Title: Obesity: Causes, Consequences and Cures/ Project 5
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A. SPECIFIC AIMS

The overall objective of this project is to evaluate policy to reduce cancer through weight control. Project 5 has three parts. First, using multivariate analysis on national survey data we seek to quantify the role of various factors that drive what we refer to as "weight-health", or health in terms of body composition. Next we examine the tie between these factors that affect body composition and body composition itself to cancer. This is another way to get at the role of obesity directly compared to the role of the underlying phenomena associated with obesity. Finally given what is learned not only in this project, but the others as well, we will perform various program evaluations to assess the effectiveness of alternative interventions. We tie together all of the projects, including this one, through evaluation.

Specific Aim 1. ***A Structural Model of Obesity: Are Health-Related Habits A Cause or Consequence? [Causes of Obesity]***

The purpose of this part of the analysis will be to identify those factors that explain unhealthy weight. Before addressing policies to reduce the prevalence of overweight and obesity we must understand the roles of various underlying factors, otherwise policies may not realize their desired effects. We will develop a conceptual framework for modeling obesity and test it empirically. In doing so, we will answer empirical questions about the importance of various underlying factors that contribute to one's "weight health" or obesity. We propose to use a nationally representative public database, the National Health and Nutrition Examination Survey (NHANES). Estimating the impact of choice variables like health-related behaviors (caloric intake and energy expenditure), as well as work choices, is challenging. These health-related decisions are not independent of weight health and are therefore made simultaneously, resulting in causality concerns. Psychological well-being could be driving many of these choices as well as the outcome. Without proper controls for unobserved well-being, estimated effects of other factors on obesity will be biased – likely exaggerated. One of the key contributions of this project will be to address such statistical issues in a number of ways. We do not strictly rely on self-reported data for indicators of obesity and we allow for measurement error in self-reports of health. We include indicators of all potential factors, observed and unobserved, physiological, behavioral, and emotional in our model. We include investments in healthy behaviors, even though they are likely endogenous to a model of obesity, by modeling them separately as a choice. In doing so we will better understand choices people make based on their preferences and health states, and learn how they fit into an overall production function of weight (often measured by body mass index – BMI).

We hypothesize that psychological well-being will drive much of what we observe in terms of both behaviors and outcomes. Policy implications if we are correct will be to address emotional well-being as well as interventions of behavioral incentives.

Specific Aim 2. ***The Tie Between Obesity, Underlying Causes of Obesity and Cancer using NHANES [Consequences]***

Using the NHANES and findings from part I of this analysis, we will examine not only the links between obesity and various types of cancer, but the mechanisms through which they operate. That is,

after learning more about the factors affecting BMI, we can link these factors to cancer and better assess the role of relevant risks and the benefits to investments in BMI-reduction.

We hypothesize that the role of obesity alone will be smaller after controlling for related behaviors and emotional health.

Specific Aim 3. The Costs and Benefits of Alternative Obesity-Related Policies [Cures]

a. Community Intervention Evaluation

Using the data available from the community-based intervention project of this proposal, we will perform a cost-benefit analysis of the community-based interventions at the individual, school and family level.

We hypothesize that, at the margin, there will be a reduction in unhealthy food choices at school, particularly among teens where intervention is greater. We hypothesize that the impact on household consumption patterns will be smaller, but in the desired direction.

b. Medical Services Approach

Because we include health insurance and access to medical services in our analysis, we plan to simulate the impact of medical coverage for nutrition counseling as a policy for reducing obesity (using our findings in Part I of this project).

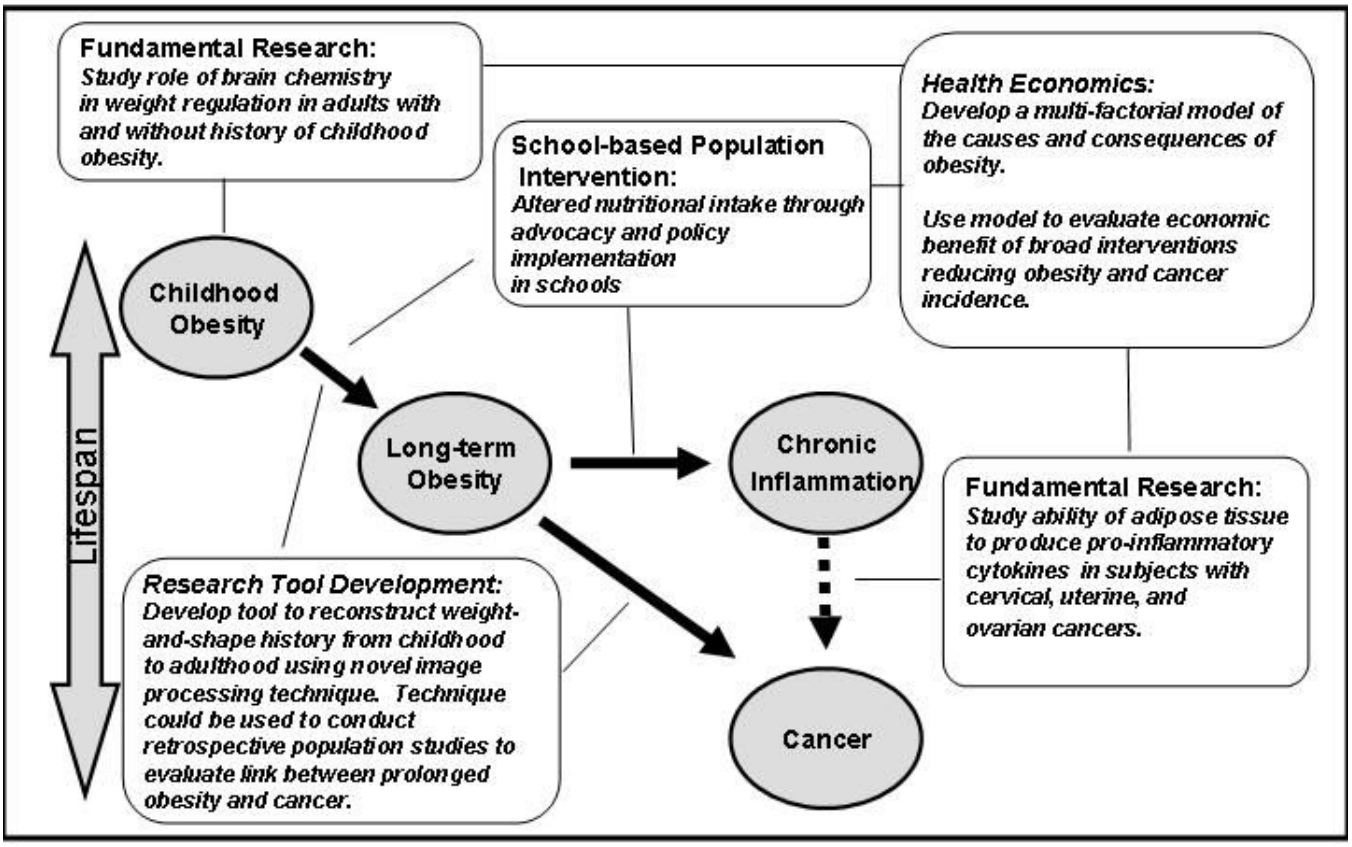
Our hypothesis is that improving access to nutrition services, at the margin, will have a positive impact on behavior and weight changes. The effect will be much greater when interacted with access to psychological services.

