Is There An Association Between Gasoline Prices & Physical Activity?Evidence from American Time Use Data.

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Abstract

Obesity is epidemic in the U.S, and there is an imperative need to identify policy tools that may help fight this epidemic. A recent paper in the economics literature finds an inverse relationship between gasoline prices and obesity-risk --- suggesting that increased gasoline prices via higher gasoline taxes may have the effect of reducing obesity prevalence. This study builds upon that paper. It utilizes cross-sectional time-series data from the American Time Use Survey over 2003-2008, utilizes the increases that occurred in gasoline prices in this period due to Hurricane Katrina and to the global spike in gasoline prices as a 'natural experiment', and explores how time spent by Americans on different forms of physical activity is associated with gasoline price levels.

Economic theory suggests that higher gasoline prices may alter individual behavior both via a 'substitution effect' whereby people seek alternatives to motorized transportation, and an 'income effect' whereby the effect of higher gasoline prices on the disposable family budget lead people to make various adjustments to what they spend money on. The latter may lead to some increase in physical activity (for example, doing one's own yard work instead of hiring help), but may also lead to decreases in other physical activities that involve expenses, such as team sports or work-outs at the gym. Thus, ultimately, the relationship between gasoline prices and physical activity must be empirically determined.

Results from multivariate regression models with state and time fixed-effects indicate that higher gasoline prices are associated with an overall increase of physical activity that is at least moderately energy intensive. The increases are most pronounced in periods where gasoline prices fluctuate more sharply. These results appear robust to a number of model specifications. One of the major components of this increase appear to be an increase in housework that is at least moderately energy intensive – such as interior and exterior cleaning, garden and yard work, etc. This tentatively suggests that there is an 'income effect' of higher gasoline prices. However, the increases in physical activity associated with increased gasoline prices are weaker among minorities and low socioeconomic status (SES) individuals. Hence, while a policy which increases gasoline prices via raised gasoline taxes may have benefits in terms of increasing overall physical activity levels in the U.S., one concern is that these benefits may not accrue to low SES individuals to the same extent as to their higher SES counterparts.

Introduction

The increase in obesity rates in the U.S. over the past few decades is well documented (Flegal et al, 2002). The Centers for Disease Control and Prevention (CDC) reports that obesity among adults increased from 14.6 percent in 1971-74 to 32.2 percent in 2003-2004 and for children aged 6 to 11, the percentage increased from 4 to 18.8 percent over the same period. This increase in obesity rates has been experienced across the socio-economic spectrum, by all races, both sexes, and all educational levels.[2] Obesity is linked to a wide range of comorbidities and enhanced risk of death (Flegal et al, 2005), and is among the leading causes of preventable deaths in the nation (McGinnis & Foege, 1993; Allison et al., 1999; Greenberg et al, 2007). By some estimates it accounts for 10 percent or more of the nation's healthcare costs (Koplan & Dietz, 1999). While there is some recent evidence that obesity rates may be stabilizing (Ogden et al. 2007, Ogden et al, 2008), its wide prevalence would continue to make it a national health concern even if the rates were to stabilize at their current levels.

There continues to be an imperative need to find effective policies that can help combat the obesity epidemic. The necessity for identifying such policies have received fresh impetus since First Lady Michelle Obama launched the 'Let's Move' initiative, which aims to reverse the epidemic of obesity among children in a generation (http://www.letsmove.gov/), via a combination of tools such as increased physical activities and developing more healthy eating habits.

A recent paper in the economics literature, by Courtemanche (2010), finds a significant association between lower gasoline prices and increased risk of obesity over 1979-2004. The findings from this paper also suggest that lower gasoline prices are associated with less frequent walking and bicycling, as well as more eating out. While the role of gasoline prices has previously been studied in context of motor vehicle

[2] While obesity rates have increased across all socio-demographic groups, there are disparities in the levels of prevalence. For example, obesity rates among non-Hispanic blacks and Hispanics are higher than those among non-Hispanic whites (Hedley et al 2004), and also higher among those with lower income and educational levels (Schoenborn et al, 2002).

fatalities, and the question of whether gasoline prices in the U.S. are "too low" has been debated in context of topics like climate change, to our knowledge the role of gasoline prices in context of obesity and obesogenic behaviors is largely unexplored. The findings by Courtemanche (2010) open up a potentially new area of research – exploring avenues via which changes in gasoline prices might lead to changes in different obesogenic behaviors, and understanding whether increased gasoline prices (via higher gasoline taxes) may be a potential policy tool to help combat the obesity epidemic. However, Courtemanche rightly cautions against extrapolating his results to a period when real gasoline prices were rising, since the relationship between gasoline prices and obesity or obesogenic behaviors may not be symmetric. This emphasizes the need to extend this research by considering a period when real gasoline prices were exhibiting increases.

This paper explores the associations between higher gasoline prices and a range of different physical activities among the U.S. population aged 15 and older, over 2003-2008. The paper exploits the fluctuations in gasoline prices that occurred in this period due to Hurricane Katrina, and then the spikes in global gasoline prices in 2007-2008 as a 'natural experiment', and explores whether engagement in different physical activities change when gasoline prices increase. Cross-sectional time series data from the American Time Use Survey (ATUS) for 2003-2008 is used. Regression models with state and time effects and other demographic and socio-economic controls are estimated to explore the association between higher gasoline prices and individual level physical activities. Results show that increased gasoline prices over this time-period are, indeed, associated with increases in a range of specific physical activities, and an overall increase in 'moderately energy intensive' physical activity – defined as activities with a 'metabolic equivalence' (MET) score of 3 or higher (Tudor Locke et al, 2009). However, the associations are weaker for minorities and those with relatively low socio-economic status. Therefore, results in this paper support the idea that increasing gasoline prices via increased gasoline taxes may indeed be a potential tool for reducing the obesity epidemic, but with the caveat that the tool may have less success reducing obesity rates among those with low socio-economic status than their higher socio-economic status counterparts.

Background & Conceptual Model.

Ultimately, obesity and overweight are largely outcomes of the imbalance between intake and usage of calories (Koplan & Dietz, 1999). While part of the trend of increase in obesity rates has been ascribed to the increasing availability of relatively cheap and calorically dense processed foods and increased caloric intake over past several decades (Frazao, 1999; Cutler et al, 2003), decline in physical activity is also deemed to be a contributing factor. The past century has seen a steady decrease in the need for physical labor in the workplace (Cutler et al, 2003), but with insufficient increases in physical activity in non-work related spheres to compensate. Reduced energy expenditure in housework (due to labor saving devices), the preponderance of cars as means of commuting, and the growing popularity of sedentary leisure-time activities such a television watching – have all contributed to the trend of overall decline in levels of physical activity in the U.S. population (Brownson et al, 2006). This decline in physical activity corresponds closely to the increase in prevalence of overweight and obesity. Moreover, minority groups who experience the highest rates of obesity -- African-Americans, Hispanics and Native-Americans—are also the minority groups who report the highest levels of inactivity (ALR, 2008). The CDC reports that more than 50 percent of adults in the nation fail to meet the recommended levels of overall physical activity. There has been a very slight increase in the percentage of the population who reported meeting the 'recommended' levels of physical activity – which is at least 30 minutes of moderate activity 5 times a week, or 20 minutes of vigorous activity 3 times a week -- between 2001 and 2008 (see Figure 1), but more than 50 percent of the population still do not meet that recommended level of activity.[3] The proportion of the adult population reporting no leisure-time physical activity at all has remained within the range of about 23.9-25.1 percent since 2002.[4]

[3] Detailed tables can be found at http://apps.nccd.cdc.gov/PASurveillance/StateSumV.asp.

[4] Charts are available at www.cdc.gov/nccdphp/dnpa/physical/stats/leisure_time.htm.

Much of the extant research (and policy recommendations) pertaining to increasing physical activity have focused on altering the built environment and neighborhood quality. For example, objective measures of as well perceptions of higher neighborhood safety are found to be correlated positively to higher physical activity (Humpel et al, 2002; Glass et al, 2006), and negatively to obesity-risk among adults (Burdette et al, 2006) and children (Lumeng et al, 2006; Sen et al, 2010). Inequality in access to physical-activity facilities has been found to be a strong predictor of obesity-risk as well as physical activity (Gordon-Larsen et al, 2006). However, the choice of neighborhood is to some extent endogenous to a person's/family's preferences for leading a physically active lifestyle, and associations in the above studies may not reflect what would happen in all communities across the US if such communities were made more activity-friendly by external diktat. Additionally, a significant re-structuring of most neighborhoods and communities across America will be a highly time and cost-intensive project, and is unlikely to be achieved in the short-term. Thus, it is important to explore other policies that might help promote physical activity that could be implemented on a broad scale and implemented relatively quickly. This paper explores whether higher gasoline taxes, which in turn increases gasoline prices, might constitute one such a policy tool. While the ultimate policy of interest here is gasoline taxes, the potential changes from increasing gasoline taxes (which would in turn increase gasoline prices) are gleaned from exploiting the dramatic change in gasoline prices that have occurred exogenously in the U.S. in the past few years (Figure 2). The reasons range from Hurricane Katrina to the global spike in gasoline prices over 2007-2008 (Figure 3), and these increases impacted the whole country. This variation in gasoline prices across time may be used as a 'natural experiment', and using a multi-period study design, we are able to compare the behavior of individuals in the time-periods when gasoline prices were higher to the behavior of their counterparts in the time-periods when gasoline prices were lower.

