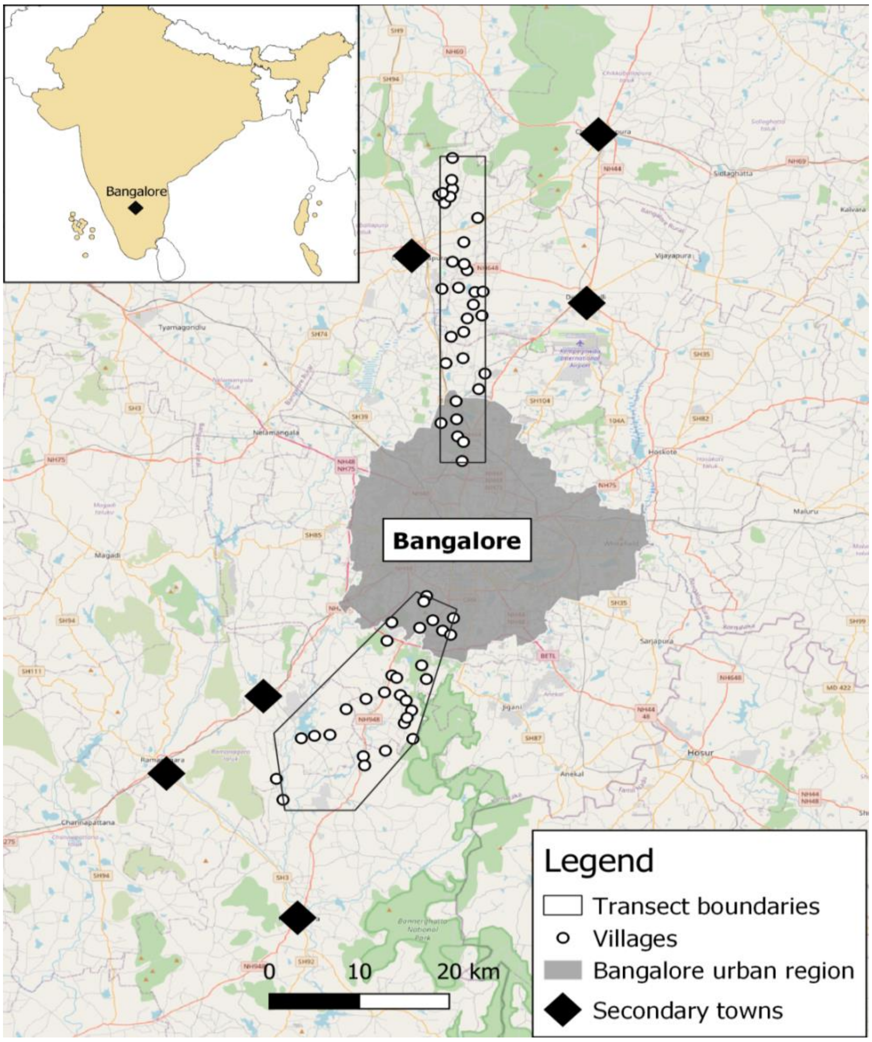

Figure 1: Study area, research transects, and sample villages.

[4] The survey instrument for the 14-day recall household food consumption data was prepared based on the Food and Agricultural Organization (FAO) guidelines for household food consumption expenditure survey in low- and middle-income countries.

3.2. Data description

3.2.1. Survey overview

While our survey consists of 1275 households, demographic and food consumption data were available for only 1121 households.[5] Of these, we had to drop 22 households owing to extreme calorie consumption values which we consider to be outliers.[6] Hence, our sample consists of 1099 households. A total of 1983 women were recorded as members of these households. Even after multiple visits to households, we could only collect anthropometric measurements for 1438 women. Hence, anthropometric data is not available for 29% of the women in our sample. The t-test results presented in Appendix Table 1 show that there are differences in some of the individual-level (marital status and occupation) and household-level characteristics (family size, asset index, and distance to Bangalore city) of women who did/did not participate in anthropometric measurements. Participated women on average are more likely to be housewives and married. They are more likely to be from households with fewer members, higher wealth, and are located closer to Bangalore city. Controlling for these factors reduces the sample by 68 observations due to missing covariates. Results of the t-tests summarized in Appendix Table 2 suggest that there is no significant difference in BMI of women for whom a covariate is missing or not missing. Our final sample consists of 1335 women for whom complete information on BMI, processed food consumption, and covariates are available. In Table 1, we present the summary statistics of the final data set.

Table 1: Summary statistics of the sample women and households

Variable	Unit	Mean	Median
Dependent variable			
BMI	Kg/m^2	23 (4.9)	23
Obesity (BMI≥25 Kg/m^2)	Dummy variable; 1=obese, 0=not obese	36	
Main explanatory variable			
Share of calories in NOVA food group	Unprocessed and minimally processed foods (%)	74.4 (9.3)	75.1
	Semi-processed food (%)	17.8 (7.5)	17
	Ultra-processed food (%)	4.1 (4.0)	3.2
Controls:			
Individual-level characteristics			
Age	Years	38 (14.7)	35

[5] Of the missing 154 households, the decision-maker part of the questionnaire was not administered for 47 households and the food consumption part of the questionnaire was not administered for 78 households, which resulted in dropping 125 households that had either food consumption data or household demographics data but not both. Among the households where both the decision-maker and food consumption part of the questionnaire was administered, 21 and 8 households had to be dropped because of incomplete/partial information on questions related to food consumption and household demographic characteristics, respectively.

[6] The observations in the 1st percentile (<=979 Kcal/AE/day) and 99th percentile (>=11379 Kcal/AE/day) are considered as extreme calorie values.