c. **Cancer Reduction Policies** – We will perform simulations of alternative methods for reducing BMI and their impacts on cancer using information from Part II of this project as well as the findings of the fundamental research described in Figure 1, that ties risk factors like chronic inflammation to cancer.

Our hypotheses will depend on findings from the earlier stages of the project as well as other projects.

The Specific Aims of the overall project are separated into three smaller sub-projects and will be discussed as separate but related endeavors. Figure 1 is a schematic model of the components of the TREC proposal at Stony Brook. This health economics component has as its independent contribution an analysis of the factors that relate to obesity in a multivariate setting. But we benefit from the risk factors identified in the fundamental project on inflammation. The research also has an evaluative component that ties to the intervention. Eventually we will also benefit from the research tool development by linking weight histories to survey data.

Figure 1. Research Components Stony Brook TREC



B. BACKGROUND AND SIGNIFICANCE

A Structural Model of Obesity: Are Health-Related Habits A Cause or Consequence? [Causes of Obesity]

The growing prevalence of obesity and obesity-related health problems have become important public health concerns. The costs of obesity are believed to be large, but have been difficult to quantify to date given the complexities and interactions between obesity, health, economic status, and behaviors. A recent study estimates the medical costs related to obesity in youth of $127 million in 1999-2000, up from just $35 million in the late seventies (Wang and Dietz, 2002). Estimated costs in adults are even higher. These estimates do not capture the total costs of obesity that go beyond medical expenditures. We know that obesity increases the risk of many physical health conditions, including but not restricted to heart disease, cancer, and diabetes. These have social welfare implications given the cost to treat these illnesses. Obesity also reduces individual welfare because of its impact on mental health and one's ability to enjoy consumption and leisure, and productivity in the workforce (both through its impact on health as well as actual productive capacity). The benefits from reducing obesity are also difficult to quantify in that we would have to measure the expected gains to quality of life including work, health, and the ability to consume. It

would be premature to engage in performing any kind of cost-benefit policy evaluation, without first understanding the inter-related factors that result in obesity.

We are not the first to discuss the importance of understanding the reasons why people are obese. Hill et al. (2003), using the same data we propose to analyze, present changing trends in consumption patterns that could explain a substantial proportion of the growth in weight trends. As they say, "There is growing agreement among experts that the environment, rather than biology, is driving this epidemic" (Hill et al., 2003, p2). They advocate for a specific behavioral target to slow the trend. In order to prescribe such a target, we need to assess the role of behaviors independent of other physical and emotional factors, in a multivariate setting. We incorporate this concept of the "energy gap" from that literature into our models. Empirical evidence using multivariate analysis is typically restricted to focused or narrow questions regarding the role of specific factors on obesity For example, Chou, Grossman and Saffer (2002) examine the role of changing prices of health-related goods, such as the price of cigarettes, on obesity over time. Coate (1983) focuses on the relationship between parent's weight and diet on obesity in children. Mela and Rogers (1998) focus on psychology, appetite and weight. Hass et al. (2003) conclude that race and access to medical services through health insurance explain a significant amount of the variation we observe in obesity outcomes in youth. Freedman and Stern (2004) define an "optimal healing environment" that is developed through collaboration between families and health care providers, which relates to medical services access again. They advocate for information interventions in social and family settings to improve behaviors. This type of evaluation of an intervention is useful for policy and is being examined in another part of this proposal. Whether such interventions alone will improve obesity in the longer run depends on the relative importance of diet in the production of better weight health. It is the intent of this study to assess the relative importance of the various factors that determine weight health in order to provide insight for interventions as well. To our knowledge no study has conceptualized an overall "production function" of BMI (described more fully below). But by combining what has been learned in prior research, taking advantage of structural changes over time (Chou et al, 2002), and directly modeling investments in health habits (Zweifel and Breyer, 1997) to produce better health, we can piece together and infer the dominant forces behind what we observe today in terms of obesity and its determinants.

Another body of relevant literature for our purposes is one that focuses on the role of obesity on other outcomes like work or health to assess costs. These studies tend to acknowledge that obesity is endogenous to such outcomes; i.e., that there is a causality problem. One approach to solve this endogeneity problem has been to use parents' BMI to instrument obesity (Cawley, 2000). We will include variables related to work and other socioeconomic factors in our analysis as a factor driving weight health, and will likewise need to account for its endogeneity. In the literature, the hypothesis is that obese workers are less in demand in the workforce, either because they are less productive due to physical limitations, or there may be some discrimination (Cawley, 2000). Another related hypothesis is that work is more difficult for obese people and they choose to work less. In any case, researchers in this area have expected to find negative correlations between obesity and work hours as well as wages. The findings are mixed but there is support of this negative correlation. We will include work variables since they may affect time available for caring for health. They may also be good indicators of stress. We benefit from the insights of these studies and we learn from them that there is the issue of causality that must be addressed. One advantage we have is a dataset that measures many inputs to healthy weight so that we can test for exogeneity of various instruments.

What follows is a discussion of 1) the conceptual framework with an econometric structure for identification of key parameters; 2) data available for the analysis; 3) an empirical methodology for testing theoretical hypotheses; and 4) a discussion of what we expect to learn from this proposed research.