The previously mentioned paper by Courtemanche (2010) is the first study we are aware of that explores whether gasoline prices could be a factor that affected obesity and obesogenic behaviors. Using data from the Behavioral Risk Factor Surveillance System (BRFSS) over 1984-2004, this study finds a significant statistical association between higher gasoline prices and lower BMI and reduced risk of obesity. The author speculates that a permanent $1 increase in real gasoline prices in the U.S. could reduce prevalence of obesity in the U.S. by as much as 9.6 percent and prevalence of overweight by 7.2 percent in less than 5 years. There is also a statistically significant association found between higher gasoline prices and more frequent walking (on average the number of times respondents walk per week increases by 0.5 in response to a $1 increase in gasoline prices), though not more frequent bicycling. The study also finds some evidence (using data from the DDB Needham Lifestyle Surveys) that higher gasoline prices are associated with eating out fewer times in the course of a year -- but this result is sensitive to the model specification, and therefore not very reliable. The paper is hampered by the very limited measures of physical activity provided in the BRFSS. Another paper, by Hou et al (2011), uses data on young adults recruited from 4 US cities for the Coronary Artery Risk Development in Young Adults (CARDIA) study and interviewed four times between 1985-86 and 2000-2001, and finds an association between higher gasoline prices and 'exercise units' of physical activity. However, that paper is also limited in its definition of physical activity, and fails to control for numerous potential confounders in the empirical model. Moreover, the data for both papers is drawn over a period over which gasoline prices were declining in real terms, and Courtemanche (2010) rightly cautions against drawing inferences regarding how obesity-related behaviors may be affected in a period where gasoline prices also exhibited increases, since "it is not clear that the effect of gas prices on obesity is symmetric." Thus, considerably more research is required to better understand the relationship between gasoline prices and obesity related behaviors.

Conceptual Model: The underlying conceptual model behind why gasoline prices may have any effect upon physical activity model is rooted in basic economic theory of consumer demand, whereby consumers aim to maximize their own utility by choosing from a basket of goods and activities, subject to the constraints of the monetary and time prices of the goods and activities, their own available income, and own available time. Within this framework, when the price of gasoline increases, it may influence choices about physical activity via both the 'substitution effect' and the 'income effect'.

The 'substitution effect' is where the consumer responds to higher gasoline prices via substituting away from activities that involve (more) gasoline-use to activities that require less or no gasoline use. Examples may include walking/bicycling/using public-transport to travel to work/school/errands instead of driving, or substituting leisure time activities that do not involve driving in place of leisure time activities that do. The degree to which such substitutions can occur is limited by other factors such as the availability of substitutes -- for example, those with access to public transportation may have greater ability to substitute away from driving than those without. A report from the Congressional Budget Office (CBO, 2008) based on California data indicated that between 2003-2006, significant declines in freeway driving in response to higher gasoline prices were mostly confined to the freeway locations adjacent to commuter rail systems. There is broad evidence that the demand for gasoline is 'price inelastic' in the short run (Haughton & Sarker, 1996; Grabowski & Morrisey, 2004; Brons et al., 2008), and that the elasticity of vehicle-miles-traveled (VMT) is even smaller than the demand for gasoline with respect to gas prices (Small & Van Dender, 2007).[5] This may be because most individuals have a limited ability to substitute out of driving. Indeed -- even over the period considered in this study -- though gasoline prices essentially doubled in real terms between 2003 and 2007, the impact on VMT in the nation was relatively small. For example, based on VMT volume data from 'Traffic Volume Trends' (US Department of Transportation and Federal Highway Administration, www.fhwa.dot.gov/ohim/tvtw/tvtpage.cfm) when gasoline prices spiked sharply following

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5. Price elasticity refers to the percentage change in consumption/measureable behavior in response to a 1% increase in price. 'Price inelastic' refers to goods whose demand changes by less than 1 percent in response to a 1 percent change in price. This discrepancy between elasticity of demand for gasoline and elasticity of VMT may be explained by marginal changes in driving behavior such as driving more slowly (CBO, 2008), and marginal changes in the types of vehicles (in terms of fuel efficiency) that consumers choose to drive.

hurricane Katrina in October 2005, the percentage decline in VMT compared to October 2004 was only 1.7 percent. When gasoline prices increased sharply again in the second half of 2007, the VMT was lower compared to the previous year for only 3 out of the 6 months. Of these, by far the largest decline was a 3.9 percent decline in December 2007 as compared to December 2006. Detailed charts of monthly traffic volumes from January 2003-Decemeber 2007 are given in Figure 4.

Thus, it is somewhat unlikely that, at least in the short run, an increase in gasoline prices will be accompanied by substantial substitutions away from driving and into functional physical activities such as walking or bicycling that can serve as an alternative to driving.[6] Notably, if limited substitutability makes the demand for gasoline inelastic in the short run, then this implies that families and individuals will have to increase their overall expenditure on gasoline. This reduces their disposable income to spend on all other goods, services and activities. This constitutes the 'income effect' of a gasoline price increase. Courtemanche's paper considers the possibility of the income effect leading to fewer instances of 'eating out'. The income effect may also impact various forms of physical activity, though the direction of this effect is largely uncertain. On one hand, the income effect may lead individuals to opt out of gym memberships or participation in team sports, on the other hand it could lead to increases in relatively inexpensive physical activities like walking or running. The income effect could also lead to increased physical activity if individuals decide to economize by doing certain chores – such as yard-work -- themselves rather than purchasing those services. Several forms of housework and yard-work, such as gardening, raking leaves, shoveling snow, washing/scrubbing windows and floors, and so forth are listed by the US Department of Health & Human Services as activities of moderate intensity that can yield health

[6] On the other hand, one might speculate that a permanent, large increase in gasoline prices may motivate individuals and societies to make lifestyle and built environment changes in the long-run, that can facilitate substitution away from driving. Hence, VMT may be more elastic to gasoline prices in the long-run than the short-run.

benefits if undertaken regularly.[7] Ultimately, the net effect of gasoline prices on different forms of physical activity as well as on overall physical activity cannot be theoretically ascertained. Therefore, this study undertakes an empirical investigation of that question.

Policy Relevance. Essentially, the key policy question that this research project seeks to address is whether higher gasoline taxes which will cause the retail gasoline price to increase may be one viable tool for reducing obesogenic behaviors. The federal retail gasoline tax in the US has remained at 18.4 cents per gallon since October of 1997. State gasoline taxes average to about 21.5 cents per gallon, though there is considerable variation across state, ranging from 8 cents per gallon in Alaska and 14 cents per gallon in Wyoming to 44.6 cents per gallon in New York state and 46.6 cents in California.[8] These taxes are lower than many other developed countries, such as UK and Germany. There have long been those who advocate increasing gasoline taxes in the US as a way to reduce gasoline consumption, both for purposes of reducing dependence on foreign oil, as well as reducing other negative externalities associated with gasoline use such as environmental costs which are currently not reflected in the price of gasoline. A study in 2007 by authors from Resources for the Future (Harrington et al, 2007) estimates the total negative external costs associated with driving to be at approximately 228 cents per gallon of gasoline – which includes costs of dependence on foreign oil, contributions to global climate change, local pollution, congestion, and costs to property and person associated with motor vehicle accidents. However, the overwhelming unpopularity of higher gasoline taxes has made it difficult to garner political support for the idea. But when natural causes took gasoline prices to higher levels than any politician would have probably dared to recommend, with nominal gasoline prices more than trebling between 2002 and 2008, the US population was forced to adapt to such prices.

[7] www.nhlbi.nih.gov/health/public/heart/obesity/lose_wt/phy_act.htm.

[8] Information on federal and state gasoline tax rates is obtained from The Tax Foundation, http://www.taxfoundation.org. The state tax rates are the current 2010 rates.

Nobel Laureate economist Gary Becker commented in his widely followed blog on July 2008 that the reduced driving brought about by the higher prices had done much of the work that higher gasoline taxes might have otherwise done in reducing negative externalities associated with driving.[9] A Time Magazine article commented that "...sometimes we change because we have no choice, and since this violates our manifest destiny to do as we please, it may take a while before we notice that those are often the changes we need to make most." (Time, 2009). Gasoline prices thereafter fell from their peak levels, and remained low for much of 2009 and 2010, but have recently been rapidly increasing again, and garnered much public and political attention. The BP oil disaster in the Gulf of Mexico in 2010 serves as a stark reminder of the potential negative consequences of gasoline use to the US population, and the recent turmoil in the Middle East renews concerns about dependence on foreign oil when much of that supply of oil comes from a potentially politically unstable region in the world. If the US economy shows continued signs of improvement, then there may be renewed interest in seeking ways to move the US society away from its current levels of fossil-fuel dependence using myriad tools including higher gasoline taxes. If gasoline prices influence obesogenic behaviors and can help ameliorate the obesity-crisis which imposes many cost-burdens on the US society, then a policy debate on gasoline taxes should also be informed by that, so that policy-makers are able to better assess the overall societal benefits versus costs of increasing gasoline taxes.

Data & Methodology.

ATUS Data. The empirical approach is to conduct multivariate regression analyses using pooled cross-sectional time-series data over 2003-2008. The dataset used is The American Time Use Survey (ATUS), an annual survey sponsored by the Bureau of Labor Statistics (BLS), initiated in 2003, and described in detail by Hamermesh et al. (2005). The survey aims to provide comprehensive information about how Americans

[9] The Becker-Posner blog, July 21, 2008. http://www.becker-posner-blog.com/2008/07/should-us-taxes-on-gasoline-be-higher-becker.html. (Last accessed in August 2010).

spend their time by informing on how respondents spent the past 24 hours. This study utilizes the waves of ATUS data from 2003 through 2008.

The target population of the ATUS is the American non-institutionalized civilian population aged 15 years or higher. The ATUS sample is drawn from the outgoing rotation groups of the Current Population Survey (CPS), and one individual from each selected household is chosen to participate in a computer-assisted telephone interview. The interviewed respondent reports each activity they undertook in the past 24 hours (specifically, from 4 am to 4 am, ending on the interview day), how long they spent on that activity, where that activity took place, and who (if anyone) was with them while they did it. The data is organized so as to account for every minute of the respondent's day. The survey is designed to oversample racial minorities, and oversample weekend days. It also has a higher proportion of responses from women compared to men. Thus, appropriate weighting is required to get representative estimates of time use in the general population.

Activities are coded at three levels of detail, beginning with 17 categories at the first (broadest) level, examples of which include 'household activities', 'working and work-related activities', 'eating and drinking', 'socializing, relaxing and leisure', 'sports, exercise and recreation', 'travel' and so forth. The full list is available from Hamermesh et al. (2005). These are then broken down further in the next two levels. For example, the first-level category of 'sports, exercise and recreation' is broken down in the next level into two sub-categories -- of whether the responded was participating in any form sports, exercise and recreation, or watching it. The final and most detailed category lists what specific type of sports, exercise or recreational activity the respondent was participating in or watching. The place where the activity occurred is also coded. This last characteristic allows researchers to identify mode of transportation to work and errands. Specifically, the survey asks about the time spent commuting to work and to errands, and then under the 'where' category it provides information on whether that commuting was done via walking, bicycling, various forms of public transportation, or in a privately-owned motor vehicle.