Marital status	1. Married	0.80	
	2. Unmarried	0.12	
	3.Divorced/widowed	0.8	
Education	Dummy variable; 1=No, 0=Yes	0.37	
Main occupation	1. Housewife	0.69	
	2. Office work	0.10	
	3. Labor intensive work	0.13	
	4. Student	0.7	
Number of children	Numer of children a woman has	2 (1.5)	2
Household-level characteristics			
Family size	Count of household members	5.1 (2.4)	5
Caste	1. General	0.45	
	2. SC&ST	0.27	
	3. OBC	0.28	
Economic status	Count of durable assets owned by the household	5.9 (1.5)	6
Food source	Market purchase from modern food outlets (%)	22.4 (28.3)	5.8
Person buying food	1. Adult female	0.26	
	2. Adult male	0.57	
	3. Anybody in the family	0.17	
Livelihood strategy	1. Pure farm	0.22	
	2. Pure off-farm	0.47	
	3. Composite (farm and off-farm)	0.28	
	4. Others	0.3	
Ration card	1. APL	0.7	
	2. BPL	0.82	
	3. No ration card	0.11	
Toilet	Dummy variable; 1=Yes, 0=No	0.82	
Calorie adequacy ratio	1. Individuals in calorie adequate households	0.71	
	2. Individuals in calorie inadequate households	0.29	
Location characteristics			
Distance to Bangalore	Kilometer distance from village centers to Banglaore city center	25.4 (10)	23
Distance to the closest town	Kilometer distance from village centers to the nearest small town	11.5 (3)	11
Transect	Dummy variable; 1=Southern, 2=Northern	0.49	
Observations	1335		

Note: Standard deviations in parenthesis. SC&ST – scheduled caste and scheduled tribe, OBC – other backward castes. APL – above poverty line, BPL – below poverty line.

[a] Livelihood strategy of the household is calculated using the occupation information of all adult household members (>15 years of age). Farm household includes all household members engaged in farm activities; Off-farm household includes all household members engaged in non-farm activities; Farm and off-farm household include a composite of farm and non-farm activities done by household members; The fourth category – Others – includes those households solely engage in dairy farming or does not engage in any livelihood strategy.

3.2.2. Dependent variable

We use anthropometric measurements to calculate the BMI of women. BMI is calculated by dividing the weight (in kilograms) of an individual by the square of their height (in meters). Women with BMI≥25 are considered obese. We have 36 percent of obesity (Table 1) among our sample women in the rural-urban interface of Bangalore.

3.2.3. Independent variable

Our main variable of interest is the calories consumed from processed foods. For this, we need a reliable measure to identify the distinctions between unprocessed, semi-processed, and ultra-processed food items. Moubarac et al. (2014) review five different processed food classification systems from different parts of the world. They suggest that the NOVA food classification system, which accounts for different levels of industrial processing, is consistent and can be used globally in designing dietary guidelines. The NOVA food classification system is widely used in the literature to study the relationship between processed food consumption and health (Juul et al., 2018; Monteiro et al., 2011; Moubarac et al., 2013). Furthermore, its approach to identifying ultra-processed foods is highly recognized in the literature (Lawrence and Baker, 2019). Since we hypothesize that the level of food processing plays an important role in predicting obesity, we adopt the NOVA classification system. This system classifies food items into three groups according to the *"nature, extent, and purpose"* of industrial processing (Monteiro, 2009). Information on processing includes the physical, chemical, and biological treatments that food items undergo after separating them from their natural form and before they are consumed as dishes or ingredients. The three food groups of the NOVA classification system are (i) Unprocessed and minimally processed foods, (ii) Processed culinary or food industry ingredients, and (iii) Ultra-processed foods. A detailed description of these three food groups is given in Monteiro et al. (2010).[7]

We calculate calories consumed in each of the NOVA food groups using the 14-day recall household food consumption data provided by the caregiver. The reported quantities of all food items consumed are converted to their caloric values using nutrient conversion factors provided in the Indian Food Conversion Tables (IFCT) (Longvah et al., 2017). The calorie values of each food item are added together to get the total amount of calories consumed by household j, i.e., cal_j. We categorize all the food items, their quantities, and respective calories into 3 groups (k) of the NOVA classification system – unprocessed or minimally processed (m), processed culinary or food industry ingredients (c), and ultra-processed food products (u). The calories within each group k are added together to get the calories consumed in each NOVA food group for household j, i.e., $q_{k,j}$. The share of calories

[7] In Appendix Table 3 we summarize all the food items consumed by our sample households into the 3 food groups of the NOVA classification system.

consumed by group k for household j, is computed by dividing the calories consumed in group k ($q_{k,j}$) by the total amount of calories consumed (cal_j).

$$Kcal_{k,j} = \frac{Amount\ of\ calories\ consumed\ in\ group\ k\ by\ household\ j}{Total\ amount\ of\ calories\ consumed\ by\ household\ j} * 100 = \frac{q_{k,j}}{cal_j}$$

Where $k = (m, c, u)$

We also calculate the quartiles for each type of food group using $Kcal_{k,j}$. Since we are interested in estimating the effect of processed foods on obesity, we consider the calories from the last two processed food groups of the NOVA classification system – $Kcal_{c,j}$ and $Kcal_{u,j}$. For the convenience of interpretation, we call them semi- and ultra-processed foods, respectively.[8]

In Table 1, we can see that three fourth of calories in household diets (75 percent) come from unprocessed or minimally processed food groups. Compared with other studies (Monteiro et al., 2018; Monteiro et al., 2011; Moubarac et al., 2013; Poti et al., 2015), which find 25 to 39 percent of calorie consumption from unprocessed or minimally processed foods our sample households consume relatively more calories from this food group. The two processed food groups—semi- and ultra-processed foods—account for around 18 and 4 percent of the total calories consumed, respectively.

