6-2017

The Connection Between Gasoline Prices and Physical Activity: Potential Ways to Combat the Rise in Obesity

John Perrotti
Union College - Schenectady, NY

THE CONNECTION BETWEEN GASOLINE PRICES AND PHYSICAL ACTIVITY: POTENTIAL WAYS TO COMBAT THE RISE IN OBESITY

by

John Perrotti

****

Submitted in Partial Fulfillment
of the requirements for
Honors in the Department of Economics

UNION COLLEGE

June, 2017

ABSTRACT

PERROTTI, JOHN A. The Connection Between Gasoline Prices and Physical Activity: Potential Ways to Combat the Rise in Obesity. Department of Economics, June 2017.

ADVISOR: Professor Younghwan Song

It is widely understood that one of the most significant public health challenges in the United States is obesity, which could rightly be considered an epidemic. Accompanied by billions of dollars in both explicit and implicit costs, obesity places great strain on the health care system and economy as a whole. Years of scientific research has linked obesity to three main determinants: genetics, over-eating, and lack of physical activity. Recent research has introduced the study of the connection between the macro-economy and rates of physical activity, thus linking economic variables to obesity. This paper investigates the connection between gasoline prices and physical activity, as a potentially novel method to combat the high prevalence of obesity in the US. Using data from the American Time Use Survey, this paper builds extensively on Sen (2012), which identified a positive association between gasoline prices and physical activity levels. Economically, the relationship exists by way of a substitution effect, as people drive less when gas prices are high, and/or an income effect, as people will become more frugal due to higher expenditures on gasoline. This paper expands beyond Sen by controlling for the long-term effect of gasoline prices, and including data up until the year 2015. This paper finds that higher gasoline prices are associated minimally with higher overall average physical activity scores on the individual level. However, this paper does not find a significant effect when analyzing specific activities such as running and bicycling. As a result, there not enough clear evidence that policies such as gasoline taxes may prove valuable in the fight against the obesity epidemic.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

Many economists, policymakers, and health practitioners agree that one of the most significant issues facing the United States today are persistently high levels of obesity. Currently, the obesity rate in the United States is roughly 37%, easily the highest in the world (Centers for Disease Control and Prevention [CDC], 2016). Furthermore, this rate has nearly doubled since 1960, meaning that obesity rates have risen almost uncontrollably across all areas of the US. Indeed, major public health groups including the American Heart Association (American Heart Association [AHA], 2016) have begun to refer to obesity as an epidemic (AHA, 2016). For the individual who is obese, they are more susceptible to a variety of serious chronic illnesses, most notably heart disease, stroke and diabetes. Even more troubling, however, is evidence from recent studies such as Campbell and Schurman (2005) linking obesity to a higher risk of nearly every chronic illness, including some cancers. In addition, Timm, Grupp-Phelan and Ho (2005) find that obesity is accompanied by a greater risk of an acute physical injury, further exacerbating its potentially grave medical consequences.

The costs of obesity go beyond the direct health consequences for the individual. Explicitly, the price of treatment for the vast magnitude of chronic illnesses associated with obesity is astronomical. When considering the implicit costs of overcrowding and misallocation of resources, the strain on the health care system becomes nearly incalculable. In this way, the individual costs one faces from being obese are externalized, and thus the entire US economy is adversely affected. Recently, the CDC estimated the annual medical cost of obesity to be $146 billion using 2008 dollars (CDC, 2016). However, the Trust for

America's Health claims that number can run as high as $210 billion (Trust for America's Health, 2016). Putting that in perspective, it is roughly equal to the amount the government spent of debt interest in fiscal year 2015, or 6% of GDP (Congressional Budget Office, 2015). It is clear therefore that obesity makes up a large piece of staggering annual health care spending numbers in the US. With the increased stress of the system as a result of the Affordable Care Act, it is likely that the annual price tag of obesity will only continue to rise.

Higher taxes and premiums are the common short term method of paying for obesity's costs. However, these "solutions" typically fall particularly hard on the poorest demographics, and arguably only increase the overall inefficiencies present in the healthcare system. As an alternative solution, many policymakers have suggested public health improvements, in the form of increased education and the elimination of "food deserts." Yet these policies often see only moderate and vague results, rather than the broad change needed to stem the nationwide obesity crisis (Samina et al. 2008). Recently, there has been an increase in the amount of literature examining economic connections to obesity and the policies that could result from such connections.

A particularly interesting variable that has been studied for its connection to obesity is gas prices. The policy implications of research on the relationship between gas prices and obesity are significant, as they introduce a novel approach for mitigating the rise of obesity, possibly through the use of gasoline taxes. Gas prices are an important indicator of the macro-economy, particularly for their direct impact on most consumers. Courtemanche (2011) finds that higher gas prices lead to people walking more and driving less, as well as being more frugal with their food purchasing decisions. By this mechanism, Courtemanche finds that higher gas prices are associated with lower obesity rates in the years following the price fluctuation. However, Courtemanche et al. (2016) finds that when controlling for the other indicators of the macro-economy such as unemployment, gas prices lose their significance towards the obesity rate. It is possible that this outcome could be due to the complicated nature of the determinants of obesity.

The US Department of Health and Human services identifies three main facets that contribute to a high risk of being one being obese, all of which are supported in scientific literature (Wilding, 2001). The first of these is genetic predisposition: every single person has different metabolic rates based on genetics, and thus everyone is at a slightly different risk of becoming obese. Secondly, the dietary practices of a certain individual serve as a predictor of their chances of gaining enough weight to be considered obese. It is nearly universally understood that greater consumption of fatty and processed foods lead to a higher risk of one becoming obese. Finally, an individual's rate and intensity of physical activity can determine whether or not they are likely to become obese. Living a sedentary lifestyle without enough exercise is of chief concern to scientific researchers, as it makes the problems associated with overeating that much worse.