One drawback is that survey does not record secondary activities (except for a supplement initiated in 2006 that includes information on eating as a secondary activity). For example, a person might have primarily exercised but secondarily listened to music. In that circumstance that time is coded as being spent on exercise but no record is made of the fact that they also listened to music.[10] Similar issues exit with 'where' an activity occurred – specifically, in case of time spent traveling to work or errands, only the primary mode of transportation is reported. Hence, if the respondent partly walked and partly took public transportation to reach a destination, only the primary form of transportation that the respondent reports will be recorded. Another drawback is that the organization of activities is sometimes less than transparent. For example, any sports or physical activities undertaken with children are listed under the categories of 'caring for household children' or 'caring for non-household children' rather than under 'sports, exercise and recreation'. Finally, there is some potential for measurement error based on how an activity is reported. For example, if the respondent primarily reports spending time taking a walk but then picks up a bottle of milk on the way, then it qualifies as 'walking' under the category of participation in sports, exercise and recreation. However, if the respondent reports 'going to pick up milk' as the primary purpose of the activity, then it qualifies under time spent traveling to grocery store. In that case, the information that the respondent actually spent time walking (to the store) is only available under the 'where' variable, which links the mode of transport used to travel to the store to the time spent traveling.

In addition to information on time spent on various activities, the ATUS dataset also contains fairly detailed demographic information on respondents such as their age, gender and race-ethnicity, information on their familial structure and marital status, employment status, state of residence, the day of the survey, and many other characteristics. In addition, the ATUS data is linkable to the original CPS data using

[10] A supplementary ATUS 'Eating & Health' module that was started after specifically records the time that was spent in eating as a 'secondary activity. To our knowledge, this is the only type of secondary activity available in ATUS. Those questions are asked to a sub-set of the original ATUS respondents only in selected years, and no information is available on the type of food eaten. Therefore, that information does not add to this study and is hence not included.

respondent identification number, to access any additional respondent information provided exclusively in the original CPS data.

In 2003, ATUS collected about 1700 complete time diaries in each month. Starting in 2004, the size was reduced to about 1100 time diaries per month, and it has stayed at approximately that level since then. After pooling the yearly samples, the final sample in this paper includes information on approximately 82,000 time diaries.

MET Scores: One particularly useful resource available in conjunction with the ATUS data is a compilation of the 'metabolic equivalence' or MET scores for each of the activities listed in ATUS. This was commissioned by the National Cancer Institute (NCI), US National Institute of Health, and was undertaken by Tudor Locke et al (2009). The process was accomplished by linking the ATUS activities to The Compendium of Physical Activities, a comprehensive list of 605 physical activities used to code the type, purpose, and intensity of physical activities performed in daily life in the US. The Compendium assigns each of these activities a MET score. A MET is defined as the activity metabolic rate divided by the resting metabolic rate, with lying or sitting quietly classified as 1 MET. For example, a 3-MET activity requires 3 times the energy expenditure needed when at rest. Energy intensity categories for categories are broadly interpreted as light (<3 METs), moderate (3–6 METs), and vigorous (>6 METs).[12] It is possible to further separate the light-intensity category into sleeping activities (<1 MET) and sedentary/lying/sitting activities (≥1 and <3 METs) based on Compendium coding.

The process of linking the ATUS activities to those listed in the Compendium as well as the challenges of that process are described in details in Tudor Locke et al (2009). The final, detailed tables listing the MET score for each ATUS activity are listed on the website of the NCI http://riskfactor.cancer.gov/tools/atus-met/ (last accessed in May, 2011). The ability to avail the MET scores for all activities is particularly useful, since it permits identification of daily activities other than recreational sports or exercise that are also beneficial for lifestyle energy-balance because of their energy intensity. Public health recommendations typically advocate spending at least 30 minutes daily, at least five days a week, on activities of moderate intensity. As mentioned before, examples of such activities can encompass numerous household chores like gardening, raking leaves, shoveling snow, washing/scrubbing windows and floors, and waxing the car; or activities undertaken with children such as jumping rope[11].

The ATUS data is linked to the gasoline price data using identifiers for the month of the survey and state of residence at that time. The ATUS data does not permit identification of the respondent's county of residence; therefore we are unable to match them to gasoline prices at a more localized level than the state. Annual state average regular grade unleaded gasoline prices are obtained from Energy Information Administration (EIA) surveys of refiners and retailers/resellers (http://www.eia.doe.gov/oil_gas/petroleum/info_glance/petroleum.html). Because the EIA price information does not include state or federal gasoline taxes, per gallon excise taxes are obtained from the Federal Highway Administration. (http://www.fhwa.dot.gov/ohim/mmfr/feb06/trmfuel.htm). The final gasoline price data, inclusive of state and federal taxes, is inflation adjusted to 2007 dollars.

Nominal gasoline prices more than tripled between 2003 and the last quarter of 2008 (Figure 2). This increase is driven largely by changes in global crude oil prices. For example, the EIA reports that the 'free on board' price of imported crude oil increased from under $30 a barrel in early 2003 to more than $100 a barrel by August, 2008 (Figure 3). In addition, Hurricane Katrina , which made landfall in late August, 2005, resulted in the temporary closing of several oil refineries in the gulf coast area (Bamberger & Kumin, Sept 2005), and the resulting supply shock led to a spike in oil prices in the immediately following months. Little of price changes of this period are attributable to changes in gasoline taxes. The nominal federal gasoline tax remained constant at 18.4 cents per gallon, and only 12 states changed their gasoline

[11] www.nhlbi.nih.gov/health/public/heart/obesity/lose_wt/phy_act.htm

taxes within this period, with the changes mostly totaling to less than 6 cents per gallon.[12] Hence, this time-period of this study offers an opportunity to study how people respond to higher gasoline prices when gasoline prices increased due to largely exogenous causes.[13]

The following types of physical activities are considered:

(1) Walking, running, bicycling or rollerblading as part of 'recreational' or 'leisure time' activities.

(2) Walking or bicycling as the primary form of transport to commute to work or errands.

(3) Playing with Children.[14]

(4) Doing housework that qualifies as *at least* moderately active (MET greater than or equal to 3),[15] --hereafter referred to as 'moderately energy intense housework' (MEIHW).

(5) Total time spent on all physical activity that *meets* or *exceeds* the definition of being 'moderately active' (MET greater than or equal to 3) – hereafter referred to as overall 'moderately energy intense physical

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12 The EIA estimates that between 73 to 79 percent of gasoline prices are explained by the price of crude oil and state and federal taxes. The remainder is attributable to refining, distributing and marketing costs, and profits.

13 Notably, the precipitous decline in gasoline prices that occurred in the final months of 2008 are broadly attributed to the rapidly deteriorating economic conditions in the US and other major economies following revelation of the depth of crisis in the housing and financial sector. The depressed gasoline prices throughout 2009 are also widely attributed to the recession. Therefore, gasoline prices in the final quarter of 2008 and through 2009 are considerably more likely to be endogenous to behaviors adopted by the American people to cope with the precipitous descent into economic recession and the high unemployment rates. Hence, ATUS data from that period is not included in this current study.

14 'Playing with children' includes two forms of activities 'playing with children – not sports' has a MET value of 3.26, and 'playing with children – sports' has a MET value of 5.0. Playing with both household and non-household children are included in this measure.

15 The following forms of housework (MET value) meet the criterion of being 'moderately active': Interior cleaning (MET 3.01), Interior arrangements, repairs, decorations, moving items in and out of storage (MET 3.33 to 3.85), lawn/yard/garden/pond/hot-tub work (MET 3.66-4.49), building/repairing furniture (4.25), building/repairing/cleaning heating and cooling systems (MET 4.42), exterior cleaning (MET 3.93), exterior repairs & improvements (MET 4.49). Readers can verify for themselves the accuracy of the activities selected based on MET>3.0, and the exact MET values by visiting http://riskfactor.cancer.gov/tools/atus-met/.

activity (MEIPA)'.[16] In this context, it should be noted that respondents with no 'moderate physical activity' on record could still be participating in the forms of physical activity that have MET values of under 3.

Empirical Model: The basic multivariate regression model estimated is as follows:

$$A^{k}_{jst} = \beta_1 G_{st} + X_j \delta + \alpha U_{st} + State_s + T_t \lambda + D_j \eta + e_{jst} \quad (2)$$

Where A^{k}_{j} represents a physical activity outcome of type 'k' undertaken by respondent 'j' who resides in state 's' and is interviewed in survey period 't' within the past 24 hours. The outcome is measured both in terms of whether the respondent engaged in that physical activity at all in past 24 hours, and the minutes spent on that physical activity – including zero minutes -- in past 24 hours. G_{st} is the gasoline price in that state, month and year. G_{st} is inclusive of state and federal taxes, and inflation adjusted to 2007 dollars. X_{jst} represents a vector of demographic and socio-economic characteristics of the respondent which includes the following: the respondent's gender, race-ethnicity, whether the respondent has a spouse or a partner, the respondent's age and age-squared, the total number of children in the household, if there are any children under 6 years in the household, the respondent's education level, the respondent's household income level, and whether the respondent resides in a metropolitan area. Education level and household income level are measured using a series of binary indicators for different categories of education (less than high school, high school, less than 4 years college, 4 year college, and graduate) and household income (there are 16 categories of annual household income, from under $5000 to over $150,000, and a seventeenth category is included to represent those who refused to provide information on household income –almost 15 percent of the sample). U_{st} represents the state unemployment rate in that month and year. It has been demonstrated in several papers by Christopher Ruhm that short term increases in unemployment rates are associated with an increase in beneficial health behaviors and health outcomes (Ruhm, 2000; 2003; 2005), including exercise

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[16] This includes all the activities included in (1) to (5) and also all other forms of sports, recreation, leisure and volunteer activities with a MET value of 3 or higher.

habits -- hence, it seems useful to control for unemployment rates when modeling physical activity behaviors. $State_j$ is a vector of state binary variables – one for each state in the data. It is conventional to use the state level dummies in such models as a method to capture unobserved, time-invariant heterogeneity at the state level that may potentially be correlated to gasoline prices, and also to the culture of physical activity in the state – including, but not restricted to public support for higher state gasoline taxes, and physical-activity friendly built environment in the state. T_{jt} refers to the controls for time variables in the model. These include a vector of year dummies, and a vector of season variables (winter, spring, summer and fall) to control for seasonal variation is gasoline prices and types of physical activities that are weather dependent. We also control for monthly precipitation for that state and year (from the National Oceanic and Atmospheric Administration). We also experiment with including a quadratic time trend (measured in increments of one month) in place of the year binary variables, including a time-trend interacted with each of the state dummies in addition to the year binary variables, and including a full range of dummies for all season-year periods in the data. D_{jt} includes a series of binary variables indicating the day of the week for which the respondent reported activities, and a binary indicator for if that day was an official holiday. All regression equations are weighted using the 'weight' variable provided in the original ATUS data to account for the over-sampling of females and weekends in the data. Error terms in all models are adjusted for clustering at the state level. The statistical software STATA is used for all estimations.