3.2.4. Calorie adequacy ratio

To estimate the relationship between processed food calories and obesity among women whose calorie consumption meet or do not meet their RDA, we calculated the adequacy of the calories consumed by the households. Based on Standardized calorie intake recommendations given by the Indian Council of Medical Research (ICMR), the adequacy of a household's calorie consumption is estimated in three steps. First, the age and gender information of all family members was used to calculate the recommended quantities of calories to be consumed by the household. Second, the total quantity of calories consumed by the household was calculated using 14-day recall food consumption data in the same way as described above. Third, the total quantity of calories consumed by the household was divided by the total calories recommended for the same to produce a calorie adequacy ratio. Households for which the calorie adequacy ratio is greater (less) than one are considered as calorie adequate (inadequate) households. In our sample, 71 percent of the households are calorie adequate and 29 percent are calorie inadequate (Table 1).

[8] We do not estimate the effect of calories from unprocessed or minimally processed ($Kcal_{m,j}$) group on obesity. This classification contains food items with no or minimum level of food processing to increase their shelf life and palatability; they often do not lead to obesity.

3.3. Control variables

Besides the semi- and ultra-processed food calories, we also control for the individual- and household-level characteristics of women in our estimations. Among the individual-level characteristics of women (Table 1), the average age is 38 years, 37 percent have no education, the average number of children is two, and 80 percent are married. 69 percent of our sample women report being housewives, 10 percent engages in relatively sedentary work in the public or private sector, 13 percent do labor-intensive activities such as agriculture or casual labor, and the remaining 7 percent are students.

Among the household-level controls summarized in Table 1, we see that sample households have around five members. The variables related to caste control for the influences of social status and economic opportunities. In our survey 45 percent of women belong to the General caste, 27 percent belong to scheduled caste and scheduled tribe (SC&ST), and 28 percent belong to the other backward castes (OBC) group. We include the number of durable assets owned by the household as a measure of economic status. The majority (48 percent) of our sample households engage in pure off-farm employment, 22 percent engage in pure farm operations, 28 percent are composite households doing both farm and off-farm employment, and the remaining 3 percent either engage in only livestock production or do not engage in any employment.

We also control for the factors that are directly related to household food consumption such as the food source and the person buying food from the market (Table 1). On average 22 percent of purchased food in our sample household comes from modern supermarkets. In 26 percent of our sample households, the market food purchases are carried out by a female household member. It's an adult male household member in 57 percent of sample households who does food purchases and in the remaining 17 percent, any member of the household may buy food from the market. 82 percent of our sample households have access to private toilets. In addition, we control for the distance to Bangalore city and closest town to control the effect of proximity to the urban center.

4. Methods

Using a probit model we estimate the effect of semi- and ultra-processed food calorie consumption on obesity.[9] The equation below summarizes our econometric model that estimates the relationship between processed calorie consumption and obesity conditional on household- and individual-level characteristics.

$$Y_{i,j} = \beta_0 + \alpha P_j + \gamma O_{i,j} + \alpha^{\times}(P_j \times O_{i,j}) + \delta L_{i,j} + \delta^{\times}(L^{\times}_{i,j}) + \beta_{dist} D_j + \beta^{\times}_{dist}(D^{\times}) + \beta_{control} X_{i,j} + \varepsilon_{i,j} \qquad (1)$$

[9] As a robustness check, we also estimate this relationship using logistic and linear probability regression models and as expected, the results are not affected by the choice of estimation model.

Here, i represents individual women in the household j. $Y_{i,j}$ is our outcome of interest, which takes value 1 for obesity if BMI≥25, and 0 otherwise. The model includes a constant β_0 and a stochastic error term ε. The parameters α, γ, δ, β_{dist}, and $\beta_{control}$ quantify the effects of variables in the vectors P, O, L, D, and X, respectively. The vector P contains quartiles of the share of calories consumed from semi- and ultra-processed foods ($P = q_s, q_u$); O contains categorical variables for the occupation of women as a proxy for their physical activity level; L contains variables that represent lifestyle characteristics– livelihood strategy of household and education of women ($L = i_l, i_e$); D contains two variables that measure the distance from the village center to Bangalore city and closest town ($D = d_{Bangalore}, d_{Towns}$); and X contains the control variables presented in Table 1.

We also allow for interaction effects between some of these variables. The interaction terms are represented by the superscript "×" to the respective parameters and vectors in equation (1). One such interaction is estimated between the share of semi- and ultra-processed calories and the occupation of women, $P \times O = (i_c \times O,\ i_u \times O)$, to test whether the relationship between processed food and obesity is mediated by physical activity level. Increased participation in the off-farm employment sector increases dietary diversity and sedentary activities, leading to greater obesity (Popkin, 2006; Popkin and Gordon-Larsen, 2004; Rahman and Mishra, 2020). Besides, the off-farm working environment might also foster awareness of healthy eating and exercise practices, and educated women living in these off-farm households might value this awareness positively and incorporate them in their day-to-day activities than uneducated women (Cawley, 2015). Such an effect of lifestyle change is estimated by the interaction variable between household livelihood strategies and the education of women – $L^{\times} = (i_l \times i_e)$. The economic growth of urban center increases obesity prevalence among people living in the vicinity (Aiyar et al., 2021). The interaction between the two distance variables, $D^{\times} = (d_{Bangalore} \times d_{Towns})$ estimates the effect of proximity to urban cener on obesity. A larger value in this interaction variable indicates that the village is remote to both Bangalore city and closest town.