Examination of these contributions to high obesity rates suggests that a study may be more robust if it analyzes the effect of gas prices on one of the three primary determinants of obesity, rather than on obesity itself. In this way, if one could potentially find an association between gas prices and physical activity, for example, the suggestion of policy implications may be more specific and effective. Genetic predisposition poses a substantial challenge to study. It is highly variable, and cannot be concretely quantified as a control. Therefore, any study directly linking obesity itself to a variable such as gas prices would suffer from some form of omitted variable bias, as all the components of genetics cannot be accurately accounted for. Dietary practices and physical activity are significantly more workable, and can be effectively incorporated into a model relating obesity and gas prices.

Sen (2012) analyzes the relationship between gasoline prices and physical activity during the years 2003-2008. Her paper uses data on gasoline prices during the selected time window as an explanatory variable for changes in physical activity. In particular, Sen uses a measure of moderately intensive activity, such as walking and yardwork, that she believes would be the type of physical activity most likely to be affected by the income effects associated with changing gasoline prices. Sen finds that higher gas prices are associated with greater levels of moderate physical activity, concluding that policies related to gas prices (gasoline taxes in particular) may be worthy of consideration in the fight to stem the tide of obesity in the United States.

This paper builds largely on the research of Sen (2012), using the same general econometric framework: with gasoline prices as the explanatory variable and rates of moderate physical activity as the outcome variable. As predicted by Sen, it is expected that the higher the gas price, the greater the amount of physical activity undertaken by an individual. This paper also uses a set of controls adopted by Sen, including state and year fixed effects, socioeconomic characteristics, and the unemployment rate. Ruhm (1996) found that higher unemployment rates are associated with greater leisure time and higher rates of physical activity. This paper also adds a novel set of time controls, which are explained in further detail below.

This paper obtains data on physical activity from the American Time Use Survey (ATUS). ATUS contains variables corresponding to a variety of different physical activity measures, as well as a measure related to be metabolic equivalent of each level of activity. Data on gasoline prices is obtained from the Energy Information Administration (EIA).

This paper contributes to the literature by examining a larger time window than Sen (2012), the years 2003-2015. This period saw not only an overall increase in gas prices, but a major exogenous shock in the 2008 financial crisis, which saw major fluctuations in the price of gasoline. Examination of this shock will be useful in determining how rates of physical activity may change during periods of extreme fluctuations in gasoline prices. Sen finds that in times of moderate fluctuations during the selected time window, changes in physical activity are more pronounced.

This suggests that the effects of a recession, in which fluctuations are extreme and unpredictable, would be even more dramatic. This would have implication for ways policy makers could devise a response to mitigate whatever effect recessions may have on physical activity and by extension, obesity. Furthermore, Tekin, McClellan and Minyard (2013) found that the Great Recession did not have the effect on unemployment as predicted by Ruhm (1996). During the Great Recession, higher rates of unemployment were association in reductions in physical activity. This highlights the need for further research on how physical activity can change during a pronounced economic downturn.

This paper expands on Sen's econometric model by adding an additional set of controls. Sen cautions that her results do not account for the possibility that changing gas prices can have an effect on obesity outside of the short-run. Thus, her results cannot completely predict how physical activity may change in response to policies such as gasoline taxes, which may take years to have their desired effect. Jacobson, King and Yuan (2011) examined this potential long run relationship. In particular, they found that fluctuations in driving behaviors (such as those brought about by gas prices) can take up to six years to cause changes in obesity. It can be reasonably suggested that physical activity may not take quite as long to be affected. However, as it is a lifestyle change, it is likely that any behavior change as a result of the gas price may not necessarily occur in the same year. Therefore, a list on controls is added to empirical model that will address gasoline prices in the previous six years.

In the next chapter, this paper discusses a review of the literature on the connection between gasoline prices and physical activity. Chapter 3 presents the data and empirical methodology of this paper, with physical activity serving as the outcome variable and gasoline prices as the explanatory variable. Chapters 4 and 5 give the results and conclusions of this paper; it was found that although gasoline prices can affect physical activity in certain cases, that effect is minimal.

CHAPTER TWO

LITERATURE REVIEW

Despite a plethora of research in the scientific community on obesity and its consequences, until rather recently, the study of the economics of obesity was limited. As the impact and scale of the obesity epidemic grew, economists began to investigate potential drivers of the obesity rate that would have a more direct implication for policy makers. Gasoline prices emerged as an area of focus primarily due to their relationship with driving habits and food purchasing decisions, which may affect physical activity or diet. This paper does not directly study the link between gasoline prices and obesity, for reasons explained below. Instead, this paper focuses on physical activity, as research has shown that less activity and exercise increases an individual's chance of become overweight or obese (Grilo, 1994).

Courtemanche (2011) was at the time the most comprehensive study of the connection between gas prices and obesity, largely introducing the literature on the subject. Courtemanche finds a negative association between gasoline prices and obesity during the time window 1979 through 2004. He further suggests that 8% of the rise in obesity rates during the latter half of the twentieth century can be attributed to a simultaneous drop in real gas prices. Courtemanche uses a state-level measure of gasoline prices as his explanatory variable and individual BMI from the Behavioral Risk Factor Surveillance System (BRFSS) as his principle outcome variable.

Particularly insightful are the mechanisms for which Courtemanche uses to explain the effect that gas prices evidently have on obesity. His results provide evidence as to income and substitution effects associated with higher gas prices. In particular, higher gas prices produce an incentive for increased frugality among individuals or households. This leads to less dining out and more conscious food purchasing decisions, decreasing the likelihood of having a high BMI. Courtemanche also outlines the relationship between gas prices and physical activity, finding that higher prices at the pump lead to less driving, more walking and more exercising. Furthermore, Courtemanche cites the results of Frank, Andresen and Schmid (2004), which finds that a greater amount of time spent in a car (such as would arise from lower gas prices) increases the likelihood of obesity.

A major caveat in Courtemanche (2011) is potential economic confounding variables that are not controlled for. Courtemanche includes individual controls, but does not account for the effect of factors such as unemployment or real GDP. Courtemanche et al. (2016) finds that when numerous other economic variables are considered, the picture becomes increasingly difficult to address. Although gasoline prices retain the same negative association with obesity when run individually, when other variables such as household income and restaurant density are considered, the authors find that gas prices lose their significance. Due to the prevalent concerns regarding omitted variable bias, Courtemanche et al. (2016) concludes that the high number of potential determinants of obesity retract from a proper understanding of the effect that gasoline prices may have on BMI.