Results.

Table 1 presents summary statistics for the physical activity variables of interest for the full sample and when gasoline prices are above and below their sample median level. In the full sample, a little more than 61 percent report at least some level of moderate physical activity in the past 24 hours. However, only about 6.6 percent report leisure time walking, running or bicycling, while about 13 percent report at least some walking or bicycling to do errands. About 42 percent report participating in some form of MEIHW.[17] A simple visual inspection of the sample means also suggests that the participation rates as well as the average time spent on the various activities are slightly higher when gasoline prices are above the median level of $2.20 per gallon, though at this stage we do not test to see if these differences are statistically significant. Table 2 presents summary statistics for the control variables in the regression models.

Table 3 presents results from the main regression estimations for the set of physical activities of interest. Results are presented both from Ordinary Least Squares (OLS) regression models run on the full sample (inclusive of all the 'zero' values for the outcome variables), as well as Probit models for participation in that activity per se. For the latter we present marginal effects calculated at the sample means. The first set of results includes the year binary variables, the second set of results includes the quadratic time trend, and the third set of results includes year binary variables as well as a time-trend interacted with the state dummies. Results indicate that, with the exception of playing with children, there is a statistically significant increase in the time spent on each of the physical activities of interest associated with a $1 increase in gasoline prices. However, the association is only weakly significant and somewhat sensitive to model specification in case of walking/biking to work or errands. There are also statistically significant

[17] Because a substantial proportion of the sample report no participation at all in each activity, it may be argued that the appropriate modeling strategy should be a 'two-part model' where the outcome is essentially broken into two distinct parts – a first part for the decision of participating at all, and a second part on the level of participation conditional upon participating at all (Duan et al, 1983). However, the two-part model is conventionally used in cases where the decision to participate per se is distinct from the decision of how much to participate (one popular application is the decision to smoke at all, versus how many cigarettes to smoke if deciding to smoke). In such situations, the first pat is often referred to as the 'hurdle' model, and the second part as the levels model. In case of the outcomes in this study, the decision of whether or not to participate at all versus how much to participate are not so distinctive, and the 0s for an activity may arise in many cases simply because the respondent did not undertake that activity in the past 24 hours, rather than the respondent making a conscious decision of not to participate in that activity (I thank the participants at the ASHE 2010 session for pointing this out). Therefore, the two-part model does not seem to be the correct approach here, and OLS regression models as well as probit models of participation using the full sample appear to be more intuitive.

increases in the probability of any participation for activities like recreational walking/biking/running as well as MEIHW in all models.[18]

The OLS regression models show that the average estimated increases in the different physical activities associated with a $1 increase in gasoline prices are as follows: 1.29 – 1.55 minutes in recreational walking/running/bicycling; 0.57-0.74 minutes in walking or bicycling to errands (not statistically significant when time-trends interacted with state dummies are included); 7.74-8.66 minutes in MEIHW; and 10.39-10.74 minutes in overall MEIPA in a 24 hour period. The association between increased gasoline prices and time spent playing with children actually appears to be negative, though it is insignificant in most models.

In terms of change in participation probabilities, the Probit Models show that a $1 increase in gasoline prices is associated with an estimated 1 percentage points in the probability of recreational walking/biking/running, an estimated 1.5-2.0 percentage point increase in the probability of any MEIHW, and a 2.4-2.8 percentage point increase in the probability of participation in any MEIPA.

Overall, it appears that the changes in participation as well as time spent on activities like walking or bicycling are not large, and sometimes statistically weak. We also explored whether there were any changes in public transport use associated with higher gasoline prices (those results are available upon request), but did not find evidence of any significant changes.[19] This suggests that there is relatively little substitution

[18] The weak or insignificant change in participation probabilities in walking/biking to errands combined with some change in the overall OLS model suggests that increased gasoline prices do not cause people to start walking or bicycling to errands, but people who already did so – perhaps because they had access to the facilities and built environment to do so -- might now increase the frequency of that activity. This conjecture is somewhat supported by results for walking and bicycling for the sub-sample who report participating in that activity (see Appendix). The estimated effect of a $1 increase in gasoline prices on minutes spent walking or bicycling conditional upon participation is between 4.81 (t-statistic 1.76).

[19] Much of the US population may simply not have access to the built environment that facilitates using public transportation to school or work. Of the 3 percent of respondents who report any usage of public transport for the entire period of the study, more than half come from just 5 states – New York, California, Illinois, Pennsylvania and New Jersey. It is possible that even within those states, only those living in certain urban areas have easy access to

away from individualized motorized transportation when gasoline prices increase, which is also consistent with the relatively small drop in VMT seen in the 'Traffic Volume Trends' data when gasoline prices increased. It may be conjectured that, at least in the short run, much of the US population is constrained by their built environment and other factors from substituting away from motorized transportation to alternate modes of transportation. However, there are statistically significant and non-trivial increases in participation probabilities and time spent on overall MEIPA when gasoline prices go up, and one key factor that seems to drive this is the increase in MEIHW associated with increased gasoline prices. The ATUS activities that qualify as MEIHW include interior and exterior cleaning, building and repairs, as well as garden, pond and yard work. These activities can potentially be done with hired help, and the increase in the respondent's own time spent doing such activities when gasoline prices increase suggests a possible 'income effect' -- whereby higher gasoline prices and the resulting pressure on family budgets lead to individuals cutting back on paid hired help, and instead devoting more of own time to performing such activities. It is also possible that gasoline is an input for the hired providers of such services, thus the prices of these services may be increasing when gasoline prices increase, which can also reduce the purchase of such services.

If the association between higher gasoline prices and MEIHW is not merely spurious, and the income effect (or some combination of the income effect and the price change of the services) is, indeed, one explanatory force behind these results, then this logically leads to the following two conjectures: First, the associations between gasoline prices and MEIHW should be weaker for respondents with relatively low socio-economic status (SES). Since low SES households are less likely to hire paid help to perform these tasks in the first place, even when gasoline prices are low, there is less scope for them to 'switch away' from

public transportation. Therefore, it is not clear whether the lack of a significant relationship between gasoline prices and public transportation use indicates an aversion to public transportation among the US population, or simply a lack of facilities and built environment to do so.

hired help to doing such chores themselves when gasoline prices increase,[20] and there should be less change in their participation probabilities or minutes spent on MEIHW when gasoline prices increase compared to their relatively higher SES counterparts. Second, if higher gasoline prices lead respondents who previously used hired help to spend more time performing the tasks themselves, then the results should be even more pronounced for the sub-set of tasks housework that arguably are most likely to be hired out – tasks such as exterior home repairs or yard work, that require the most exertion and energy expenditure. The next stage of this study explores whether these conjectures are validated by empirical findings.

To explore whether associations between gasoline prices and MEIHW differ by SES, the model is estimated after dividing the overall sample based on different dimensions of SES — minorities versus non-Hispanic whites, single parents versus all others, and those with a educational attainment level of high-school or less versus those with more than high school. The model is also estimated separately for those with family incomes below \$35,000 per year, \$35,000 to \$100,000 per year, and above \$100,000 per year. The rationale is that while switching away from hired help is likely to be irrelevant for the relatively low-income households (under \$35,000), it is also less likely to occur for the relatively high income households (above \$100,000) since gasoline prices constitute a smaller share of their disposable incomes. Thus, we may anticipate seeing the largest effects of gasoline prices in the \$35,000 to <\$100,000 household income range.

To explore whether the associations with gasoline prices are stronger for the types of housework that may otherwise be most likely to be performed by hired help – a sub-set of the activities included in MEIHW, which require most exertion, are selected. These are the activities that have a MET of 3.8 or higher, 3.8 being the MET ascribed to 'walking', and this category is hereafter referred to as 'energy intense housework (EIHW)'. They include cleaning, repair and maintenance work done on the exterior of the

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[20] Low SES households may also simply have less need for some of these activities – for example, they may not have a yard, or may not have a residence large enough to require substantial cleaning, or they may be more likely to live in a rented apartment and thus not be responsible for exterior cleaning or repairs.

house, building and repairing of furniture and heating/cooling systems, and yard and lawn work including cleaning and maintenance of outdoor water features. The association between this outcome variable and gasoline prices are estimated for the full sample as well as the SES categories described above. Finally, OLS and Probit Models for overall MEIPA are estimated for the different SES categories. Results are presented in Table 4.

The results appear to lend general support to both conjectures. The associations between increased gasoline prices and participation probabilities and minutes spent on MEIHW appear to vary by SES. For Non-Hispanic whites, not single parents, more than high-school level education, and $35,000-$100,000 income range, there are statistically significant increases both in the probability of participating and time spent on MEIHW. In contrast, there are no statistical increases in participation probabilities or minutes spent among minorities. For single parents, those with income less than $35,000, and those with less than a high-school education, results are more mixed. However, in all cases the estimated increases in minutes and participation probability appear smaller and statistically weaker than those of their higher SES counterparts.[21] Among those with household income above $100,000, change in participation probabilities and minutes are also smaller compared to those in the $35,000-$100,000 income range, supporting the conjecture that high-income households are less affected by higher gasoline prices than more middle-income households.