5. Results

5.1. Main regression analysis

Table 2 presents the regression results for the relationship between the consumption of calories from processed foods and obesity. The results show that, compared with quartile 1, the semi-processed food calories at the highest quartiles of consumption (quartile 4) increases the prevalence of obesity among women. Unlike the evidence from high-income countries (Asfaw, 2011; Monteiro et al., 2018; Moubarac et al., 2013; Poti et al., 2017) we find that ultra-processed food calories do not matter for obesity. As we proposed in section 2.1, this relationship could be driven by a higher income elasticity of semi-processed foods (relative to ultra-processed foods) that leads to greater consumption of semi-processed foods at lower incomes. Or, combined with greater affordability through the PDS and a lower opportunity cost of time spent on home-cooking (as compared with higher-income groups), semi-processed foods may be the ‘processed food of choice’ in the diets of lower-income groups. Hence, they constitute a greater share of the household’s diet. Excess consumption of semi-processed foods (as seen in Table 2) even in the presence of ultra-processed foods may thus create a greater risk for obesity in these peri-urban areas.

Table 2: Association of processed food calories with obesity – probit regression estimates

VARIABLES	Obesity
Semi-processed calories (%) (ref. Quartile 1)	
Quartile 2	-0.01 (0.95)
Quartile 3	0.04 (0.75)
Quartile 4	**0.24* (0.08)**
Main occupation (ref. Housewife)	
Office work	-0.21 (0.57)
Labor intensive work	-0.15 (0.61)
Student	0.08 (0.87)
Semi-processed calories (%) X Main occupation (ref. Quartile 1 X Housewife)	
Quartile 2 X Office work	0.25 (0.52)
Quartile 2 X Labor intensive work	0.21 (0.50)
Quartile 2 X Student	-1.02 (0.10)
Quartile 3 X Office work	0.06 (0.87)
Quartile 3 X Labor intensive work	-0.17 (0.59)
Quartile 3 X Student	-0.11 (0.82)
Quartile 4 X Office work	0.30 (0.42)
Quartile 4 X Labor intensive work	**-0.65* (0.06)**
Quartile 4 X Student	**-1.43** (0.02)**
Ultra-processed calories (%) (ref. Quartile 1)	
Quartile 2	0.18 (0.17)
Quartile 3	0.14 (0.29)
Quartile 4	0.09 (0.49)
Ultra-processed calories (%) X Main occupation (ref. Quartile 1 X Housewife)	
Quartile 2 X Office work	0.15 (0.70)
Quartile 2 X Labor intensive work	0.01 (0.98)
Quartile 2 X Student	-0.12 (0.83)
Quartile 3 X Office work	0.25 (0.50)
Quartile 3 X Labor intensive work	0.37 (0.28)
Quartile 3 X Student	0.46 (0.40)
Quartile 4 X Office work	-0.12 (0.76)
Quartile 4 X Labor intensive work	0.06 (0.86)
Quartile 4 X Student	-0.01 (0.99)
Distance to Bangalore (km)	-0.01 (0.63)
Distance to the closest town (km)	0.04 (0.30)
Distance to Bangalore X Distance to the closest town	-0.00 (0.32)
Household livelihood strategy (ref. Pure farm)	

Pure off-farm	**-0.30** (0.02)**
Composite (farm and off-farm)	**-0.35*** (0.01)**
Others	-0.15 (0.57)
Literacy of women (dummy – No education)	-0.21 (0.25)
Household livelihood strategy X Education of women	
Pure off-farm X No education	**0.47** (0.02)**
Composite (farm and off-farm) X No education	0.22 (0.33)
Others X No education	0.18 (0.71)
Controls	
Age (years)	**0.01* (0.08)**
Marital status (ref. Married)	
Unmarried	-0.23 (0.25)
Divorced/widowed	-0.01 (0.94)
Number of children (count)	**0.07*** (0.01)**
Household members (count)	0.03 (0.12)
Caste (ref. General)	
SC & ST	-0.08 (0.41)
OBC	0.21 (0.02)
Assets (count)	**0.12*** (<0.01)**
Grocery purchase from modern food outlets (%)	0.00 (0.44)
Main grocery shopper (ref. Adult female)	
Adult male	-0.13 (0.18)
Anybody in the family	0.06 (0.64)
Toilet (dummy - yes)	0.15 (0.16)
Transect (dummy - South)	**-0.26*** (0.01)**
Constant	**-1.37*** (0.01)**
Mean obesity	0.36
Pseudo R-squared	0.12
LR statistic	**210 (<0.01)**
Observations	1,335

Note: ***p<0.01, **p<0.05, *p<0.1. p-values in parentheses. SC&ST – scheduled caste and scheduled tribe, OBC – other backward castes.

To estimate the proposed argument in section 2.1, we test the relationship between processed foods and obesity by household asset quartiles. The results are presented in Table 3. The household assets can be used to measure the socioeconomic status (SES) of individuals, with higher assets implying higher SES (Gwatkin et al., 2007). SES of individuals has been linked with dietary preferences in LMICs like India with the rich consuming more ultra-processed foods due to greater affordability of the same (Daniel et al., 2011; Green et al., 2016; Satija et al., 2015). In table 3, we see that obesity in upper-middle SES households is driven by the consumption of calories from semi-processed foods. But, similar to high-income countries, it is the share of calories from ultra-processed foods that are correlated with obesity among high SES households. Combined with the results from Table 2, this indicates that at the early to middle stages of economic development, as represented by households living in our study context of peri-urban areas, semi-processed food consumption may be driving obesity. At higher levels of development, this relationship becomes an outcome of ultra-processed food consumption as typically seen in high-income countries.