C. EXPERIMENTAL DESIGN AND METHODS

Conceptual Framework

A production function of BMI. In economics outcomes are often considered to be the consequence of a production process. We conceptualize health outcomes as a commodity that we can produce and benefit from. In other words, we invest in our health to produce better health, or to improve our chances at better health in the future. It is not the investment per se that we get utility from (where utility is our indicator of satisfaction), but the *consequence* of the investment i.e. better health. So when we purchase a flu shot from a given provider of medical services, for example, we are not getting utility from the shot. We are getting utility from the reduction in the propensity to get sick from the flu having made this investment. We see that flu shot as an input into a production process of our state of health in that flu season. The economic model we use is often referred to as a *production function* for a particular health outcome. Individuals choose inputs into production but are constrained by their own efficiency in their ability to turn health-related habits into healthy outcomes. And they are trading off choices that might improve health weight with other consumption choices that might yield more satisfaction.

When discussing obesity as a particular health outcome, we make health-related investments or disinvestments that will contribute to our BMI which determines obesity. These behavioral investments are a choice we make that influences our propensity for better health. So our objective may be to lose weight, but we cannot just decide to pay some money and buy weight loss. It is weight loss that we are buying, but only indirectly through other choices. These investment choices are a function of many factors, including income, preferences for health, work, leisure, sports, food, and so on. The model for BMI is more complex than the flu shot example we gave, because some of the investments we make are commodities we do get utility from directly rather than indirectly through BMI. For example, playing soccer is something that would lower BMI as well as increase utility directly if we enjoy the game. Investments in exercise therefore must account for individual heterogeneity in preferences for exercise.

Besides behavioral factors that we do have control over, there are many factors outside of our control, or that we have limited discretion over, that impact our BMI. These include our genetic make-up, and ability to process information (which is a function of investments (choices) in human capital like education but also genetics). Psychological factors drive both our choices and our outcomes. Conceptually all of these inputs into the production process affect BMI, but how important each is in explaining the outcome remains an empirical question. The answer will have strong implications for the success of policies in reducing obesity. The challenge will be to identify the best strategies in the face of these complexities.

Figure 2: Structural Model of Weight Health

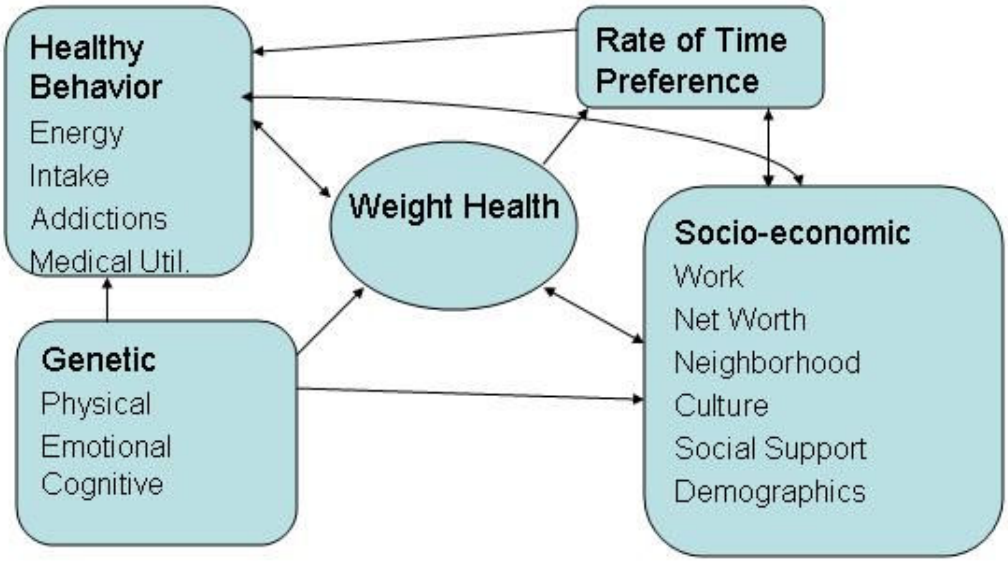


Figure 2 shows the complexities of the model of BMI production. Each of the inputs to BMI production listed represents a vector of factors that enter into the production process. Note also that these vectors are not independent of each other nor are they exogenously predetermined in the model. And while this is a model of the inputs to the production process, BMI is also an input to some of the relevant factors revealing causality concerns that need to be addressed in any empirical methodology. Furthermore, while the model of BMI production might be the same across individuals, the estimated effects of various inputs might vary by age, gender, race, and other factors. This too will need to be allowed for in the analysis. While we cannot model all of the interdependencies in various factors, we can make assumptions and test them over time. In other words, this proposed project is a longer term endeavor. Over the next few years we will vary the model to alternate assumptions and test them. Only in this way can we identify causal relationships. We will begin with a general model, and then define a given set of assumptions in the econometric framework for the initial part of the analysis.

One of the many advantages of pursuing a project like this in the trans-disciplinary setting is that we will benefit from the fundamental knowledge possessed by the clinicians that an economist is lacking. So we learn how to include relevant physiological markers for obesity risk from doctors. We learn how to measure psychological functionality from psychologists. We put it all together in a structural economic model that will address the endogeneity issues described above.

A Model of The Consumer's Problem

The proposed model builds upon seminal work by Grossman (1972), applications of Grossman to obesity by Chou et al. (2002), and Zweifel and Breyer's discrete choice model of investments in health practices (1997). The theoretical framework for describing the production process of BMI is one where individuals gain utility from consumption of goods and services (which is determined by what they can afford, or income), leisure time (which includes leisure activities that may overlap with health production such as exercise), and good health and attractiveness directly (in this context as measured by BMI). They make choices about how much to consume of goods and services (and simultaneously work, since income and our ability to afford consumption is a function of work), and health inputs, so as to maximize their utility (well-being), subject to some constraints. The constraints are where the model of BMI production becomes particularly relevant. People are making consumption choices and trading off investments in health with investments in other consumption goods and services (say broccoli verses McDonalds might be one such relevant tradeoff; watching tv verses going to the gym is another), subject to a production constraint. So one of the choices they make will account in some way to their impact on BMI. But they are also constrained by genetics that include cognitive and physical make-up that impact their ability to produce better health through BMI, as well as time-constraints.