As explained in the previous section, the analysis of this paper focuses on the relationship between gasoline prices and rates of physical activity. This paper studies one of the major determinates of obesity rather than obesity itself primarily due to the concerns expressed in Courtemanche et al (2016). An approach of this manner would not require controls for restaurants and food prices and may provide results that are more concrete. The connection between variables of the macro-economy and rates of physical activity is documented by Cabane and Lechner (2014). In a broad survey of the literature, the authors find that a positive association between leisure time and levels of physical activity is supported by the existing research. More leisure time is associated with higher rates of unemployment that could arise during periods of economic downturn, which are often accompanied by fluctuations in the price of gasoline.

Hou et al. (2011) investigates the results of the Coronary Artery Risk Development in Young Adults (CARDIA) study, which recruited participants in four major US cities and assessed their physical activity rates and intensity. Making use of a longitudinal regression analysis, the authors linked the physical activity assessment to county level gasoline prices. Findings indicate a positive association between gasoline prices and physical activity, specifically activity that would not otherwise have been practiced by an individual. This may include walking to work or doing housework that would have otherwise been hired out. This paper also provided a general mechanism for how the relationship arises, based on the income and substitution effects described by Courtemanche (2011). Hou et al. argue that since gasoline consumption is responsive to price, people will adjust their habits in response to higher prices by decreasing how often they drive. This would be accompanied by a rise in physical activity.

The most comprehensive analysis of the effect of gas prices on physical activity currently is Sen (2012), going beyond Hou et al. (2011) by expanding research to the entire United States. In addition, the use of data from the American Time Use Survey (ATUS) provides a quantification of physical activity in the form of a metabolic equivalence (MET) score. The MET score allows for a differentiation of the intensity of physical activity, and the inclusion of activity that may not necessarily be thought of as exercise, such as housework. This allows Sen to determine if certain types of physical activity are more responsive to changing gas prices than others. Sen argues that the model used by Hou et al. (2011) suffers because it does not account for potential confounding variables. In her model, Sen adds a novel set of controls, including socio-economic characteristics, state unemployment rate, and state and time fixed effects, each of which may impact physical activity.

Sen (2012) finds evidence of a positive association between gas prices and physical activity in the time window 2003-2008. This relationship is primarily driven by increases in activity that is moderately intensive, such as house and yard work. Sen explains her results by concurring with Courtemanche (2011) on the existence of an income effect, as people become more frugal with their purchasing choices when gasoline prices are higher. In this way, they may choose to carry out basic household tasks themselves rather than hiring a third party. Sen also finds evidence of greater amounts of leisurely walking, running and bicycling, which would support the substitution effect. When determining which effect is greater, Sen reports that the effect of gasoline prices on walking and bicycling to work related activities is minimal at best. Therefore, the substitution effect may be less apparent due to inelasticity in the necessitation of driving. This suggests that high gasoline prices may not be enough to physically remove people from their cars and increase the use of public transportation.

Economic downturns have been of interest to behavioral economists for a long period of time. The effect that recessions have on leisure time, and its connection to physical activity, has been widely studied. Ruhm (1996) finds in a survey of US economic crises that high unemployment rates, characteristic of recessions, are associated with greater leisure time and as a result greater physical activity and overall health. It is possible then, that a recession would be beneficially for the obesity rate. However, gas prices traditionally tend to spike during a time of pending crisis, then fall significantly in the following months (US Dep. of Energy, 2017). The effect of recession-induced changes in gasoline price on physical activity must thus be determined empirically.

The Great Recession which resulted from the financial crisis of 2008 was the largest economic downturn since the Great Depression. It was a time of high unemployment, sluggish growth, and overall pessimism about the direction of the national and global economy. Tekin et al. (2013) find evidence that the relationship Ruhm (1996) outlined did not hold true in the years of the Great Recession, likely due to the sheer magnitude and scope of the crisis. Although the results varied demographically, Tekin et al. conclude that high levels of stress during the Great Recession may have outweighed the benefits that come from being unemployed. The findings of Sen (2012) show that it could be possible that quickly falling gas prices beginning in 2008 only exacerbated the fall in physical activity during the recession. On the other hand, since people as a whole were more cash-strapped during the crisis, the effect of gasoline prices may not have been as severe. Policy makers would benefit from research investigating what in fact did occur.

Sen (2012) cautions in her discussion that her results do not account for the potential long term effects of gasoline prices on physical activity. Behaviors can take time to adjust, so changes in an individual’s physical activity levels likely will occur sometime after the initial fluctuation, and not necessarily in the same year. If the prices follow a consistent trend in a certain direction, such as what occurred in 2014 following the fracking boom, individuals may respond rather slowly. Moreover, any change in BMI as a result of the changing physical activity would be even more drawn out. Jacobson, King and Yuan (2011) support the caution outlined by Sen. In their study of how miles driven (time spent in a car) affect obesity, the authors find that changes in BMI can take up to six years to pan out.

Sen provides distinct evidence for the effect gasoline prices have on physical activity, and the set of controls she uses strengthens the robustness of the data. This paper expands on the research of Sen (2012) by extending the observation window to include the years up to and including 2015. An interesting result reported by Sen is that changes in physical activity by individuals tended to be more pronounced during periods of extreme fluctuations in the gasoline price. By including years up to 2015, this paper captures the effects of the financial crisis of 2008, which was accompanied by a sharp drop in gasoline prices beginning in mid-2008 following the collapse of Bear Stearns.

This paper also adds to Sen (2012) by controlling for the long-term "lag" in behavioral changes following gasoline price fluctuations. This effect was outlined by Jacobson, King and Yuan (2011). This paper will add a set of variables to the econometric model controlling for gasoline prices up to six years in the past.