Table 3: Association of processed food calories with obesity by income level of the households

VARIABLES		Low	Low-middle	Upper-middle	High
Semi-processed calories (%) (ref. Quartile 1)					
	Quartile 2	0.03 (0.89)	-0.22 (0.28)	-0.18 (0.48)	0.01 (0.98)
	Quartile 3	-0.13 (0.49)	0.01 (0.98)	0.28 (0.27)	-0.32 (0.51)
	Quartile 4	0.02 (0.91)	-0.08 (0.72)	**0.51** (0.04)**	-0.24 (0.61)
Ultra-processed calories (%) (ref. Quartile 1)					
	Quartile 2	0.14 (0.51)	0.10 (0.62)	0.41 (0.13)	0.27 (0.46)
	Quartile 3	0.21 (0.27)	0.24 (0.27)	0.04 (0.88)	**0.67* (0.07)**
	Quartile 4	-0.05 (0.79)	0.10 (0.63)	0.14 (0.63)	-0.10 (0.79)
Constant		0.46 (0.61)	-0.75 (0.52)	-0.43 (0.74)	-0.39 (0.85)
Mean obesity		0.24	0.36	0.42	0.5
Mean assets		4.2	6.0	7.0	8.4
Pseudo R-squared		0.10	0.13	0.16	0.24
LR statistic		**55.80 (<0.01)**	**68.59 (<0.01)**	**67.93 (<0.01)**	**60.62 (<0.01)**
Controls		Yes	Yes	Yes	Yes
Observations		475	378	301	179

Note: ***p<0.01, **p<0.05, *p<0.1. p-values in parentheses.

Controls include the main occupation of women, distance to Bangalore city and closest town (and the interaction variable between the two), lifestyle characteristics (livelihood strategies and education), age, marital status, number of children, household size, caste, asset index, supermarket food purchases, the person purchasing the food, access to a toilet, and transect dummy

Another potential explanation for the differences between lower, middle, and higher SES could be the access to semi-processed foods. A recent study for Karnataka shows the ration card holders rely more on the energy-dense foods purchased at a subsidized price in PDS and open markets (Cunningham et al., 2021). Table 4 shows what happens to obesity in households that hold ration cards when exposed to processed foods. Below poverty line (BPL) ration cardholders, who are entitled to the largest share of benefits from PDS, are at greater risk of obesity due to excess consumption of calories from semi-processed foods. Above poverty line (APL) ration cardholders (not poor but feel food insecure in some cases), who are entitled to a small quantity of subsidized staples by PDS, are likely to obese due to consumption of excess calories from ultra-processed foods. Both semi- and ultra-processed foods appear to reduce obesity in non-ration cardholders. The non-ration cardholders who are considered to have higher SES might consume a better quality diet (Cunningham et al., 2021). Thus, counter-intuitively, it would seem that the rationing through PDS, which was established to eradicate hunger in India, now enables people to consume excess energy-dense foods (either through staples such as rice and wheat or through semi-processed foods such as sugar and oil). In these peri-urban food markets, rethinking the current subsidies that enable greater consumption of semi-processed foods may be important. Moving away from semi-processed foods to providing fresh foods could be a solution as experts work on strengthening the PDS to improve urban food security.

Table 4: Association of processed food calories with obesity by ration cards

VARIABLES		BPL card	APL card	No ration card
Semi-processed calories (%) (ref. Quartile 1)				
	Quartile 2	0.09 (0.42)	0.15 (0.89)	**-1.39*** (<0.01)**
	Quartile 3	0.08 (0.51)	-1.11 (0.22)	-0.86 (0.11)
	Quartile 4	**0.28** (0.03)**	-0.17 (0.82)	**-1.21** (0.02)**
Ultra-processed calories (%) (ref. Quartile 1)				
	Quartile 2	0.17 (0.16)	**1.71** (0.04)**	**-1.26** (0.02)**
	Quartile 3	0.19 (0.12)	-1.48 (0.16)	0.17 (0.72)
	Quartile 4	0.11 (0.41)	-0.98 (0.30)	-0.28 (0.49)
Constant		-1.06 (0.10)	5.31 (0.22)	0.04 (0.98)
Mean obesity		0.33	0.51	0.37
Mean card holders		0.82	0.06	0.11
Pseudo R-squared		0.11	0.43	0.26
LR statistic		**156.26 (<0.01)**	**50.29 (<0.01)**	**53.21 (<0.01)**
Controls		Yes	Yes	Yes
Observations		1097	83	149

Note: ***p<0.01, **p<0.05, *p<0.1. p-values in parentheses.

Controls include the main occupation of women, distance to Bangalore city and closest town (and the interaction variable between the two), lifestyle characteristics (livelihood strategies and education), age, marital status, number of children, household size, caste, asset index, supermarket food purchases, the person purchasing the food, access to a toilet, and transect dummy. BPL – below poverty line. APL – above poverty line.

Overconsumption of ultra-processed foods has been identified as a major risk factor for obesity in high-income countries. Similarly, we check if the overconsumption of semi-processed foods in the relationship of dietary adequacy matters to obesity. In Table 5, we present the effect of processed foods on obesity in calorie adequate and inadequate households. As expected, we find that excess consumption of semi-processed food calories (quartile 4) is strongly associated with obesity in calorie adequate households. Consumption of calories from processed foods does not affect the likelihood of obesity for those in calorie inadequate households whose calorie consumption is below their RDA. This highlights that there is a threshold in the form of one's baseline ability to meet their RDA for calories, beyond which excess consumption of processed foods is associated with obesity.

Table 5: Association of processed food calories with obesity by calorie adequacy of households

VARIABLES		Calorie adequate	Calorie inadequate
Semi-processed calories (%) (ref. Quartile 1)			
	Quartile 2	0.04 (0.79)	-0.20 (0.44)
	Quartile 3	0.09 (0.53)	-0.02 (0.92)
	Quartile 4	**0.39** (0.01)**	-0.16 (0.55)

Ultra-processed calories (%) (ref. Quartile 1)			
	Quartile 2	0.15 (0.35)	0.24 (0.33)
	Quartile 3	0.13 (0.42)	0.16 (0.54)
	Quartile 4	0.18 (0.28)	-0.18 (0.42)
Constant		**-1.39** (0.05)**	-0.94 (0.39)
Mean obesity		0.35	0.36
Mean households		0.29	0.71
Pseudo R-squared		0.13	0.13
LR statistic		**168.12 (<0.01)**	**66.16 (0.03)**
Controls		Yes	Yes
Observations		923	372

Note: ***p<0.01, **p<0.05, *p<0.1. p-values in parentheses.