Our conceptual model will begin, however, with just the utility side of the model, without constraints. We will then add in constraints. Using this model, we will derive hypotheses regarding investments in better health, and test these hypotheses in an empirical specification of BMI production. In developing a detailed model of consumer investments in factors affecting obesity, we seek to gain an understanding of how and why people make these choices, as well as the effects of these choices on obesity. Thus, although the overall objective of this project is to understand the factors that drive BMI, we cannot do this without first understanding the individual decisions that underlie the factors. This is the main contribution of the proposed conceptual model.

1. Willingness to Pay for Better Chances at Lower BMI

In this part of the analysis, we will develop a model of the tradeoffs between investments in better chances at good BMI and investments in consumption of other goods and services. Decisions we make at any given point in time will affect our propensities for BMI in the immediate future (the short run). We will derive the marginal rate of substitution between these different investments to get at individual willingness to pay for a better chance at BMI, that is dependent on the current BMI state. In other words, the investments I make are not independent of my current weight and height. The decisions we make are state-dependent.

2. The Constraints: A Model of BMI Production

This part of the model will consist of three constraint sets:

- a *budget* constraint which includes wages, hours of work, and disposable income from wealth to measure what we can afford. We will define potential expenditures on health related activities, including diet and diet information (which is a commodity that may be purchased or acquired), exercise, smoking, drinking, medical services and

consumption of other goods and services. This budget constraint needs to account for varying prices of medical services by health insurance.[1]

- A *time* constraint that allows for time spent working, engaged in healthy activities, and consumption of other goods and services.
- A *production function* (or technology) that defines all of the inputs to BMI, that determine BMI, including endogenous choice variables as well as predetermined or exogenous factors. These inputs would include medical services, exercise, diet and health-related behaviors. We will also consider the role of cognition, psychological health and physical health in affecting this production process.

3. Econometric Models and Testable Hypotheses

The outcome equation that we seek to model is the production function of BMI as well as a propensity toward obesity. The empirical model may be written as:

$$O^* = \alpha_0 + \alpha_1 G \ + \alpha_2 P \ + \alpha_3 B \ + \gamma + \varepsilon$$

where,

O^* = weight related health – an unobserved measure of our propensity for good health due to our weight (often proxied using observable measures such as BMI, or Obesity propensity)[2]

G= vector of biological factors – family health traits, salt sensitivity, cognition, health status

P = vector of psychosocial attributes – socio-economic status and rate of time preference, which includes social support, stress, emotional well-being

B = vector of behavioral components that include energy intake, addictions, medical utilization – investments made last period – to create the "energy-gap" index

γ = unobserved factors that drive B and O^*, for example, Health need for intervention

From the conceptual model, we know that B is a vector of choices made to achieve a given level of O^*, but these choices are state dependent. That is, how much we invest in B depends on O*, since we may choose to act only when we reach some sufficiently undesirable level of weight health. That threshold of need for intervention varies across individuals and is unobserved. It is therefore something that would be picked up in the error term, and non randomly distributed across individuals. In our model, γ would measure this unobserved factor that drives both B and O*. We want an unbiased estimate of the effectiveness of various behaviors in producing a better outcome. Without addressing this unobserved threshold issue, however, we would instead get an estimate of the propensity to participate in the behavior based on the outcome. In statistical terms. α_3 would be biased because B is correlated with γ in the error term. So we model B explicitly to get an indicator of individual propensities to participate in a given behavior. From analysis on data from behaviors we can also carve out an

[1] Medical services can provide information regarding risky weight levels and therefore are a form of investment in behaviors that impact obesity.

[2] We know that what people are choosing when they invest in lowering their weight is actually "better health", "better looks", and "better work potential". In this sense what is being demanded is derived from "lowering weight". This has implications for the model in that we need to account for one's preferences for these three reasons for wanting better weight as well as one's propensity to succeed (addictive personality). We do so in our controls for psychosocial attributes.

instrument for γ. If we can control for γ, we would purge the estimated effect of B of its bias. Because this is key, we will invest time in producing an index of propensity for healthy behavior using confirmatory factor analysis. We can then model the two outcomes, healthy habits and obesity, simultaneously.[3]

Notice there are no time subscripts on the factors. The theoretical framework defines periods in a way such that investments today do not affect outcomes today, but rather in the next period. But the timing is specific to the behavior in question so we will define it specifically for each factor in the data section. Using lagged values of behaviors might make them less of a problem in terms of causality since our decision to participate last period in a behavior (say a diet) is decided by last period's weight health rather than next period's. But we cannot conclude that B is exogenous if we use last period's behavior, because O_t^* is correlated with O_{t-1}^*. Also, there might be some other unobserved factor that drives our decision to take on a particular behavior that is fixed over time. So we will treat B as endogenous and test for exogeneity.

Our model of investing in health-related behaviors can be represented by:

$B=B(O^*,G, P,C,X)$

Where X represents other relevant factors relating to the decision to participate in healthy activities but not obesity directly (relevant prices of activities, which includes health insurance)

We will model individual behaviors for two reasons: 1. to gain a better understanding of individual choices as this is important for policy decisions, and 2. this part of the analysis is a contribution on its own because we will learn about factors that contribute to the propensity to invest in behaviors that we know influence weight. If psychology has a lot to do with those investments, the policy implications are very different than if it is purely economic factors. This part of the analysis also provides insight into the role of obesity propensity on behavior.

D DATA

We plan to use the 1999-2004 National Health and Nutrition Examination Survey (NHANES) collected by the Centers for Disease Control and Prevention National Center for Health Statistics and Health and Human Services (HHS). The data are collected from a nationally representative sample of individuals aged 1 to 120 and their households. The advantages of this dataset are numerous. First, it is longitudinal (surveyed every two years) so that we can do a better job with measurement error of key variables (a snapshot of behaviors is not as good as a longer term view; and repeated responses allow for consistency checks). Also, given the longitudinal nature we can study behaviors dynamically in a hazard setting, as well as use panel data techniques to allow for unobserved heterogeneity in the data. And finally, our models require indicators of behaviors that occur before the weight outcome we observe. Second, the data are a rich source of objective indicators of health (not all self-reported – BMI is obtained), as well as socioeconomic factors including social support and family structure as well as income, occupation and health insurance benefits. Most importantly they ask very detailed questions about healthy habits and behaviors as well as health status that are inputs to BMI production. The

[3] In order to identify a model like this we need to make some distributional assumptions about the model of healthy behaviors.

study data are collected using three mechanisms: an interview, an examination component (mobile exam center), and a laboratory component (results of the blood and urine analysis of exam). This allows for consistency checks on self-reported information as well as more accurate indicators of health measures.