There is well-developed literature, particularly Sen (2012), documenting a positive association between gasoline prices and physical activity. Also, Courtemanche (2011) and Courtemanche et al. (2016) find evidence of a possible connection to the likelihood of an individual becoming overweight or obese due to changing gas prices. This paper expands on the current research by analyzing the effects of the financial crisis and Great Recession of 2008-2009. In addition, this paper investigates the potential long-term effects of gasoline price fluctuations on physical activity. The importance of a distinct understanding of these relationships is of utmost concern for policy makers wishing to ameliorate the nationwide obesity epidemic. If policies that raise the real price of gasoline, such as a gasoline tax, will potentially reduce the amount of time people spend in cars and increase their physical activity, they may serve a role in the fight against obesity.

CHAPTER THREE

DATA AND EMPIRICAL METHODOLOGY

This paper uses the same general econometric framework as Sen (2012). There is a lack of concrete variables documenting physical activity in the Behavioral Risk Factor Surveillance System (BRFSS), used by Courtemanche (2011). Therefore, this paper uses variables from the American Time Use Survey (ATUS) to represent the intensity of an individual's physical activity levels. Since the ATUS was first carried out in 2003, this paper uses data files from each of the years 2003-2015. The ATUS data is supplied under the umbrella of the Bureau of Labor Statistics.

The ATUS uses a fairly complex method of measuring physical activity. Activity types are coded into three tiers of detail. Tier one is the least specific, tier three the most specific. Each tier one code has a set of tier two codes within it, beginning with 01. Tier three codes are sorted into respective tier two codes in the same manner. The codes are then combined to create a six letter final code, which is used as the representation of the physical activity type. For example, a tier one code of 13 represents the broad category of "sports, exercise and recreation." Within this tier one code of 13, a tier two code of 01 represents "active participation in sports, exercise and recreation." Finally, at the most detailed level, a tier three code (within the tier one code of 13 and tier two code of 01) of 14 represents "golfing." Therefore, a code of 130114 indicates that the participant played golf. A specific code only has the value respective to the tier above it. In other words, "14" is only golfing if it is under the tier one "13" and tier two "01." A full list of these coding categories and their values is available from Hamermesh, Frazis and Stewart (2005).

This system, though detailed and comprehensive, is somewhat challenging to empirical study. Tudor-Locke et al. (2009) created the metabolic equivalence, or MET score. The MET score quantifies each of the ATUS coding lexicons into values that represent a certain level of physical activity. The MET scale is classified as follows. Scores between 1 and 3 indicate lightly intensive activity, scores of 3-6, moderately intensive, and scores greater than 6 as vigorous. Scores of less than 1 indicate inactivity such as sleeping. The quantification of activity in this manner allows for an accurate representation of the different levels of activity and provides a way to determine which types may be more responsive to gasoline price fluctuations.

This paper considers several measures of physical activity to serve as an outcome variable. The first of these is an average measure of overall MET score per individual. This measures how active people are as a whole during a 24-hr period. The other categories are measures of specific activity categories, leisure time walking, bicycling, and running, playing with children, Moderately Energy Intensive Household Work (MEIHW), and Moderately Energy Intensive Physical Activity (MEIPA). These activities are considered both as dummy variables and as variables weighted by duration.

The ATUS database also provides several individual level control variables that this paper will use to increase robustness of the data. These variables include demographic characteristics of the respondent such as race, gender, age, education and income. With the exception of age, dummy variables were created for each individual case within these categories. Details on how these dummy variables were constructed is shown in Table 1. This paper also uses variables on whether the respondent was married or had a partner at this time of the survey, as well as how many children they had and if they had a child under

6 living in the household. Finally, a binary variable was used to indicate whether the respondent lived in a metropolitan area. All of these variables may affect physical activity.

Data on gasoline prices is obtained from the Energy Information Administration (EIA). The measurement used by this paper as outlined by the State Energy Data System (SEDS) is the motor gasoline average price in all sectors. This is represented by the code "MGTCD." This measurement is obtained annually for the years 1997-2015 for each state. Going back to 1997 allows for an analysis of the long-term effect of changing gasoline prices for all years in the window including 2003. These prices will be linked to the ATUS data by state and time of the survey. This paper also controls for state level characteristics as referenced by Sen (2012) and Ruhm (1996). Ruhm finds that unemployment is positively associated with more leisure time, which could in turn effect physical activity levels. Unemployment data is obtained from the Iowa division of the Bureau of Labor Statistics.

<u>Equation 1:</u> Simple Econometric Model

$$\begin{aligned} A_{ist} = {} & \beta_0 + \beta_1 pgas + \beta_{2-7} pgas_{t-x} + \beta_8 ump + \beta_9 race + \beta_{10} gender + \beta_{11} age \\ & + \beta_{12} age^2 + \beta_{13} nchild + \beta_{14} childu6 + \beta_{15} marital\ status + \beta_{16} educ \\ & + \beta_{17} income + \beta_{18} metarea + \beta_{19} state + \beta_{20} year + \beta_{21} season \\ & + \beta_{22} dayofweek + e \end{aligned}$$

The econometric model this paper uses is shown above. A_{ist} is the particular type of activity (overall MET, leisure time walking, bicycling, and running, playing with children, MEIHW, and MEIPA) for individual respondent *i* who lives in state *s* at time *t*. With the exception of overall MET, this variable will either measure participation in a particular activity or the duration that they engaged in that activity. The primary explanatory variable is gasoline price in the year of the survey, represented by *pgas*. The controls for past gasoline prices are represented by $pgas_{t-x}$, x is the numbers of years following the date of the survey, ranging from 1-6. *S*tate level control variables include unemployment rates, population, precipitation, and climate. The individual controls include race, gender, age, number of children, children under 6 in the household, spouse status, education, income and whether the respondent lives in a metropolitan area. *State, year*, *season* and *dayofweek* are fixed effects controlling for the state the respondent was from and the year, season and day of the week during which the survey was carried out. A full list of variable descriptions is shown in Table 1.

CHAPTER FOUR

RESULTS

A series of different regressions were run analyzing how gasoline prices may affect physical activity. Dependent variables varied depending on the parameter being observed. There were two general categories, the first consisting of four different specific activity conditions, the second a measure of overall average MET score.