Controls include the main occupation of women, distance to Bangalore city and closest town (and the interaction variable between the two), lifestyle characteristics (livelihood strategies and education), age, marital status, number of children, household size, caste, asset index, supermarket food purchases, the person purchasing the food, access to a toilet, and transect dummy

A well-known way to alleviate the risks from overconsumption is the role of exercise (Dang et al., 2019; Monda et al., 2008; Popkin, 2009). In our study context, while the direct effect of occupation on obesity is not statistically significant, its interaction with semi-processed food calories shows interesting patterns (Table 2). The relationship between excess consumption of semi-processed food calories (quartile 4) and obesity is weak for women engaged in labor-intensive work and for students relative to housewives in quartile 1. This indicates that the physical activity of women may moderate the relationship between semi-processed food calories and obesity. That is, for women engaged in labor-intensive work such as farming and/or casual labors and for students, who might do sports and other forms of exercise at their educational institutions, excess consumption of semi-processed food calories appears to be expended by relatively more physical activities.

Off-farm employment is known to increase dietary diversity (Rahman and Mishra, 2020). It is also associated with a greater sedentary lifestyle, which is correlated with obesity (Popkin, 2009; Popkin and Gordon-Larsen, 2004). In our study context, we find that relative to pure farm households, pure off-farm and composite (farm and off-farm) households are less likely to have obese women (Table 2). There can be two possible explanations for this result. First, as discussed by Pingali and Khwaja (2004), increased income through off-farm employment initially can lead to improved diet quality. This may allow households to improve diets without affecting obesity. Second, off-farm employment might also bring some lifestyle changes such as eating more nutritious food and/or engaging in exercising habits that reduce obesity (Cawley, 2015; Popkin, 1999). This can be explained by the interaction between household livelihood strategies and the education of women. Uneducated women in pure off-farm households are more likely to be obese than educated women. This indicates that the education of women moderates the effect of lifestyle changes that accompany off-farm employment on obesity.

In addition to the factors explained above, some of the individual-level (age and number of children) and household-level (assets and caste) controls are significantly associated with obesity (Table 2). Older women are more likely to have greater control over income and less mobility, which makes them more vulnerable to be obese (Aiyar et al., 2021; Balarajan and Villamor, 2009). The more children a woman has the higher the likelihood of obesity prevalence due to the weight gain during pregnancy, childbirth, and its retention in the subsequent pregnancy (Balarajan and Villamor, 2009; Dake et al., 2011). In line with these, we show that older women and women with more children are more likely to be obese. The higher economic status of the household increases the incidence of obesity. Women in the OBC caste category are more likely to be obese than the General caste category. This might be due to the effect of different cultural factors, social status, and economic opportunities on obesity that accompany the caste of an individual/household in India. Furthermore, women from the Northern research transect are more likely to obese. Steinhübel and Cramon-Taubadel (2020) show that there are significant differences in the household characteristics between the northern and southern transect of our study setting. That is, the households in the northern transect are more likely to use modern agricultural practices, relatively higher share of off-farm employment, and more educated household head than the households in the southern transect. These differences might increase income and sedentary lifestyle among women in the northern transect, which increases their likelihood to be obese.

5.2. Endogeneity between processed foods and obesity

There are few limitations of this study. It is possible that the relationship between processed foods and obesity proposed might not be unbiased due to unobserved heterogeneous factors and potential reverse causality between the two variables. The cross-sectional nature of our data limits our ability to account for such unobserved factors. To account for the potential endogeneity bias through the instrumental variable (IV) regression method, we need valid instruments. We tried applying the IV method using relevant instruments that we could create from our data set (mean share of expenditure made on processed foods in a village and the percentage of households in a village who eat their meals outside the home) and estimate the causal relationship between processed foods and obesity. The tests for the endogeneity of regressors fail to reject the null hypothesis that the variables on the share of calories from semi- and ultra-processed food are exogenous. Thus, we do not consider these estimations as our main results, instead, provide them in Appendix Table 4 for reference. Future research can try to address this limitation by using strong instruments such as the distance to the nearest supermarket and/or by using panel data. Furthermore, since the calories from processed foods in our study are measured at the household level, we can draw no conclusions on the intra-household distribution of processed food calories and its relevance to obesity. However, our results even at the household level show interesting patterns between processed foods and obesity at the early to middle stage of ST, as observed in India. Estimating the effect of individually processed calorie intake on obesity can be one of the recommendations for future research.

6. Conclusions

We analyze the relationship between processed food consumption and obesity in India. Even though there has been a more than 100 percent increase in the prevalence of obesity in India, the literature explaining the same is limited. This paper provides evidence on how increased processed food consumption due to dietary transition is associated with the increased prevalence of obesity in the Indian peri-urban context. For this, we use primary survey data on food consumption and obesity of women in the rural-urban interface of the mega-city of Bangalore. In the empirical analysis, controlling for possible confounding factors, we model how the share of calories consumed from semi- and ultra-processed foods are associated with the prevalence of obesity among women.

The regression results provide three important insights on the role of processed foods in the rising prevalence of obesity in India. The first, unlike the evidence from developed countries, it is not ultra-processed but semi-processed foods that are significantly associated with an increasing prevalence of obesity in peri-urban India. This relationship between semi-processed food calories and obesity is stronger among lower-income groups (Table 3) and among BPL ration card holders that procure subsidized semi-processed foods from PDS (Table 4). Since semi-processed foods are widely consumed in everyday diet, an increase in income enables households, especially the ones in the lower-income groups, to consume excess quantities of semi-processed foods. Furthermore, the distribution of semi-processed foods such as sugar and oil through PDS at subsidized prices improves their access and affordability for lower-income groups. Thus, even in the presence of ultra-processed foods, semi-processed foods drive the risks for obesity in peri-urban India. These results also highlight that diet-related nutrition challenges faced by India are occurring at a much lower level of dietary transition. At higher income levels, the diet correlates of obesity shift to ultra-processed foods. This might be due to the improved affordability of ultra-processed foods and the higher opportunity costs of cooking food at home for higher-income groups (than the lower-income groups).