Additionally, associations between gasoline prices and EIHW are stronger and larger in magnitude than for MEIHW for the full sample and for all the higher SES categories. The associations are not significant for minorities, single parents, or lower income families, but are significant for those with lower education (though the magnitudes are smaller than the corresponding higher education group).

[21] We also find that the association with state unemployment rates and EIHW, MEIHW and MEIPA are in a positive direction, and that EIHW in particular is lower for the higher household income categories. These findings broadly support the conjecture that time spent on energy intensive housework has an inverse relationship with income.

Regression results for the other outcome variables by SES groups are estimated, but not presented here in details. There is no physical activity which consistently shows a greater increase among the lower SES groups compared to the higher SES groups when gasoline prices increase.

What of the association between overall MEIPA and gasoline prices for the different SES categories? Again, for non-Hispanic whites, not single parents, $35,000-100,000 income, and more than high-school level education, there are unambiguous statistically significant increases in both participation probabilities and minutes spent on MEIPA. Participation probabilities increase by 3-4 percentage points for the above groups, while minutes spent increase by 11-14.7 minutes. There is less evidence that participation probabilities increase for any of the lower SES groups or the high income group. However, there is evidence that minutes spent on overall MEIPA increase for most of these groups too, with the increases ranging from 7-11.6 minutes. Thus, while the stronger evidence of increase in overall MEIPA is seen among the higher SES groups, there appears to be some increase in MEIPA among lower SES groups too.

Alternate Specifications & Robustness Checks: We explored the possibility of including a dummy for each month of the year instead of the each season in the framework of our original model. However, this posed a serious multicollinearity problem. Gasoline prices are measured at the state level per month, and a combination of state, year and month-level dummies explains most of the variation in gasoline prices in our data. Hence, including controls for months in the models leads to large standard errors and statistically imprecise estimates for gasoline price effects.[22] At the same time, not including month-level controls leads to the apprehension that there may be month-level confounding factors that the season effects cannot fully control for, and the positive and significant associations between gasoline prices and physical activity is an

[22] The adjusted R^2 from the model regressing the tax-inclusive gasoline prices on the combined set of state, year and month binary variables is approximately 0.885, and the VIF score for gasoline prices is close to 9.

artifact of those confounders. Hence, we use some alternate model specifications to verify that the association between gasoline prices and physical activity is, in fact, 'real', and report the results in Table 5.

Model specification 1 identifies the relationship between gasoline prices and physical activity based on short periods of what might be considered 'intense monthly fluctuations' in gasoline prices that are exceptional to the normal seasonal/monthly patterns. The spike in gasoline prices following Hurricane Katrina in the end of August 2005 provides one such period. Several such periods also occur between summer of 2007 and fall of 2008. Examples include the rare situation where prices in winter of 2007 are actually higher than they were in August 2007. Also, a 28 percent increase in real gasoline prices occurs within a span of 3 months – March to June 2008. Thus, Model Specification 1 only uses data from July to October 2005 (that is, 2 months before to 2 months after Katrina), and from June 2007 to September 2008. State, year, season, and day of week fixed effects continue to be included in the model.[23]

Model Specification 2 works off the same principle of identifying the association between gasoline prices and physical activity using intense and unseasonable monthly fluctuations in gasoline prices. However, instead of a subjective choosing of the periods by the authors, this specification includes a full set of dummy variables for each season-year combination in the data, such that winter of 2003 is 'season-year 1', spring of 2003 is 'season-year 2' and so forth. Hence, gasoline prices are identified purely via monthly fluctuations that occur *within* a specific-season year, and it is likely that the unseasonable fluctuations identified in the previous specification will play a key role here too. State and day of week effects continue to be included.

We find that these specifications substantially strengthen our key results. Specifically, a $1 increase in gasoline prices is now associated with a 4 percentage point increase in participation probability in overall MEIPA, and a 15 minute increase in minutes spent. Parallel increases are found in the probability of participation and in minutes spent both on MEIHW and EIHW. These results reassure that the association

[23] The results are robust to small changes in the precise time periods chosen for this model.

between gasoline prices and physical activity is not spurious. They also indicate that relatively unexpected fluctuations in gasoline prices may lead to the largest changes in physical activity.

We estimate a final model specification (Model Specification 3) to explore whether any 'weather effects' continue to bias the association between gasoline prices and physical activity. This approach utilizes a variation of the difference-in-difference-in-difference approach within the framework of Model Specification 2. If the association between higher gasoline prices and physical activity is also picking up the correlation between warmer weather and physical activity, then the associations between gasoline prices and physical activity would seem larger (smaller) in those states where winters are more (less) severe and hence a greater (lesser) hindrance to outdoor physical activity. To investigate this, states are separated into 'colder' and 'warmer' groups based on USDA weather zones, and an interaction of the binary indicator for colder states with gasoline prices is added to Model Specification 2. [24] Results in Table 5 show that the coefficient estimate of this term is positive, but relatively small and always statistically insignificant. Hence we fail to reject the hypothesis of equal association between gasoline prices and physical activity in colder and warmer states. Nonetheless, the coefficient estimates of the original gasoline price variable are slightly smaller than Model Specification 2 for MEIPA, MEIHW and EIHW (about 1.65- 2.0 minutes lower), and a more cautious approach would to interpret these coefficients as being better indicators of the association between higher gasoline prices and physical activity.

We also perform some other robustness checks to address alternate issues of concern. For instance, one issue in OLS models is whether the results are influenced by outliers with exceptionally high levels of time spent on that activity. One standard method to address this is using log-linear models, where the

[24] States are divided into 'colder' and 'warmer' states based on how much of the states lie in specific USDA weather zones, which are based on expected winter temperature (http://mgonline.com/articles/zonemap.aspx). States where most of the land is in zone 7 or higher are categorized as 'warmer' states, and the remainder are 'colder' states. The 'warmer' states include FL, GA, AL, TX, SC, MS, LA, NM, AZ, CA, and NV. A dummy variable for colder states was also included in the model, but it was, of course, subsumed by the state fixed effects.

natural log of the outcome variable is substituted for the unit value. Results using this approach are presented in Table A of the Appendix. Because natural log of zero is undefined, the cases where 0 minutes spent on an activity are replaced by 0.01 minutes (that is, less than 1 second) spent on the activity. The results are qualitatively very similar to those using regular OLS models, the only difference is that the association between higher gasoline prices and time spent walking or bicycling to errands now ceases to be statistically significant. Another issue is the extent to which gasoline prices are associated with changes in various physical activities conditional on participation. To explore this, models are re-estimated only for the sub-samples participating in each specific activity (results also in Table A). Results show that conditional upon participating, walking or bicycling to work and errands, MEIHW, energy-intensive housework and overall MEIPA are higher when gasoline prices are higher.

Another question is whether physical activity is influenced not just by contemporaneous gasoline prices but also gasoline prices in the somewhat more 'long run'. To explore this, the average gasoline prices for the previous 3 months are included in the models in addition to the gasoline prices for the contemporaneous month. Those results are also presented in Table A. There is little indication that gasoline prices from the previous 3 months have any statistically significant associations with the physical activities of interest, and indeed, in some cases the signs go in the negative direction. This may likely be because gasoline prices fluctuate continuously over these periods, thus the lagged gasoline prices are often higher or lower than current gasoline prices. Such fluctuations, and the resulting uncertainty, can make it more difficult for individuals to make 'long-term' decisions regarding their gasoline consumption patterns. Thus, this study's data is not suitable for deciphering how individuals will react in the long-run to a more permanent increase in gasoline prices – for example, one brought about by an increase in gasoline taxes.

Models are also estimated using gasoline prices exclusive of state taxes. Though only 12 states change gasoline prices within our study period, there may be concerns that such changes are potentially endogenous to changes in state attitudes about driving, or to the state government's plans to modify the built environment to facilitate physical activity. Thus, all models are re-estimated using state level gasoline prices without the state gasoline taxes. The results are virtually identical to those in Table 3. Models were also estimated after omitting the data from California, which typically has the highest gasoline prices among all states. Again, results change very little. These results, as well as results from models by SES status after including the full vector season-year dummies, are available upon request.

Discussion & Conclusion.

The findings from this study indicate that higher gasoline prices are associated with increased participation in and increased time spent on certain physical activities. Hence, they lend conditional support to the hypothesis that increasing gasoline prices may reduce certain obesogenic behaviors. The results indicate that higher gasoline prices are associated with an increase in both participation in and time spent on overall moderately energy intense physical activity. Specifically, while higher gasoline prices show some associations with increases in recreational walking/ bicycling/running, and in walking/bicycling to errands, the category of activity that show the strongest increases when gasoline prices increase is at least moderately energy intensive housework. This suggests that the main 'effect' of gasoline prices on physical activity may not operate as much through substituting away from motorized transportation because of it is now more expensive, but more so via the income effect --- i.e. the extra expenses on gasoline constraints the family budget, and may lead families to cut back on certain other expenses like hired help for household chores, repairs, or yard work. It could also partly be because increased gasoline prices increase the price of such services, since gasoline may be an input for providers of those services. This argument is further supported because the associations with gasoline price are strongest for time spent the types of housework that require the most exertion and hence may be most likely to otherwise be hired out – yard and lawn work, exterior cleaning, building and repairs. Moreover, the associations are weaker for people of lower SES, who are arguably less likely than their higher SES counterparts to use hired help regardless of gasoline price levels.

They are also weaker for households with annual income above $100,000, whose budgets may be less affected by changes in gasoline prices. Furthermore, the study's findings suggest that the changes in physical activity are more pronounced when fluctuations in gasoline prices are relatively unanticipated.

These findings underline the importance of considering energy-intensive lifestyle activities such as housework in context of overall energy-balance, instead of focusing exclusively on what the CDC defines as 'leisure time physical activities' – that is, leisure time sports and exercise. At the same time, these findings raise concerns about using higher gasoline taxes as a potential tool to increase physical activity, because these increases may accrue disproportionately to higher SES groups.

The study has a number of limitations. Some of them arise due to the nature of the ATUS data. There are the inherent concerns of accuracy of self-reported secondary data. In addition, since the information only pertains to the past 24 hours, there are concerns about whether that particular 24 hour period is representative of the 'typical' time use pattern of a particular respondent. There is also no information provided in the ATUS on any pre-existing health conditions of respondents that might preclude certain physical activities, nor is there any information on neighborhood characteristics or the built environment that might facilitate certain physical activities.