Each of the four different activity conditions that made up the first category were derived from the MET score of a particular activity. The first group of activities considered were the leisure time a respondent spent walking, running and bicycling, which was created using the ATUS tier lexicon. For example, the activities considered were included in the ATUS section 'Sports, Exercise and Recreation,' coded with a tier one value of 13. The second activity condition was how much time a respondent spent playing with children, also created using the activity tier system. Third was moderately energy intensive household work (MEIHW), designated as being a household activity with a MET score greater than or equal to three. The final condition in the first group was a measure of overall moderately energy intensive physical activity (MEIPA), designated as being any activity with an MET score greater than or equal to three.

The second category of activities was a measure of the overall average MET score for a respondent weighted by the duration of the activities undertaken. This measure represented the average intensity and duration for a particular respondent in a given 24-hour period. In other words, the more energy intensive activity an individual partook in during a given day, the higher the overall average MET score.

Each condition in the first category (the specific activities) was regressed on gasoline prices (in dollars per gallon) using both a Linear Probability and OLS model. The linear probability models measured participation in an activity, as dummy variables were created for whether a respondent had engaged in the particular activity during the time of the survey. No participation models were created for the second category (average MET score), as the variable was continuous. The standard OLS models were weighted by duration (in minutes) giving a measure of the time a respondent spent engaging in a particular activity. Each regression model contained the demographic controls for race, marital status, gender, age and age squared, income, education, children in the household, metropolitan area, and unemployment. Each model also contained fixed effect controls for state, season and day of the week. A separate analysis was done substituting a state-time trend interaction term for the traditional year fixed effects. For all of the regressions, standard errors were clustered at the state level.

The model proposed in the previous section also contained controls to account for the lag effect of gasoline price fluctuations. These controls consisted of data on gasoline prices in the years prior to the conduction of the survey. Early regressions found that in each of the models in which they were used, the lag price effects were not significant. As a result, they were dropped from the final models included in these results. Descriptive statistics are shown in Table 2.

Regression estimates for the first category of activity conditions are shown in Table 3. Columns 1 and 3 contain the models that estimated participation in an activity and columns 2 and 4 contain models that estimated the duration of activities. Columns 3 and 4 use the state interacted time trend, while 1 and 2 use the traditional year fixed effects.

On the left side of the table are the list of the four different activity conditions, leisure exercise, playing with children, MEIHW, and MEIPA. All of the models are regressed on real gasoline prices for that state and year. For moderately energy intensive household work, the only significant value was reported in the participation-time trend regression (Column 3). For this condition, a $1 increase in gasoline price was associated with a roughly 1% decrease in likelihood that the respondent participated in an activity that classifies as MEIHW. Similar results were reported for overall MEIPA, with a $1 change in gasoline price associated with about a 2% decrease in likelihood of a respondent engaging in MEIPA (Column 3). However, in all the other models (columns 1, 2 and 4), none of the coefficients showed significant effects. This suggests that people were slightly less likely to engage in an activity that qualifies as MEIHW or MEIPA, when gas prices are high. In addition, the results show that duration of these activities was not affected by gas price changes. Gasoline price was also not found to have a significant effect on leisure time walking, running or bicycling, nor on the amount of time respondents spent playing with children. This was observed for all of the different models.

Results suggested that overall average MET score was more likely to be affected by gasoline price, and are reported in Table 4. When using the state interacted time trend model, a $1 increase in the per gallon price of gasoline was associated with an increase in overall average MET score of about .004 units. In other words, following a $1 increase in gasoline price per gallon, average MET score increases roughly .04%. This effect, though minimal suggests that people as a whole may be more active when gasoline prices are higher, meaning that they increase both the intensity and duration of their current activities, rather than engaging in new ones.

Appendix A1 presents the full regression output for overall MET score controlling for the two-year lag, with all the control variables listed. The majority of the controls were significant at the 1% level, with the exception of unemployment rate, suggesting that it is not related to any change in physical activity. For the variables representing children in the household, both a greater number of children of any age in the house and the presence of children under six years of age were associated with increases in MET scores. Having a spouse and being of an older age were also associated with greater MET scores. Living in a metropolitan area were associated with lower MET scores. Among the racial controls, black and Hispanic respondents were less likely to have higher MET scores than white respondents. Those with lower incomes were less likely to have higher MET scores than those of higher incomes. Furthermore, greater education levels were associated with lower MET scores, but the effect became smaller and more positive as education level increased. Men were associated with having higher overall MET scores than women.

Overall, the effect of gasoline prices on physical activity is statistically strongest when the type of activity considered is average overall MET. Weaker results are reported for the more specific activities, indicating that fluidity of behavior in response to gas price fluctuations may be minimal. In addition, these results show that people may be more inclined to increase the duration and intensity of their current activities, rather than to begin engaging in new types. These findings differ slightly from Sen (2012), which found a positive relationship between MEIPA and gasoline price and significant results for several of the other conditions. Sen (2012) also did not find a significant relationship between gas prices and time spent playing with children. This paper differed from Sen (2012) in that it expanded the time window to 2015 and controlled for the effect of past gas prices, even though the latter of these proved to be insignificant. Expanding the data from 2008 to 2015 exhibits the financial crisis and recent drops in oil prices, which could potentially affect the results.

CHAPTER FIVE

DISCUSSION

This paper investigated the relationship between real gasoline prices and rates of physical activity. Following the findings of Sen (2012), it was hypothesized that as gasoline prices rise, physical activity would also rise by the means of an income and substitution effect. Using data from the American Time Use Survey (ATUS), physical activity codes were quantified using MET scores, which provided the outcome measure of physical activity. This paper used two broad measures of physical activity; several specific conditions and a measure of overall MET score. Since obesity is correlated with physical activity rates, the implication of this paper was to address possible economic means for addressing the obesity epidemic in the United States.

This paper found evidence of a positive relationship between real gasoline price and overall average MET score. This relationship however, was minimal, at only a fraction of a percent rise in MET score per $1 rise in gasoline price. Nonetheless, the results suggest that people are more active on a broad scale when gasoline prices are higher. Despite the evidence of a relationship between overall physical activity and gas price, when analyzing the specific activity measures, the effect of gasoline price was largely minimal and was insignificant. In this way, people may be more likely to increase the overall intensity and duration of activities they already engage in, rather than to add new activities to their day.