Second, there is a threshold effect in the relationship between processed food consumption and obesity. For those who consume lower than the RDA for calories, there is no effect of the consumption of semi-processed foods on their obesity. This relationship turns significant only when women meet their RDA for calories (calorie adequate). Thus, RDA for calories creates a threshold after which obesity becomes linked with dietary preferences for processed foods. This result calls into question a monolithic view that all processed foods are bad for health. The existence of the threshold implies that targeting nutrition information on weight management and calorie consumption for women at early stages of economic development may be a key input into preventing the obesity epidemic from reaching lower-income groups. Research on the dietary and economic effects of processed foods on BMI and health also needs to account for this threshold.

Third, the relationship between semi-processed food calories and obesity is mediated by the physical activity level of women. In line with the broader literature (Dang et al., 2019; Monda et al., 2008; Popkin, 2009), our results show that engaging in relatively labor-intensive physical activities reduces obesity among women who consume excess semi-processed food calories. The results also suggest that off-farm employment characteristics of the households help to reduce obesity. These effects, further, moderated by the education of women, with low literate women being at a higher risk to be obese.

The findings of our study provide a descriptive exposition on the role of processed foods in the dietary transition and the increasing prevalence of obesity. We propose two policy recommendations based on this research. The first is to improve the awareness, access, and affordability of fresh, unprocessed or minimally processed foods. Even though a few semi-processed foods such as sugar and oil are provided to people at cheap prices through PDS, overconsumption of these foods, in turn, increases obesity. Thus, it is important to encourage people to invest in eating healthy foods and other health-enhancing behaviors by subsidizing healthy food. Our estimates provided in Appendix Table 5 support this suggestion by showing that unprocessed or minimally processed foods reduce the prevalence of obesity. Pre-emptive action through greater awareness may be key to stem the obesity epidemic. Second, since we show that physical activity levels and education moderate the effect of processed foods on obesity. We also hypothesize that the obesity alleviating effects among higher-income groups may come from their ability to engage in health behaviors like exercising. Educating people to engage in healthy lifestyle choices is an important input to reduce obesity in a rapidly evolving peri-urban context. As individuals increase their income levels due to economic growth opportunities, targeting interventions to increase awareness in their diet and lifestyle may be a key input for nutrition policy in LMICs like India.

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Appendix

Appendix Table 1: t-tests for mean differences between women with and without BMI information in the sample.

Variable	t-tests	
	Without BMI	With BMI
Age	39	38
Education	1.3	1.3
Marital status	1.5***	1.2
Occupation	1.8***	1.5
Additional occupation	1.9***	1.4
Religion	1	1
Caste	2.1	2.1
Family size	6***	5
Asset_index	5.6**	5.8
Ration card	2	3
Vegetarian family	1.9	1.9
Person buying food	1.9	1.9
% of food purchased from modern food outlets	17.5***	22.2
Livelihood strategy	2.1	2.1
Bathroom	1.6	1.6
Toilet	0.8	0.8
Distance to Bangalore	26.9**	25.4
Distance to nearest towns	11.3	11.6
Transect	1.5	2.4

Note: *** significant at P-value<0.01, ** significant at P-value<0.05

Appendix Table 2: t-test for women with and without missing covariates

	t-tests	
Variable	BMI for missing covariate	BMI for non-missing covariate
Marital status	22.1	22.4
Occupation	22.7	23.4
Additional occupation	23.7	23.4
Caste	25	23.4
Ration card	22.6	23.4
Bathroom	23.3	23.4
Toilet	24.1	23.4
Vegetarian family	25.5	23.4
Person buying food	24.8	23.4
% of food purchased from modern food outlets	24.5	23.4

Note: *** significant at P-value<0.01, ** significant at P-value<0.05

Appendix Table 3: Summary of food items classified under 3 food groups of NOVA classification system

Unprocessed or minimally processed food	*Semi-processed food*	*Ultra-processed food*
• **Cereals:** Rice; Wheat; Bajra; Ragi; Jowar; Small millets; Maize; Barley • **Vegetables:** Potato; Onion; Radish; Carrot; Turnip; Beetroot; Sweet potato; Arum; Pumpkin; Gourd; Bitter gourd; Cucumber; Parwal; Ridge gourd; Snake gourd; green papaya; Cauliflower; Cabbage; Brinjal; Lady's finger; Spinach; Salad; French beans; Tomato; Chillies; Capsicum; Green plantain; Green jackfruit • **Fruits:** Lemon; Banana; Kiwi; Jackfruit; Watermelon; Pineapple; Coconut; Guava; Water chestnut; Orange; Papaya; Mango; Melon; Pears; Berries; Lichi; Apple; Grapes; Pomogranet; Chiku • **Dry fruits and nuts:** Groundnut; Dates; Cashewnut; Walnut; Raisin; Almond • **Animal products:** Eggs; Mutton; Pork; Chicken; Fish; Beef; Milk liquid; Milk condensed/powder; Curd • **Spices:** Honey; Garlic; Ginger; Tamarind; Curry leaves; Oilseeds; Turmeric; Black pepper; Curry leaves; Dry chilies • **Drinks:** Homemade fruit juice; Tea; Coffee	• Refined wheat flour • Ghee • Butter • Sugar • Jaggery • Salt • Mustard oil; Groundnut oil; Edible oil • Chira/Awlaki • Puri/Kadle puri • Suji • Sewai/vermicelli	• Bread • Ice cream • Candy • Margarine • Lemonade • Purchased juice • Cola Mazaa • Biscuits • Cake/Pastry • Purchased sweets • Salted refreshments • Sauce • Jam, Jelly • Maggi noodles • Paratha (packaged) • Roti (Packaged) • Pizza • Burger • Chicken nugget • Wraps • Rolls • French fries • Frozen food • Pickles