Dependent Variable, Weight Health: Our main equation outcome is weight health. We use a number of indicators for measurement of this dependent variable. From the household survey questionnaires we get self-reported information of height and weight to construct BMI as well as discrete indicators of obesity and overweight. We also get a self-assessment of weight health (overweight, underweight, right) as well as satisfaction with weight and preferences for change, changes in weight and weight and height history dated back 10 years and at the age of 25. We have this retrospective data reported in a panel which provides us with a mechanism for dealing with any measurement error through consistency checking. It also gives us an opportunity to examine reporting behavior and how it relates to other factors.

Besides the survey questionnaires there is a Mobile Exam Center (MEC) component linked to this survey that provides medical information including body weight and composition (anthropometry) measures that are more objective than self-reports. This provides an excellent way to test for measurement error bias in the self-reports. This provides information about sample respondents that are typically unobserved. People have heterogeneous propensities to mis-report, and those propensities carry over to other behaviors as well. It helps us to understand and control for measurement error in other self-reports as well if we could control for this propensity.

Roughly 29% of our data sample (overall - all ages) is obese, using the standard definition of having a BMI of 30 or higher. Among those categorized as obese, 12% consider themselves to be "about the right weight" compared to 59% of the non-obese sub-sample. If we look retrospectively, 24% of those who were ever obese are currently satisfied with their weight compared with 61% who were never obese. There is sufficient variation in BMI as well as changes in BMI.

MEASUREMENT OF INDEPENDENT VARIABLES[4]

Behavioral Factors – these include health-related activities (improvements or disinvestments)

1. **The Energy-Gap**: An indicator of energy expenditure relative to energy intake.[5] The relationship between individual intake and energy expenditure factors and weight may be analyzed individually. What may be of more interest is an overall rating or some summary indicators of diet behavior/s and physical activity that may be constructed from underlying commonalities. Ultimately we will construct an indicator of the energy gap using all of these measures. We will perform sensitivity analysis to various definitions of intake and energy expenditure. Our hypotheses, as proposed by Hill et al. (2003), is that this gap, if defined as intake – expenditure, will be positively correlated with weight and propensity for overweight. In this section we discuss data availability for measuring the various components of behavior.

[4] Model specification may vary by age, gender or race. For example, in the model for childhood obesity we will include breastfeeding indicators. For older people we will include more information about functional status (Activities of Daily Living)

[5] See Hill et al., 299(5608): 853 for a definition of the "energy gap".

i. ***Intake***:

a. Diet and Nutrition

NHANES has very detailed information about intake, including both individual foods and nutrients consumed. This is a main strength of the data. In the questionnaire we have information about milk (quantity, type and frequency), salt (quantity, type, frequency), meat (quantity, type, frequency), seafood, carbs, meals outside the home (frequency). They are also asked about their "food security" or their ability to afford nutrition. There is a questionnaire module on the use of dietary supplements as well.

In the examination module they reconstruct daily intake by asking respondents to report their nutritional consumption including time of day (type of meal as well) and location of meal. From the reports we are able to get total nutrients (energy/calories, vitamins, minerals, fat, carbs…). The laboratory component collects data from blood and urine analysis on nutrients including glucose, calcium, iron... Triglycerides, cholesterol, and other indicators of poor diet are included in the laboratory component of the survey. TREC physicians would be involved in the assessment of these data.

In addition, for years 2001-2002 and forward, NHANES has integrated the "Continuing Survey of Food Intakes by Individuals (CSFII) into the 2001-2002 data. This integrated component is called "What we eat in America"[6] and is collected as part of NHANES but is collected on a continuous yearly basis. Two days of data are collected for all respondents, and the Day 2 interview is conducted by telephone. So we have annual intake from 2001-2004 and separate analysis can be performed on this sub-sample. We can also use these data combined with the 1999-2000 instruments for validation.

b. Alcohol, Drugs, Smoking

Questions about the frequency, quantity, and type of alcohol and illegal drug consumption (marijuana, cocaine…) as well as cigarette/cigar smoking are asked in the questionnaire as well as the examination components. Of course, these are self-reported and therefore may be measured with error and subject to reporting biases. The detailed results from urine and blood samples should provide sufficient objective data to strengthen these indicators. From these data we will construct an indicator of "addictive" behavior. This will likely be correlated with sugar and caffeine intake as well. If obesity is predominantly the consequence of addiction, focusing on diet changes may be challenging for policy.

ii. ***Energy Expenditure***

a. Physical Activity Indicators

Questions are asked about the frequency, duration, and type of physical activity over the last thirty days as well as for "usual daily activities". These include activities required for transportation and on the job (whether paid work, housework, or school) as well as energy expended on leisure (which includes low energy activities like watching television and computer use – unrelated to work – as well

[6]For a discussion of the USDA dietary survey integration see http://www.cdc.gov/nchs/about/major/nhanes/nhanes99-02.htm.

as just about any kind of sport), and health promotion exercise.[7] Physical activity relative to peers are also included. We can calculate average energy expenditures for individuals based on work, leisure, and time spent on healthy habits. It is understood that these activities are correlated with functional status which is why we model them separately.

2. ***Medical Utilization***

a. Inpatient and Outpatient care

The questionnaire includes questions about the type (clinic, doctor's office or HMO, hospital ER, etc.) and frequency of medical services used in the last twelve months –for both physical health and mental health services.

Utilization is a function of health status and the respondent's ability to pay for medical services (which is a function of income and the price they face – their health insurance).[8] We have indicators of the factors influencing utilization.