Overall MET scores, a broad category, was the only condition this paper found to be positively associated with higher gasoline prices. This seems to suggest that changes in gasoline prices are more likely to affect overall physical activity within a 24-hour period, rather than any one type of activity in particular. The lack of specificity may imply that other confounding factors are contributing to the rise in activity levels. This is contradictory to Sen (2012), which found positive relationships between gasoline prices and all the activity categories except playing with children for the years 2003-2008. Without evidence of specific relationships between gasoline prices and physical activity, it is hard to link these results to potential policy proposals.

The results of this paper suggest that the findings of Sen (2012) may have become less relevant in recent years. The findings of this paper are more consistent with those of Courtemanche et al. (2016), which suggested that fluctuations in gasoline prices do not significantly impact obesity rates. Courtemanche (2011) had found evidence of a negative relationship between gasoline prices and obesity rates, results more in line with Sen (2012). This seems to suggest that the effect of gasoline price on physical activity and obesity has dissipated since 2008. This could potentially be due to the rapid fluctuations in gasoline price that occurred during the 2008 financial crisis or the recent global crude oil glut. These rapid fluctuations may have made it more difficult for people to adjust their physical activity behavior over the short term.

Sen (2012) proposed the use of gasoline taxes as an economic policy to address obesity. The fact that the effect of gasoline price was not significant for the specific categories (which were often of greater activity scores), indicates that using gasoline taxes as a potential combat to obesity may be problematic. As explained above, this paper did find evidence that overall activity levels tend to have a positive relationship with gasoline prices. Nonetheless, it is more difficult to determine exactly what specific activities respond the most to fluctuations in the price of gas. In this way, it is challenging to know if activities more closely linked with lower BMI (such as intense exercise), would be the ones actually affected by gasoline price changes, such as a gas tax.

The findings of this paper indicate that policymakers may have a tough time arguing for increasing the gasoline tax, a typically divisive issue. Although broad measures of activity were found to be related positively to gasoline price, this paper found little evidence to suggest that gasoline taxes would actually lead to a decrease in obesity. Furthermore, these taxes would potentially have adverse effects on the economy and transportation sector that would be too high to justify. In addition, these taxes would presumably be paid by the entire country, whether they are obese or not, so healthy individuals may be penalized unfairly. Gasoline taxes may be more attractive if they can be internalized to affect only those with high BMIs, but this would present numerous ethical controversies.

Ultimately, the somewhat ambiguity of the results of this paper highlight the need for future research on this topic. What would be most beneficial is an expansion of the physical activity categories beyond those of this paper, to include nearly every type of physical activity in the ATUS coding lexicon. This would allow for a more detailed analysis into which activities are actually affected by changes in gasoline prices. If policymakers could say that a certain activity, already known to be correlated with obesity rates, was significantly related to gasoline price, they may have more ammunition when pitching gasoline taxes.

The national profile of obesity also presents an area for future research. Southern states in particular suffer from higher rates of obesity and lower amount and duration of physical activity. These states also have higher rates of vehicle miles traveled (VMT), a measure of how often people drive. Therefore, it is possible that physical activity levels in southern states will be more responsive to changes in gasoline prices. A state-by-state analysis of the relationship tested in this paper and in Sen (2012) may present results that are more useful. Furthermore, this would be a way to ensure that a gasoline tax is paid for exclusively by the people most slated to benefit from it.

This paper found evidence of an association between higher gasoline prices and higher levels of overall physical activity. These findings however, may not be specific enough to justify gasoline taxes such as those proposed by Sen (2012). Nonetheless, this paper provides a gateway to further research into a possible economic avenue to addressing the nation's obesity crisis.

NOTES

Since this paper was in some respects an expansion of Sen (2012), an attempt was made to replicate her results for the years 2003-2008. This was not successful; likely due to the climate data used by Sen (2012) no longer being available at the time of this study.

BIBLIOGRAPHY

Adult Obesity Causes and Consequences, Centers for Disease Control and Prevention, 15 Aug. 2016, https://www.cdc.gov/obesity/adult/causes.html. Accessed 13 Feb. 2017.

Adult Obesity Facts, Centers for Disease Control and Prevention, 1 Sept. 2016, https://www.cdc.gov/obesity/data/adult.html. Accessed 28 Feb. 2017.

American Heart Association. *Understanding the American Obesity Epidemic.* http://www.heart.org/HEARTORG/HealthyLiving/WeightManagement/Obesity/Understanding-the-American-Obesity-Epidemic_UCM_461650_Article.jsp#.WCifPIMrJOQ.

Brownson, Ross C., Tegan K. Boehmer, and Douglas A. Luke. "Declining rates of physical activity in the United States: what are the contributors?."*Annu. Rev. Public Health* 26 (2005): 421-443.

Cabane, Charlotte, and Michael Lechner. "Physical activity of adults: a survey of correlates, determinants, and effects." *ZEW-Centre for European Economic Research Discussion Paper* 14-088 (2014).

Campbell, T. Colin, and Thomas M. Campbell. "The china study." (2005): 1.

Courtemanche, Charles J., Joshua C. Pinkston, Christopher J. Ruhm, and George L. Wehby. "Can Changing Economic Factors Explain the Rise in Obesity?." *Southern Economic Journal* (2016).

Courtemanche, Charles. "A silver lining? The connection between gasoline prices and obesity." *Economic Inquiry* 49, no. 3 (2011): 935-957.

Eric A. Finkelstein, Justin G. Trogdon, Joel W. Cohen and William Dietz, "Annual Medical Spending Attributable To Obesity: Payer-And Service-Specific Estimates," Health Affairs 28, no.5 (2009):w822-w831

Frank, Lawrence D., Martin A. Andresen, and Thomas L. Schmid. "Obesity relationships with community design, physical activity, and time spent in cars." *American journal of preventive medicine* 27, no. 2 (2004): 87-96.

Gasoline and Diesel Fuel Update, Energy Information Administration, 2 Oct. 2017, https://www.eia.gov/petroleum/gasdiesel/. Accessed 2 Oct. 2016.