Appendix Table 4: IV-probit regression for the effect of processed food calories on obesity

The main challenge in instrumental variable (IV) regression is finding valid instruments that meet two criteria. First, the instrument should be highly correlated with the variables on the share of semi- and ultra-processed foods. Second, the instruments should not be correlated with any of the unobserved factors affecting obesity in women. Thus, the instruments chosen should be directly related to processed foods but not directly related to obesity. We identified—the mean share of expenditure made on processed foods in a village and the percentage of households in a village who eat their meals outside the home—as two instruments to apply IV-probit regression. We argue that households tend to eat more processed foods if they live in a community where other households also eat more processed foods through their social contacts. Thus, households in a village with an average high share of expenditure on processed foods might tend to consume more processed foods due to the influence of their neighbors. Furthermore, meals eaten outside the home are often processed and convenient. Thus, households in a village with a greater share of eating out practice might also tend to eat meals outside the home. Using these two instruments we apply IV-probit regression to estimate the effect of shares of calories from semi- and ultra-processed foods on obesity. The results (presented below) show that the shares of calories from semi- and ultra-processed foods do not significantly affect obesity. However, the tests for the endogeneity of regressors fail to reject the null hypothesis that the variables on the share of calories from semi- and ultra-processed food are exogenous. For robustness check, we ran the estimations using a two-stage linear regression model with BMI of women as an outcome variable. The results and tests of endogeneity (not present here) remain the same. Since the share of calories from semi- and ultra-processed foods are found to be exogenous in the context of the rural-urban interface, a standard probit model is suitable in this situation. Thus, we consider the probit regression estimations as our main results.

VARIABLES		Obesity
Semi-processed calories (%)		-0.16 (0.77)
Ultra-processed calories (%)		0.29 (0.76)
Main occupation (ref. Housewife)		
	Office work	0.12 (0.66)
	Labor intensive work	0.07 (0.92)
	Student	0.08 (0.96)
Age (years)		0.02 (0.61)
Marital status (ref. Married)		
	Unmarried	-0.22 (0.46)
	Divorced/widowed	-0.21 (0.75)
Number of children (count)		0.06 (0.49)
Household members (count)		0.03 (0.35)
Caste (ref. General)		
	SC & ST	-0.49 (0.73)
	OBC	0.36 (0.43)

Assets (count)	0.22 (0.49)
Household livelihood strategy (ref. Pure farm)	
Pure off-farm	-0.23 (0.51)
Composite (farm and off-farm)	-0.42 (0.24)
Other income sources	0.66 (0.81)
Education of women (dummy - No)	-0.39 (0.46)
Household livelihood strategy X Education of women	
Pure off-farm X No education	0.65 (0.31)
Composite (farm and off-farm) X No education	0.05 (0.94)
Others X No education	-0.64 (0.82)
Main grocery shopper (ref. Adult female)	
Adult male	-0.15 (0.49)
Anybody in the family	-0.05 (0.91)
Toilet (dummy - yes)	0.18 (0.49)
Distance to Bangalore (km)	-0.01 (0.68)
Distance to the closest town (km)	0.02 (0.78)
Distance to Bangalore X Distance to the closest town	-0.00 (0.95)
Transect (dummy - South)	-0.22 (0.25)
Constant	-0.51 (0.86)
Mean obesity	0.36
Test of endogeneity of share of semi- and ultra-processed calories: H_0: Regressors are exogenous	
Wald chi-square test of exogeneity	0.23 (0.89)
Observations	1,335

Note: ***p<0.01, **p<0.05, *p<0.1. p-values in parentheses.

Appendix Table 5: Association of unprocessed food calories with obesity

VARIABLES		Obesity
Unprocessed calories (%) (ref. Quartile 1)		
	Quartile 2	-0.16 (0.21)
	Quartile 3	-0.08 (0.54)
	Quartile 4	**-0.27** (0.04)**
Constant		**-1.04* (0.06)**
Mean obesity		0.36
Pseudo R-squared		0.11
LR statistic		**204.53 (<0.01)**
Controls		Yes
Observations		1,335

Note: ***p<0.01, **p<0.05, *p<0.1. p-values in parentheses.

Controls include the main occupation of women, distance to Bangalore city and closest town (and the interaction variable between the two), lifestyle characteristics (livelihood strategies and education), age, marital status, number of children, household size, caste, asset index, supermarket food purchases, the person purchasing the food, access to a toilet, and transect dummy

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43	Yustika, Ahmad Erani	Transaction Costs and Corporate Governance of Sugar Mills in East Java, Indovesia, 2005
44	Feulefack, Joseph Florent, Manfred Zeller u. Stefan Schwarze	Accuracy Analysis of Participatory Wealth Ranking (PWR) in Socio-economic Poverty Comparisons, 2006

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- Umwelt- und Ressourcenökonomik
- Welternährung und rurale Entwicklung

In der Lehre ist das Department für Agrarökonomie und Rurale Entwicklung führend für die Studienrichtung Wirtschafts- und Sozialwissenschaften des Landbaus sowie maßgeblich eingebunden in die Studienrichtungen Agribusiness und Ressourcenmanagement. Das Forschungsspektrum des Departments ist breit gefächert. Schwerpunkte liegen sowohl in der Grundlagenforschung als auch in angewandten Forschungsbereichen. Das Department bildet heute eine schlagkräftige Einheit mit international beachteten Forschungsleistungen.

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