The sign of the effect of medical services depends on the type of service but in all cases is ambiguous. Since access to health care provides information regarding diagnosis and treatment – including information about health-improvement behaviors – access should improve weight outcomes. However, there are two reasons why we might expect a negative sign on utilization. First, insured individuals are more likely to utilize medical services and they may also take on more health risks since they are insured. In this case we would expect sicker and overweight people using more. Second, to the extent that utilization is often treatment rather than prevention, we would expect overweight people to be using more medical services. These reasons for an offsetting effect of utilization also make it endogenous to the model of weight. The reason for identifying the two reasons for a potentially negative effect is because even health insurance may be theoretically endogenous. Although in the market for medical services, we would not expect to see a significant increase in risky behavior as a consequence of insurance.

b. Prescription Drugs

Respondents are asked type, quantity, and duration of any prescription or non-prescription drugs. In this category we exclude dietary supplements since they are included in the intake section. Drugs for controlling weight would be endogenous and would have to be used with caution. These might be useful in a model of changes in weight over time.

c. Price of Medical Services

We know the type of health insurance as well as the duration of access. The household questionnaire also has plan details, like utilization review and copayments… Health insurance lowers the price of medical services to the consumer, which increases utilization at the margin, and therefore affects any health outcome, including obesity.

[7] On the job activities can be compared to responses about work hours and type since these are also asked in a separate section of the questionnaire.

[8] The discussion about information being costly is relevant here since medical services are costly – whether the patient is self-pay or paying an insurance premium, but the cost varies.

Psychosocial Attributes

This is where we include individual heterogeneity in socio-economic status and demographics including race, culture, neighborhood and region (contextual effects), social support and family structure, class (wealth category), as well as psychological factors like stress, and emotional well-being.

1. Socio-economic Status

NHANES collects all of the relevant demographic information like age, gender, race, and culture (languages spoken and country of origin) about the individuals. All of these control for factors that might explain some of individual preferences for behaviors and weight (and what we refer to as rate of time preference). Also included in the survey are household structure and work which gets at time constraints and preferences as well. Household income, housing information (ownership, duration, age…), occupation, and education are also available. The role of wealth is ambiguous since higher wealth means the ability to afford more information as well as better health care. However, higher wealth can also mean more consumption of all goods and services, including bad foods and inactive leisure activities (computers). Education should be correlated with cognition and the ability to acquire and use information. Holding all else constant, education should be associated with healthier weight.

Family structure is relevant in a model of obesity. It determines the allocation of time available for healthy habits. Habits are typically correlated within a family and so family types will determine habits and ultimately weight. Social Support is tied to time availability as well as stress and includes all forms of potential support – through family, friends, religious organizations and clubs. Support is defined as emotional and financial.

Table 1 shows the relationship between weight outcomes and socioeconomic status. Blacks are at greatest risk of overweight and obese. Much of that is working through education and income sine we see strong ties between these factors and weight as well. Marital status is significantly correlated with weight.

Geocoded data to get contextual effects: We plan to apply for access to the confidential geography data which must be obtained through a Census Research Data Center (RDC). SUNY Stony Brook is a member of the NYC RDC which would facilitate use of this data more readily.

2. **Psychological well-being**: Arthur Stone and Deb Dwyer will take the lead here. Constructing an indicator of psychological well-being is no trivial task. Because our hypothesis is that psychological well-being may drive much of the behavior regarding weight health, it is important to be able to capture this latent factor with instruments. There are numerous psychological factors that are candidates for a psychological well-being indicator in NHANES. Unfortunately many of them are asked for only sub-samples of the overall sample. In general we have in the questionnaire the last time the respondent spoke to a mental health person (which is tied to access to care), if they had been told they have attention deficit hyperactivity disorder, as well as global health, which we know is influenced/part of mental health. Emotional health is included in the functional status questionnaire as well and was defined as the number of days of the last 30 where their "mental health" (defined as stress, depression, and problems

with emotions) was "not good." Functional items, alcohol use, stress on the job, pain are assessed in survey and all contribute to, or are associated with, psychological well-being. Combining these variables for commonalities should give us some insight to psychological well-being.

Respondents aged 20-39 examined by MEC also were assessed for diagnoses of panic disorder, generalized anxiety disorder, and depression (in 1999-2000). These can be used to validate the survey instruments in the questionnaire for the full sample as well as for analysis on the smaller sub-sample. Stone has made significant contributions to our understanding of self-report data (Stone, Shiffman, & Attienza, 2004) and to the measurement of psychological well-being in survey data (Kahneman et al., 2004). We will build on his models for constructing indices. Dwyer (1999) has made contributions in the measurement of health in general and will be able to contribute in this part of the project as well. Our hypothesis is that psychological well-being drives much of the behavior related to weight-health including work choices and energy gap. Psychological well-being is also the reason many of those factors are endogenous, and is endogenous itself. By modeling psychological well-being and obesity simultaneously we may purge such bias. We will examine its role in the individual behaviors as well as obesity.

Genetic and Health Factors

1. **Exogenous Health Status**: What we would like to include is an indicator of health stock, or genetic health, independent of the environment and behaviors, and exogenous to the weight outcome. Health does influence our propensity to participate in behaviors that affect weight, but that would enter through models of behavior. In a production function of obesity, we just want to control for baseline health to learn the extent to which genetics play a role in the weight outcome. We will work with the physicians involved in TREC to identify genetic components of health from the laboratory results.

   For children up to age 15 we have health information about parents as well as post-natal care and birth weight. We would expect these instruments to be correlated with health stock and exogenous to models of obesity.

   For adults we do have onset of some medical conditions, like asthma which would give us an assessment of health stock early on. We also have medical conditions of parents which would give us an indication of inherited health stock.[9]

2. **Endogenous Health**: would be included in a model of behavior (and later on in the project as an outcome of obesity. Cancer in particular). The most challenging issue in constructing indicators of current health will be incorporating the wealth of instruments available in the questionnaire, examination, and laboratory components of NHANES. Given the expertise of two of the researchers in this area of health measurement (Stone and Dwyer), constructing valuable indicators of various components of physical and mental health, disease and functionality, would be feasible. The hypothesis of the

[9] We understand that what is inherited may very well be environmental and behavioral factors which would then be endogenous as well. Thought will be given to the degree of endogeneity in each case, as well as implementation of tests of exogeneity of any indicators used.