Grilo, C. M. "Physical activity and obesity." *Biomedicine & pharmacotherapy* 48, no. 3 (1994): 127-136.

Hamermesh, Daniel S., Harley Frazis, and Jay Stewart. "Data watch: The American time use survey." *The Journal of Economic Perspectives* 19, no. 1 (2005): 221-232.

Harrison, Roger A., Islay Gemmell, and Richard F. Heller. "The population effect of crime and neighbourhood on physical activity: an analysis of 15 461 adults." *Journal of epidemiology and community health* 61, no. 1 (2007): 34-39.

Hou, Ningqi, Barry M. Popkin, David R. Jacobs, Yan Song, David K. Guilkey, Ka He, Cora E. Lewis, and Penny Gordon-Larsen. "Longitudinal trends in gasoline price and physical activity: the CARDIA study."*Preventive medicine* 52, no. 5 (2011): 365-369.

Jacobson, Sheldon H., Douglas M. King, and Rong Yuan. "A note on the relationship between obesity and driving." *Transport Policy* 18, no. 5 (2011): 772-776.

Ogden CL, Carroll MD, Fryar CD, Flegal KM. Prevalence of obesity among adults and youth: United States, 2011–2014. NCHS data brief, no 219. Hyattsville, MD: National Center for Health Statistics. 2015.

P.H. Wilding, J. (2001), Causes of obesity. Pract Diab Int, 18: 288–292. doi:10.1002/pdi.277

Raja, Samina, Changxing Ma, and Pavan Yadav. "Beyond food deserts measuring and mapping racial disparities in neighborhood food environments." *Journal of Planning Education and Research* 27.4 (2008): 469-482.

Ruhm, Christopher J. *Are recessions good for your health?*. No. w5570. National bureau of economic research, 1996.

Segal, Laura M., Jack Rayburn, and Alejandra Martin. "The State of Obesity, 2016." *Trust for America's Health*(September 2016).

Sen, Bisakha. "Is there an association between gasoline prices and physical activity? Evidence from American time use data." *Journal of Policy Analysis and Management* 31, no. 2 (2012): 338-366.

Sen, Bisakha, Nitish Patidar, and Sheikilya Thomas. "A silver lining to higher prices at the pump? Gasoline prices and teen driving behaviors." *American journal of health promotion* 28, no. 3 (2014): 146-154.

Tekin, Erdal, Chandler McClellan, and Karen Jean Minyard. *Health and health behaviors during the worst of times: evidence from the Great Recession*. No. w19234. National Bureau of Economic Research, 2013.

The Federal Budget in 2015: An Infographic, Congressional Budget Office, 6 Jan. 2016, https://www.cbo.gov/publication/51110. Accessed 19 Oct. 2016.

The State of Obesity 2016: Better Policies for a Healthier America, Trust for America's Health, Sept. 2016, healthyamericans.org/reports/stateofobesity2016/. Accessed 19 Feb. 2017.

Timm, Nathan L., Jacqueline Grupp-Phelan, and Mona L. Ho. "Chronic ankle morbidity in obese children following an acute ankle injury." *Archives of pediatrics & adolescent medicine* 159.1 (2005): 33-36.

Tucker, Patricia, and Jason Gilliland. "The effect of season and weather on physical activity: a systematic review." *Public health* 121, no. 12 (2007): 909-922.

Tudor-Locke, Catrine, Tracy L. Washington, Barbara E. Ainsworth, and Richard P. Troiano. "Linking the American Time Use Survey (ATUS) and the compendium of physical activities: methods and rationale." *Journal of Physical Activity and Health* 6, no. 3 (2009): 347-353.

Understanding the American Obesity Epidemic, American Heart Association, 9 Mar. 2016, www.heart.org/HEARTORG/HealthyLiving/WeightManagement/Obesity/Understanding-the-American-Obesity-Epidemic_UCM_461650_Article.jsp#.WQOe-xPyuUk. Accessed 13 Feb. 2017.

TABLES AND FIGURES

Table 1: Variable Descriptions

Variable Name	Description (Source)
General	
A_{ist}	Either participation in or duration of particular activity carried out by individual *i* during time *t* and in state *s*
pgas	State level gasoline price for the year in which the survey was given out (EIA)
$pgas_{t-x}$	State level gasoline price for the previous 1-6 years (EIA)
State Level	
ump	State level unemployment rate for the survey year (BLS)
Individual Level	
race	Race of respondent (ATUS), dummies were created for white, black, Hispanic, and other
gender	Gender of respondent (ATUS), dummies were created for male and female
age	Age of respondent (ATUS)
age^2	Age of respondent squared
nchild	Number of children respondent has (ATUS)
childu6	Presence of children under 6 in the household (ATUS)
spouse	Marital status of respondent (ATUS), dummies were created for married and unmarried partners
educ	Set of binary variables indicating level of education of individual (ATUS), dummies are created for lower than high school, high school, some college, college and graduate school
income	Respondent's family income (ATUS), eight different income categories are created in increasing order, a category was also created for missing income variables (see Appendix A1)
metarea	Binary variable indicating whether respondent lives in a major metropolitan area (ATUS)
Fixed Effects	
state	Binary variable for state of respondent's residence
year	Binary variable indicating the year of the survey
season	Binary variable indicating the season the survey was done
dayofweek	Variable indicating the day of the week