Researchers may also debate the merits of focusing only on moderately energy intense activities (a MET value of 3 or higher) while essentially ignoring physical activities with a lower MET value. The guidelines from US Department of Health & Human Services and the CDC focus on moderate or rigorous physical activity when advocating ways to promote healthy living. However, Tudor-Locke et al (2009) comment that "time spent in lower-intensity physical activity might still be important in terms of energy balance", and it might be argued that physical activities with MET values of less than 3 done for a long period of time could yield health benefits equivalent to physical activities with MET value of 3 or more done for a comparatively shorter period of time. These may be useful questions to pursue in future research.

This study uses data that does not permit an in-depth analyses of how US society might respond in the long-run to a permanent increase in gasoline prices or a gasoline 'price floor' as was advocated by Philip Gordon of the Brookings Institute in a Financial Times column (Gordon, 2006). If a permanent increase in gasoline prices lead to popular demand for changes in the built environment and alternates to motorized transportation, then in the long-run there may be scope for substitution away from motorized transportation, and the substitution effect may play a bigger role than what is found in this study. At the same time, if unanticipated increases in gasoline prices have the most impact on physical activity, then it is unclear whether the same increase brought about via pre-announced policy change will have the same effect.

Finally, this study focuses on physical activity and does not concern itself with the other major aspect of obesogenic behaviors – caloric intake. Increased gasoline prices could lead households to substitute away from 'eating out' to preparing more food at home, both due to tightening family budget, the desire to avoid driving to restaurants, and because higher gasoline prices may increase the price of food at restaurants more so than food at home. This may have health benefits since restaurant and fast-food meals are usually more calorically dense than home-cooked meals (Lin & Frazao, 1997). On the other hand, tight budgets and the desire to avoid frequent car trips could lead households to substitute away from purchasing healthy but relatively expensive and perishable foods like fresh produce. Finally, if individuals expend energy in moderately active housework or by walking to errands in response to higher gasoline prices with no any conscious desire to reduce obesogenic behaviors, then they may compensate for such energy expenditure by increasing their caloric intake. Thus, the question of how increased gasoline prices may influence caloric intake is important in this context. The ATUS data informs on time spent grocery shopping, cooking and eating, but not on the nature of the food consumed.[25] Therefore, we plan to explore associations between

[25] The ATUS also identifies whether the eating occurred inside the house or at another venue. However, it is debatable whether this information by itself is a useful proxy for actual caloric intake or types of foods consumed.

gasoline price changes and eating behavior in future research with other datasets providing detailed information on the types of food purchased or consumed.

In conclusion, taken in conjunction with studies such as Courtemanche (2010), this paper provides qualified support for the idea that increasing gasoline taxes may be one tool to help reduce obesogenic behaviors and obesity-prevalence. At the very least, these results strongly indicate that further research to understand the relationship between gasoline prices and obesogenic behaviors should be useful and informative for future public policy formulation.

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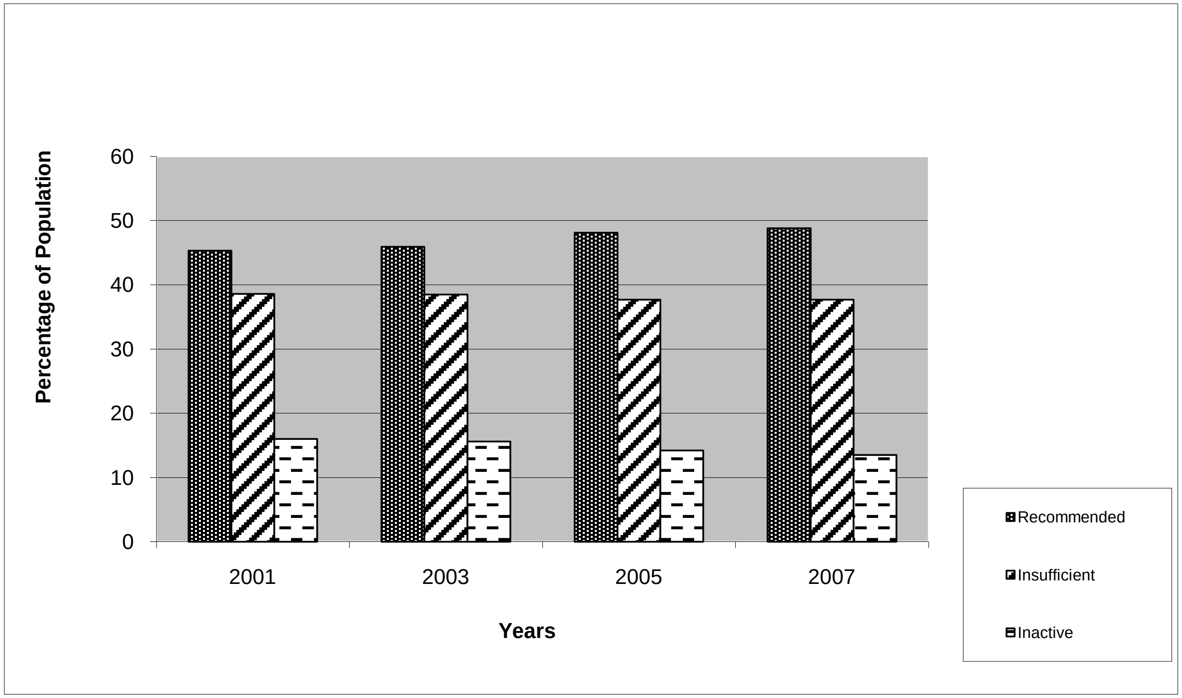
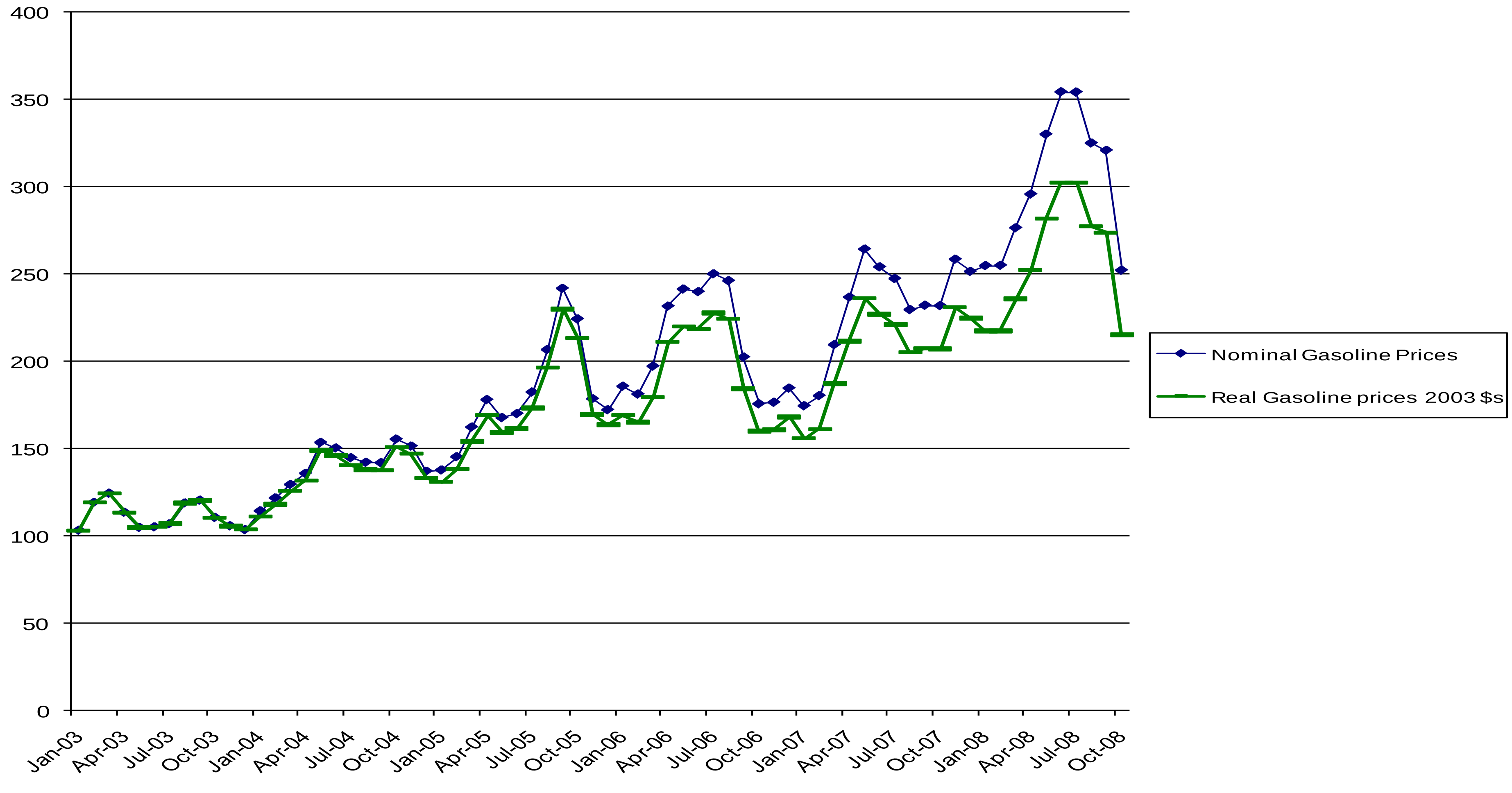
Figure 1: Physical Activity Levels Among the US Population for Specific Years.



Notes: Data is obtained from the Centers for Disease Control & Prevention. The definitions are as follows: **Recommended physical activity** — reported moderate-intensity activities in a usual week for greater than or equal to 30 minutes per day, greater than or equal to 5 days per week; or vigorous-intensity activities in a usual week for greater than or equal to 20 minutes per day, greater than or equal to 3 days per week or both. **Insufficient physical activity** — doing more than 10 minutes total per week of moderate or vigorous-intensity lifestyle activities, but less than the recommended level of activity. **Inactivity** — less than 10 minutes total per week of moderate or vigorous-intensity lifestyle activities.