Stony Brook TREC proposal is that inflammation plays an important role in the tie between obesity and cancer (See Figure 1 of this proposal). We therefore will construct an indicator of inflammation from the laboratory analysis of blood and urine samples. Some specific variables are listed below:

i. *Functional Status*: Standard survey instruments of self-reported limitations of work and play are available. These self-reports have been examined by Dwyer and Mitchell (1999) and shown to be valid indicators of functional status. Activities of Daily Living (ADLs), and Instrumental Activities of daily living (IADLs) are also included in the questionnaire. In the examination component fitness and muscle strength are examined.

ii. *Disease*: Standard survey instruments of self-reported assessments of overall health are available. According to work by Dwyer and Mitchell (1999), these self-reports are based on underlying disease and not functional status. So they make a good overall index of health as it relates to underlying disease.

The questionnaire collects self-reports on many diseases as well as onset for many of them (particularly where relevant – asthma and diabetes). The examination and laboratory components have good objective indicators of disease as well.

iii. *Mental Health*: is included is psychosocial attributes above.

3. **Cognition**: This is to get at one's underlying ability to process information that is important in explaining outcomes. To the best of our knowledge there are no cognition tests (clinical rating scales) performed on NHANES respondents. These would be ideal in measuring cognition (Schmitt et al., 2002). There are other indicators that would be correlated with cognition, like attention deficit hyperactivity disorder (which is more likely to be have been diagnosed in children of the NHANES cohort). Alternatively one can assess cognition of responses to repeated survey questions checking for internal inconsistencies (Sudman, Warnecke, Johnson et al., 1994). NHANES is ideal for this type of analysis given the overlap in various components of the questionnaires resulting in repetition of some variables. Also, some of the IADLs available are correlated with cognition as well. Frisoni et al. (1999) find strong links between cognitive assessment scores and physical functioning as well as pain. Given we observe the latter we can infer (simulate) indicators of cognition from that work.

E. Empirical Methodologies

- Multivariate analysis of O*, measured in different ways and compared, and corrected for the propensity to invest in health. In other words we model the propensity for a given energy-gap index explicitly in a first stage regression, and control for it in the second stage.
- The models will be run separately by age group, gender, and race to allow for different slope coefficients
- Hazard Model of Investments and Disinvestments in BMI health. We will model investments the decision to improve the "energy-gap" in a dynamic framework. We ask the question "at what point does weight become enough of a problem that one makes a change?" and "at what point

does one regress back?". We do this to learn more about the decision to invest in healthy behaviors so that we can more effectively alter behavior through policy incentives.

F. PRELIMINARY DATA FINDINGS AND WHAT WE HOPE TO LEARN – DETAILE HYPOTHESES

This is a long term project. We expect to spend two to three years on this model of obesity production. In order to do it well, we need to spend some time on measurement of key variables and learning from the data. We need to know what survey responses are measuring by examining relationships between self-reports as well as by comparing them to more objective data collected by MEC. Once we understand the data we use, we need to understand how they impact the propensity for good weight health. It is a given that various behaviors will drive weight up or down. What is not understood is the magnitude of the effects, and whether the underlying cause of weight problems is behavior or something else unobserved but correlated with behavior. So we need to understand the relevant factors and how they inter-relate to each other before putting them into a model of obesity. Our hypotheses are numerous. We believe that psychological well-being drives both the factors that affect weight health, and the weight outcomes we observe. Changing lifestyles (more stress, time constraints (dual career households) and more sedentary) work through the energy gap as well as social support structures to play a role in the obesity trends over time. In the first few years of the project we will account for the various components of weight determination to better understand the causes of the problem.

G. SENSITIVITY ANALYSIS

With the data in order, we will alternate models of the production process for obesity. As already mentioned, we will perform some sensitivity analysis in the assumptions we make regarding various causal relationships between obesity and the underlying factors. Other assumptions one makes when doing multivariate analysis has to do with the timing of various factors (already mentioned as well), as well as the role of preferences for various activities and factors. What we propose here is an alternative model with a different set of assumptions about how behavior and choices affect the weight outcome. The point of this exercise is robustness. What can we learn from tackling this question a number of ways. We will use what we learn about measuring factors and their inter-relationships in this analysis.

A Utility Based Approach (led by Hugo Benitez-Silva)

An alternative approach to model the relationship between individual choices and weight health, represented by BMI, is the result of taking what we call a *Utility Based Approach*. The idea of this approach is fairly straightforward, and relies heavily on the work of Grossman (1972), and more recently Rust and Phelan (1997), Khwaja (2003), and Davis and Foster (2003). We start by explicitly defining a utility function, that is, a process by which individuals obtain a level of happiness or welfare, as a function of some (state) variables over which they have some control.

For example, in our model utility will depend on consumption, leisure, and health. The exact form of this utility function will be the product of some assumptions regarding the relationships we are studying. We will assume individuals prefer to consume more to less, to have more leisure, and that better health will enhance their happiness. However, we will also have to define how these inputs interact with each other, for example consumption and leisure are likely to be substitutes since you have to work in order

to earn resources to be able to consume goods, but both might be complements with health, meaning that you prefer to consume more when you are healthy, or you prefer to enjoy leisure if you are healthy.

In this model individuals will choose how much to consume, how much to work, and how much to invest in their health. Investments in health entail both monetary resources as well as time. Individuals consume out of their earnings and capital gains, and can work part-time or full-time. Health, in this case will be weight health, and it depends probabilistically on how much you invest in the current period, but also on your health stock and your genetic characteristics.

This type of model accounts for the dynamic nature of the decisions and processes explained above. This means that we solve the model assuming that the individual makes all these decisions over her life cycle, which is usually defined to last from age 20, when individuals enter the labor market, to age 100. In this case we will consider starting the model slightly earlier given the importance of early decisions on the weight health stock. This type of models are unlikely to be solvable without the help of a computer, however, the payoff is an analytic tool amenable to simulation of how individuals react to policy changes that affect their constraints, or even their preferences.

One other advantage of this approach is that it can be estimated using the NHANES, given that the data set has information of a population that matches the age of the agents in the model, and has detailed information on the many choices individuals make over their lives. Estimating the model means that we can back out the actual parameters that deliver the best possible fit of the model to the data, this means we would be able to quantify the role of weight health in the utility function, and the effect of an array of characteristics on the production of BMI. These parameters are then assume to be fixed to policy changes, and therefore allow us to provide policy simulations understood to be superior to that of models that do not explicitly model utility (Lucas, 1976).