Table 2: Descriptive Statistics

Variable	Observations	Mean	Standard Deviation	Min	Max
METa	170842	1.60	0.26	0.92	4.50
MEIPAd	170842	77.23	120.18	0.00	1405.00
MEIHWd	170842	48.46	96.98	0.00	1405.00
ltwbrd	170842	4.19	20.18	0.00	840.00
pwcd	170842	7.98	37.32	0.00	840.00
Real Gas Price	170842	2.26	0.44	1.34	3.47
Unemployment Rate	170842	6.58	2.09	2.30	14.90
Number of Children	170842	0.87	1.15	0.00	12.00
Child under 6	170842	0.17	0.38	0.00	1.00
Spouse	170842	0.50	0.50	0.00	1.00
Unmarried Partner	170842	0.03	0.18	0.00	1.00
Age	170842	46.89	17.70	15.00	85.00
Age^2	170842	2512.43	1754.70	225.00	7225.00
Male	170842	0.44	0.50	0.00	1.00
Female	170842	0.56	0.50	0.00	1.00
Metropolitan Area	170842	0.82	0.39	0.00	1.00
Fall	170842	0.24	0.43	0.00	1.00
Winter	170842	0.26	0.44	0.00	1.00
Spring	170842	0.25	0.43	0.00	1.00
Summer	170842	0.25	0.43	0.00	1.00
Lower than High School	170842	0.16	0.37	0.00	1.00
High School	170842	0.26	0.44	0.00	1.00
Some College	170842	0.18	0.38	0.00	1.00
College	170842	0.29	0.45	0.00	1.00
Graduate School	170842	0.11	0.32	0.00	1.00
Black	170842	0.13	0.34	0.00	1.00
Hispanic	170842	0.13	0.34	0.00	1.00
Other Race	170842	0.05	0.22	0.00	1.00
income_miss	170842	0.08	0.27	0.00	1.00
income1	170842	0.04	0.20	0.00	1.00
income2	170842	0.06	0.23	0.00	1.00
income3	170842	0.07	0.26	0.00	1.00
income4	170842	0.11	0.32	0.00	1.00
income5	170842	0.11	0.31	0.00	1.00
income6	170842	0.16	0.37	0.00	1.00
income7	170842	0.22	0.41	0.00	1.00
income8	170842	0.14	0.35	0.00	1.00

Table 3: Regression estimates for selected physical activity conditions and gasoline prices ($ per gallon)

Real Gasoline Prices for that State and Year	(1) Participation	(2) Duration	(3) Participation	(4) Duration
Leisure-time walking,	0.0379	2.011	-0.00514	-0.0398
bicycling, running	(1.419)	(1.092)	(-1.649)	(-0.191)
Playing with children	0.0104	-0.485	-0.000577	0.0821
	(1.050)	(-0.350)	(-0.358)	(0.325)
MEIHW[1]	-0.0257	-3.583	-0.0123***	0.134
	(-1.170)	(-0.869)	(-3.691)	(0.197)
Overall MEIPA[1]	0.00687	-1.008	-0.0167***	0.438
	(0.312)	(-0.209)	(-3.931)	(0.452)
State fixed effects	Yes	Yes	Yes	Yes
Day of week fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes		
Season fixed effect	Yes	Yes	Yes	Yes
State * time trend			Yes	Yes

N=170,842

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Gasoline prices are for a given state in a given year in dollars per gallon. None of the models control for lagging gasoline prices as they were found to be insignificant. All models control for gender, race, age and age squared, marital status, income, children in the household, metropolitan area, and education. Fixed effects for state, season and day of week are included for all models. Columns 3 and 4 substitute a state interacted time trend for traditional year fixed effects. Population weights are provided using ATUS weight the estimates, and standard errors are clustered at the state level.

[1]MEIHW and MEIPA denote moderately energy intensive household and total physical activity. This corresponds to an MET score of 3 or higher.

Table 4: Regression estimates for overall average MET score and gasoline prices ($ per gallon)

	(1)	(2)
	OLS Model	
Real Gasoline Prices for that State and Year	0.0101 (0.861)	0.00445** (2.544)
State fixed effects	Yes	Yes
Day of week fixed effect	Yes	Yes
Year fixed effect	Yes	
Season fixed effect	Yes	Yes
State * time trend		Yes

N=170,842

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Gasoline prices are for a given state in a given year in dollars per gallon. None of the models control for the lag effect, as it was found to be insignificant. All models control for gender, race, age and age squared, marital status, income, children in the household, metropolitan area, and education. Fixed effects for state, season and day of week are included for all models. Columns 2 and 4 substitute a state interacted time trend for traditional year fixed effects. Population weights are provided using ATUS weight the estimates, and standard errors are clustered at the state level.

APPENDIX A1

Full Regression output for average MET Regression

VARIABLES	(1) full
METa	
Real Gasoline Price	0.0292**
	(2.310)
Real Gasoline Price Year t-1	-0.0171
	(-0.776)
Real Gasoline Price Year t-2	-0.0376
	(-1.430)
Unemployment Rate	-0.000424
	(-0.472)
Number of Children	0.00707***
	(7.755)
Child under 6 in household	0.0444***
	(16.58)
Married Partner	0.0162***
	(8.392)
Age	0.00954***
	(31.00)
Age squared	-0.000119***
	(-40.15)
Male	0.0334***
	(15.72)
Metropolitan Area	-0.0149***
	(-5.343)
Fall	-0.0220***
	(-7.350)
Winter	-0.0483***
	(-12.83)
Spring	-0.0152***
	(-4.803)
Lower than High School	-0.0772***
	(-17.63)
High School	-0.0508***
	(-15.64)
Some College	-0.0434***
	(-11.20)
College Graduate	-0.0192***
	(-7.472)
Black	-0.0611***
	(-23.55)
Hispanic	-0.00824*
	(-1.777)
Other Race	-0.0262***
	(-7.105)
Income status missing	-0.0296***
	(-7.379)
Income Level 1[1]	-0.106***
	(-17.48)
Income Level 2[1]	-0.102***
	(-26.33)
Income Level 3[1]	-0.0837***
	(-21.64)
Income Level 4[1]	-0.0565***
	(-17.09)
Income Level 5[1]	-0.0409***
	(-9.027)
Income Level 6[1]	-0.0268***
	(-8.779)
Income Level 7[1]	-0.0119***
	(-3.572)

Gasoline prices are for a given state in a given year in dollars per gallon. This regression includes the gasoline price controls for the previous two years. Fixed effects for state, season and day of week are included for all models. The traditional year fixed effects are used for this model. Population weights are provided using the ATUS weight, and standard errors are clustered at the state level.

[1]Income levels are as follows: 1 (less than $5,000-$7,499) ; 2 ($7,500-$12,499); 3 ($12,500-$19,999); 4 ($20,000-$29,999); 5 ($30,000-$39,000); 6 ($40,000-$59,000); 7($60,000-$99,999); 8 ($100,000-$150,000 and greater)