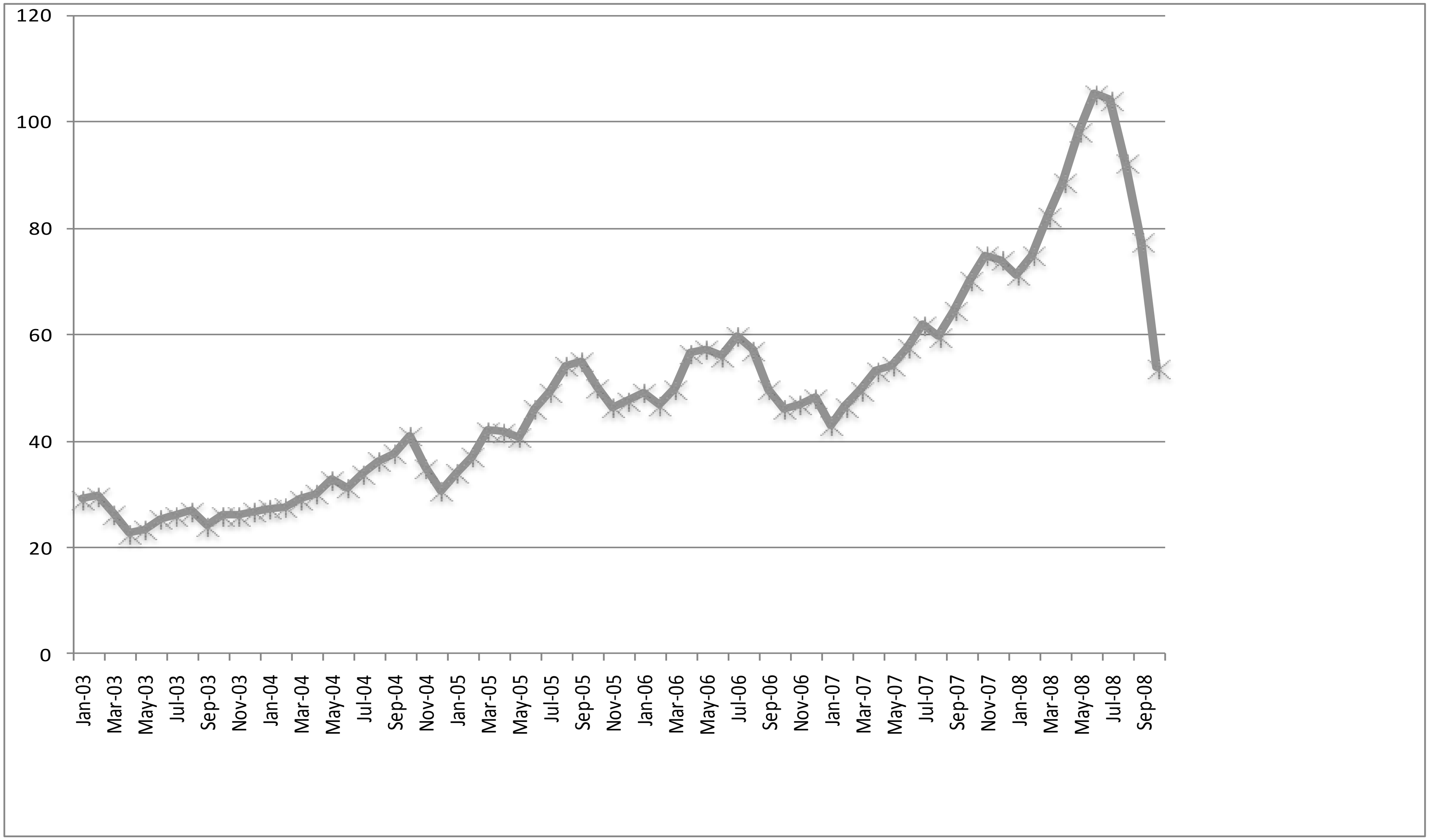
Source: CDC, http://apps.nccd.cdc.gov/PASurveillance/StateSumV.asp.

Figure 2: Nominal and Real Gasoline Prices in the U.S. 2003-2008.



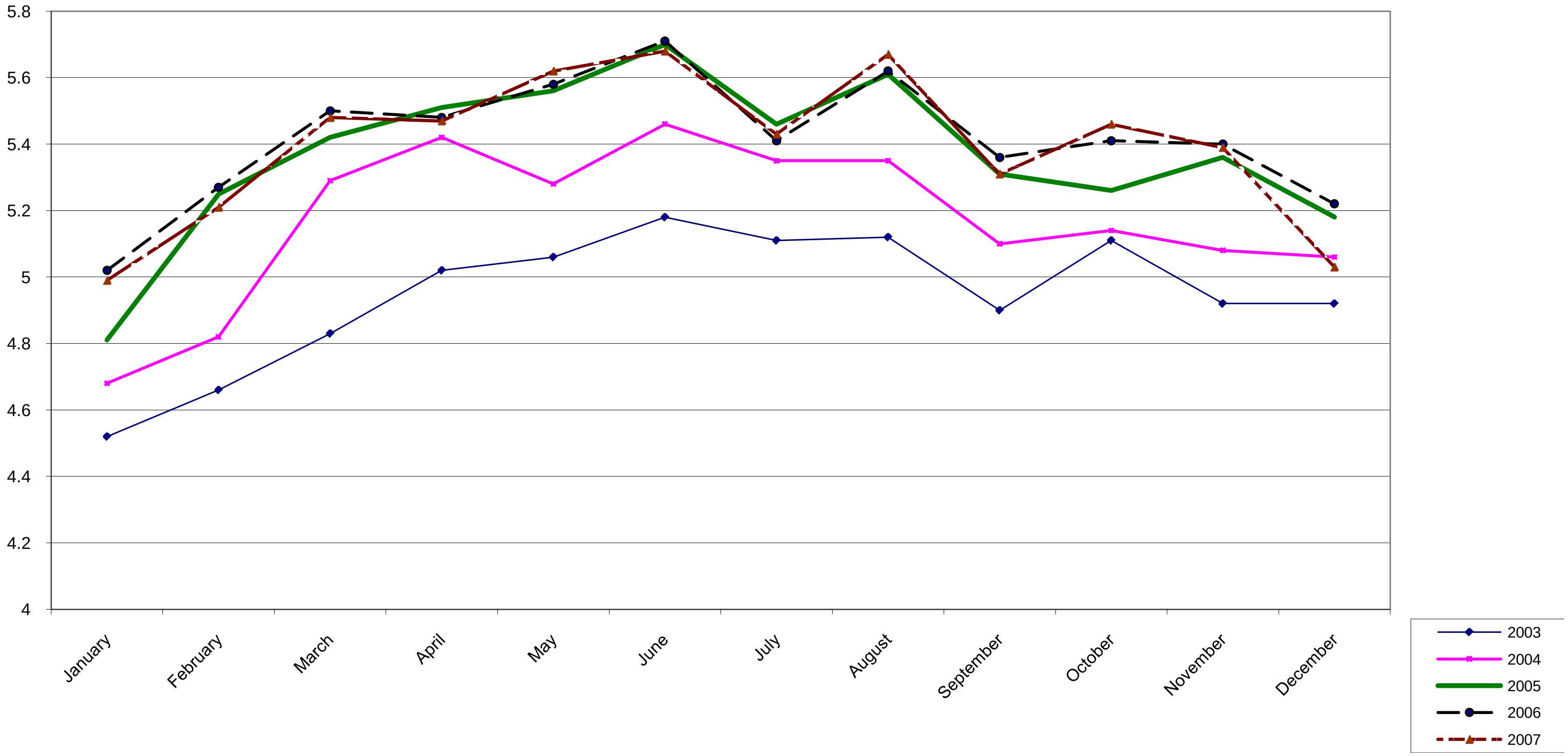
Notes: Retail Prices for Regular Unleaded gasoline in cents per gallon. Source: Data is obtained from the Energy Information Administration (EIA) surveys of refiners and retailers/resellers (http://www.eia.doe.gov/oil_gas/petroleum/info_glance/petroleum.html).

Figure 3: Real Prices of Imported Crude Oil ($s Per Barrel) to the U.S. 2003-2008.



Source: Data on inflation adjusted 'Free on Board' imported crude oil, obtained from the Energy Information Administration (EIA).

Figure 4: Vehicle Miles Traveled, by Month. 2003-2007.



Source: ‘Traffic Volume Trends’ (US Department of Transportation and Federal Highway Administration, www.fhwa.dot.gov/ohim/tvtw/tvtpage.cfm).

Table 1. Sample Means of Different Physical Activities.

	Full sample. N= 81957		Gas price below Median. N=40709		Gas price above Median. N=41248	
	Minutes (full sample)	Participation	Minutes (full sample)	Participation	Minutes (full sample)	Participation
Leisure-time Walking, Biking, Running	3.89 (19.11)	0.066	3.55 (18.71)	0.062	4.22 (19.09)	0.070
Walk/bike work/errands	3.13 (14.80)	0.136	2.91 (14.53)	0.115	3.21 (15.05)	0.143
Playing with Children	9.06 (39.11)	0.087	8.67 (37.76)	0.081	9.60 (40.41)	0.096
Moderately Energy Intensive Housework (MEIHW) [1]	50.81 (99.41)	0.423	50.45 (99.07)	0.424	51.82 (99.75)	0.426
Overall Moderately Energy Intensive Physical Activity (MEIPA) [2]	80.56 (119.01)	0.612	78.48 (118.13)	0.601	82.37 (120.55)	0.621

Notes: The median gas price in 2007 dollars is $2.21. These figures are sample means, and are not weighted to account for oversampling. Weighted population-representative means are available upon request.

[1] : All housework that involves a MET value of 3 or higher.

[2]: All physical activity that involves a MET value of 3 or higher.