The techniques used to obtain estimates using this *Utility Based Approach* have been used in labor economics and health economics quite successfully, for example in Rust and Phelan (1997), French (2001), van der Klaauw and Wolpin (2002), Khwaja (2003), and Davis and Foster (2003). One of these techniques is Maximum Likelihood estimation, which tries to find the set of parameters that, given our model, make more likely the observed set of choices and events in the data. One other technique, the Simulated Method of Moments routine tries to find the set of parameters that minimize the distance between the predictions of the model and the data, where these predictions are defined as moments of the variables of the model.

It is probably apparent to the reader that this *Utility Based Approach* imposes a lot more structure to the problem analyzed, given that we need to make some parametric assumptions regarding the relationships between the observed variables, and about the preferences of the agents, that are usually much milder in the empirically based approach we have presented above. We believe this alternative approach is a good sensitivity analysis for our project, and likely to provide good benchmarks to compare to our predictions using the empirically based approach.

Aim 2: The Tie Between Obesity, Underlying Causes of Obesity and Cancer using NHANES [Consequences]

BACKGROUND/MOTIVATION

The purpose of this part of the analysis, which would take place in years 3 and 4 of the project, is to take what we have learned about the factors that influence obesity (from Part I of this research project), as well as the fundamental or biological risk factors assessed from the fundamental project, and tie it to cancer – testing their findings using national survey data (NHANES). So the purpose is twofold: 1. to test what was found on a smaller sample in an experimental setting on a national database in order to be able to generalize the findings and 2. tie what we learn about the important underlying factors relating to obesity and their role on cancer propensities. For example, it is possible that it is not obesity per se that increases one's propensity for cancer, but the underlying factors that are correlated with both obesity and cancer. After all, not only the obese develop cancer. We can test for the role of obesity directly as well as the role of the underlying factors, by modeling cancer as a function of both. It is the purpose of this study to determine just how much of the tie is directly attributable to being obese.

METHODS/DATA

We will use NHANES data from 1999-2004. They collect details about types of cancer that we can tie to the data we produce from the first aim of this study.

Aim 3: The Costs and Benefits of Alternative Obesity-Related Policies [Cures] - Policy Evaluation

A**. COST-BENEFIT Analysis of Community Interventions**
We will be assessing the costs and benefits of interventions and policies throughout the five year period. We will perform cost-benefit evaluations of the Connolly-Shoonan intervention in schools, families and communities. In that study data are collected before and after interventions on behaviors and outcomes. There are different types of interventions and each will be evaluated in terms of costs and benefits. Data should become available as early as the 2nd year of the center's existence.

B. Role of Medical Services:
An alternative policy to community awareness programs would be to provide incentives for nutritional counseling through medical services. At this time most insurance plans do not cover this benefit. However, the prevalence of nutritional services provisions in nursing home facilities has grown dramatically between 1985 from 84% to 99.2% (Bernstein et al., 2003). Those who use nutritionist services are likely to be a non-random sub-sample of the general population and their propensity to visit a nutritionist is not only tied with access (affordability) but with weight health. One might think that those with a weight problem are more likely to use nutritional counseling. It might be the case that those who are more "weight conscious" and active in healthy habits are more likely to go. It would be interesting to learn the effectiveness of nutritional counseling in controlling weight in a multivariate setting. In order to do so we need to account for the non-randomness of utilization. The evaluation would be of treatment effects of nutritional counseling. We would also study program effects of expanding coverage, accounting for various propensities to use medical services in the face of non-mandatory participation in these services.

C. COST-BENEFIT ANALYSIS of obesity reduction policies on CANCER REDUCTION only
We would define benefits here as the gains in reducing cancer prevalence from cutting obesity. The costs would be those involved in the intervention. So we would take the evaluation from Part III A of this proposal and redefine the benefits in terms of cancer gains (defined as reduction in

propensities, possibly measured through risk markers obtained from McNurlan et al.) as opposed to reductions in BMI.

We would also simulate the gains in cancer reduction if we changed behavior in a way dictated by Part II of this proposal. In other words, if we learn that eating junk food increases weight and the propensity for cancer, we would estimate the benefit of reducing junk food intake of those at risk.

Other Directions

Measurement of key variables in survey data for drawing inferences on the general population is an important underlying theme of this proposal. We would like to tie the work done by the computer scientists (Kaufman et al.) on using photographs to produce a retrospective weight history into survey data. This would give us better genetic components to weight-health. From that project they get precise estimates of body composition. They will compare these estimates to BMI, which is what we use to measure weight in surveys. They will get another indicator of body composition from photographs and compare how closely it relates to BMI as well as the body composition measure. In doing this we test validation of both BMI and the photography indicator. The BMI indicator is relevant for our research since we use it in survey data. The photography indicator is useful to tie "weight histories" in survey data. This relates to our project in the following ways:
1. we learn from that project and it affects interpretations of our work using BMI.
2. We can improve survey data by working with HHS to incorporate the weight histories into their NHANES surveys. They have a mechanism for analysts to submit survey alteration requests.

Table 1. Proportion of select groups who are Healthy Weight, Overweight and Obese, for Adults 18 years of age or over, United States, Average Annual, 1999-2001

Selected Characteristics	Healthy Weight	Overweight	Obese
Gender - Total	40.8%	57.1%	21.6%
Men	34.8[10]	65.2	
Women	50.9	49.1	
Race			
White	41.4	56.5	20.8
Black	32.6	66.0	30.2
Hispanic	35.6	63.1	23.4
Education			
Less than high-school	36.7	60.7	25.4
Some college	40.3	57.6	22.3
Bachelor or higher	46.7	51.3	15.5
Below Poverty level	40.9	56.1	25.0
Marital Status			
Never married	50.2	46.3	18.4
Married	37.8	60.7	22.6
Cohabiting	44.2	53.3	20.1
Divorced or separated	38.9	59.1	23.7
Widowed	41.3	55.1	20.8
Health-Related Behaviors			
5 or more drinks in one day when drink	9.12%		9.0%
3 or more drinks in one day when drink	22.0%		19.6%

Source: Data were compiled from Tables 6 and 7 of Schoenborn et al., National Center for Health Statistics, 2004. Health-Related Behaviors were constructed from NHANES 2001-2002 data by authors.

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[10] The total omits those who are underweight. By gender all we have is "not overweight" so not necessarily healthy – which is why these average to higher than the gender total.

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