Table 2. Summary Statistics for Control Variables

Variable	Mean (Std. Dev.) (N=81957)	Variable (N=72750)	Mean (Std. Dev). (N=81957)	Variable (N=72750)	Mean (Std. Dev) (N=81957)
Respondent is Male	0.433	High School Only	0.273	H-hold Income 35-<40K	0.052
Respondent is African-American	0.119	Some College	0.265	H-hold Income 40-<50K	0.082
Respondent is Asian	0.027	4-yr College	0.183	H-hold Income 50-<60K	0.078
Respondent is Hispanic	0.122	Graduate	0.104	H-hold Income 60-<75K	0.091
Respondent is other race	0.019	H-hold Income < 5K	0.021	H-hold Income 75-<100K	0.140
Spouse in household	0.523	H-hold Income 5 -<7.5 K	0.022	H-hold Income 100-<150K	0.059
Partner in household	0.030	H-hold Income 7.5 -<10 K	0.022	H-hold Income 150K <	0.035
Child under 6 in household	0.201	H-hold Income 10-<12.5K	0.030	State Unemployment Rate [1]	5.286 (1.035)
Respondent's age	45.874 (17.523)	H-hold Income 12.5 - <15K	0.027	Average monthly precipitation (inches) [1]	3.273 (2.065)
Total number of h-hold children	0.909 (1.157)	H-hold Income 15-<20K	0.043		
Diary date a holiday	0.017	H-hold Income 20-<25K	0.054		
Non-rural area of residence	0.807	H-hold Income 25-<30K	0.056		
Interview in Summer season	0.243	H-hold Income 30-<35 K	0.056		

Notes: These are sample means, and are not weighted to account for oversampling. Standard deviations are for continuous variables only. The omitted category for schooling level is 'less than high school'. The omitted category for household income is 'income not reported'. Household income is not inflation adjusted since precise dollar figures are not provided. Variables in the regression model but not in this table include day of the week of diary, and year of survey. [1]: These variables are measured at the state level and merged in by state and month.

Table 3. Results from Multivariate Regression Models for Selected Physical Activities and Gasoline Prices (in $s per gallon).

Real gasoline prices for that month	Probit Model	OLS Model		Probit Model	OLS Model		Probit Model	OLS Model
Leisure time Walking, Bicycling, Running	0.011** (2.29)	1.29 ** (3.00)		0.010 ** (1.97)	1.28 ** (2.61)		0.010 * (1.87)	1.55 ** (3.30)
Walk/bike to work or errands	0.023 (1.63)	0.62 * (1.70)		0.030* (1.66)	0.74 ** (1.98)		0.030* (1.67)	0.57 (1.56)
Playing with Children	0.002 (0.77)	-0.71 (-1.41)		0.005 (1.44)	-0.98 * (-1.80)		0.004 (1.20)	-0.80 (-1.58)
MEIHW [1]	0.020** (2.14)	8.66 ** (3.92)		0.015 ** (2.44)	7.74 ** (3.42)		0.015 ** (2.56)	8.34 ** (3.54)
Overall MEIPA [1]	0.024 ** (2.13)	10.67 ** (5.38)		0.025 ** (2.30)	10.39 ** (4.42)		0.028 ** (2.52)	10.74 ** (4.80)
State Fixed Effects	Yes	Yes		Yes	Yes		Yes	Yes
Day of week Fixed Effect	Yes	Yes		Yes	Yes		Yes	Yes
Year Fixed Effects	Yes	Yes					Yes	Yes
Season Fixed Effect	Yes	Yes		Yes	Yes		Yes	Yes
Time Trend				Yes	Yes			
Time Trend Squared				Yes	Yes			
Time Trend x State Fixed Effects							Yes	Yes
Season by Year Fixed Effects								

Notes: N=81957. T-statistics in parenthesis. **: $p<0.05$. *: $p<0.10$. Retail gasoline prices are inclusive of state and federal taxes, adjusted using CPI 2007=100, and in dollars per gallon. All models additionally control for the respondent's gender, race-ethnicity, marital status, whether living with a partner, age, age-squared, number of children in household, any child under 6 in household, residence in metropolitan area, education level, household income level, if interviewed on a holiday, state unemployment rate and average precipitation in that state and month. Pooled observations for 2003-2008, residents from all states but excluding D.C. Equations are weighed using the population weights provided in the ATUS data. Standard errors are adjusted for clustering at the state level. [1]: Moderately energy intense housework (MEIHW) and physical activity (MEIPA) denote all housework and physical activity with a MET value of 3 or higher.

Table 4: Multivariate Regression Models for Selected Physical Activities and Gasoline Prices for Selected Time Periods & Different SES Groups.

	Outcome Variable: MEIHW		Outcome Variable: Energy-Intense Housework (3.8<=MET)		Outcome Variable: MEIPA	
	Probit Model	OLS Model	Probit Model	OLS Model	Probit Model	OLS Model
Full sample (N=81957)	0.020** (2.15)	8.66 ** (3.92)	0.035 ** (3.57)	10.25 ** (2.85)	0.024** (2.14)	10.67 ** (5.38)
Analyses for Different SES Groups						
Minorities (N=23491)	0.003 (0.19)	2.00 (0.08)	0.001 (0.11)	4.02 (0.92)	0.001 (0.07)	5.24 (1.43)
Non-Hispanic Whites (N=58466)	0.031 ** (2.24)	9.97 ** (3.61)	0.05 ** (4.99)	11.05 ** (4.55)	0.034 ** (2.57)	11.43 ** (3.43)
Single parents (N=14136)	0.026 (1.58)	6.43** (2.41)	0.01 (1.00)	0.92 (0.69)	0.021 (1.40)	8.62 ** (2.81)
All others (N=67821)	0.040** (2.04)	8.99** (3.08)	0.040 ** (3.67)	11.45 ** (2.88)	0.040 ** (2.77)	12.77 ** (3.18)
HH-Income < $35,000 [1] (N= 27051)	0.012 (0.83)	8.08* (1.80)	0.03** (2.60)	4.35 (1.39)	0.008 (0.41)	11.62 ** (2.49)
$35,000<= HH-Income <$100,000 [1] (N= 35747)	0.030 * (1.95)	10.76 ** (2.35)	0.04 ** (3.81)	13.42** (3.65)	0.037 ** (1.97)	14.74 ** (2.28)
$100,000 <= HH-Income [1] (N=8311)	0.024 (0.93)	6.33* (1.65)	0.060* (1.66)	5.18 ** (2.34)	0.045 (1.23)	8.07** (2.25)
High School or Less (N=36563)	0.017 (1.49)	5.30* (1.65)	0.019 (1.39)	6.73** (2.90)	0.017 (1.15)	7.25 ** (2.10)
More than High School (N=45421)	0.024 * (1.93)	9.39 ** (3.15)	0.050 ** (4.92)	11.12 ** (3.87)	0.032 ** (2.03)	11.03** (3.18)

Notes: T-statistics in parenthesis. **: p<0.05. *: p<0.10. Retail gasoline prices are inclusive of state and federal taxes, adjusted using CPI 2007=100, and in dollars per gallon. All models additionally control for the variables listed in Table 3. Standard errors are adjusted for clustering at the state level.
[1]: This analyses excludes those respondents whose annual household income is missing (about 15 percent of sample).

Table 5: Multivariate regression Models with Selected Periods and (Year x Season) Fixed Effects.

	Outcome Variable: MEIHW		Outcome Variable: Energy-Intense Housework (3.8<=MET)		Outcome Variable: MEIPA	
	Probit Model	OLS Model	Probit Model	OLS Model	Probit Model	OLS Model
Model Specification 1						
'High Fluctuation' Time Periods Only [1] (N=20807)	0.033* (1.92)	12.53** (3.41)	0.050** (3.47)	11.24 ** (3.56)	0.040** (2.23)	15.13** (3.06)
Model Specification 2						
Includes (Season x Year) Fixed Effects[2] (N=81957).	0.035** (3.94)	12.63** (4.58)	0.052** (5.04)	10.52** (4.75)	0.043** (2.49)	15.32** (4.29)
Model Specification 3						
Mode Gasoline Prices	0.030** (2.88)	10.83** (4.03)	0.050 (4.16)	8.57** (4.58)	0.041** (2.87)	13.68** (3.58)
Gasoline Prices x Cold States[3]	0.008 (0.87)	2.00 (1.24)	0.009 (1.52)	2.20 (1.25)	0.005 (0.48)	1.51 (0.51)
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Day of week FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Season FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: T-statistics in parenthesis. **: $p<0.05$. *: $p<0.10$. Retail gasoline prices are inclusive of state and federal taxes, adjusted using CPI 2007=100, and in dollars per gallon. All models additionally control for the variables listed in Table 3. Standard errors are adjusted for clustering at the state level.

[1]: July to October 2005 (2 months before to 2 months after Katrina), and June 2007 to September 2008.

[2]: A separate dummy variable is included for each season-year combination through the entire period covered by this study.

[3]: 'Cold states' are defined as states with most of the land area lying in USDA weather zones 7 or lower. This model specification also included just the binary variable for 'cold states', but that variable is of course subsumed by the state fixed effects.

Appendix

Table A. Regression Estimation Using Natural Log of Physical Activity, and Using Lagged Gasoline Prices.

	Natural Log of Dep Var	Dep Var (Participants only)	Gasoline Prices & Lagged Gasoline Prices	
	OLS Model	OLS Model	Probit Model	OLS Model
Leisure time Walking, Bicycling, Running	0.198 ** (3.55)	3.14 (0.76) N=5451	0.033 ** (3.40) -0.013 (-1.47)	1.71 ** (2.69) -0.47 (-1.15)
Walk/bike to work or errands	0.070 (1.17)	4.81* (1.76) N=11199	0.014 (1.42) -0.008 (-0.66)	1.143 * (1.94) -0.74 (-1.47)
Playing with Children	-0.034 (1.13)	-3.51 (-0.75) N=7108	-0.001 (-0.29) -0.003 (-0.67)	-0.210 (-0.27) -0.651 (-0.81)
MEIHW	0.270 ** (3.12)	13.39** (2.88) N=34697	0.022 ** (1.99) -0.0003 (-0.07)	6.92 ** (2.31) 2.20 (0.78)
Energy Intense Housework	0.619 ** (8.51)	10.10* (1.86) N=11816	0.066 ** (6.47) -0.001 (-0.15)	11.49 ** (4.91) -1.01 (-0.57)
All MEIPA	0.356 ** (4.60)	12.47** (3.54) N=50193	0.034 ** (2.61) -0.007 (-0.63)	13.19 ** (4.60) -0.72 (-0.23)

Notes: All models control for all variables described in Table 3, and state, year, season and day of week fixed effects.