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ABSTRACT

It is well known that public or pooled insurance coverage can induce a form of ex-ante moral hazard: people make inefficiently low investments in self-protective activities. This paper points out another ex-ante moral hazard that arises through an induced innovation externality. This alternative mechanism, by contrast, causes people to devote an inefficiently high level of self-protection.

As an empirical example of this externality, we analyze the innovation induced by the obesity epidemic. Obesity is associated with an increase in the incidence of many diseases. The induced innovation hypothesis is that an increase in the incidence of a disease will increase technological innovation specific to that disease. The empirical economics literature has produced substantial evidence in favor of the induced innovation hypothesis.

We first estimate the associations between obesity and disease incidence. We then show that if these associations are causal and the pharmaceutical reward system is optimal the magnitude of the induced innovation externality of obesity roughly coincides with the Medicare-induced health insurance externality of obesity. The current Medicare subsidy for obesity therefore appears to be approximately optimal. We also show that the pattern of diseases for obese and normal weight individuals are similar enough that the induced innovation externality of obesity on normal weight individuals is positive as well.

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1 Introduction

Within economics, it is well-known that pooled insurance coverage can create a disincentive for the insured individual to invest in self-protective activities – a form of *ex-ante* moral hazard (Ehrlich and Becker, 1972). Much of the health economics literature, by contrast, has focused on *ex-post* moral hazard induced by insurance coverage (Pauly, 1968; Manning et al., 1987). Both the *ex-ante* moral hazard and the *ex-post* moral hazard lead to a negative externality: the former causes people to invest insufficiently in self-protection, while the latter causes people to consume health care resources at an inefficiently high level. In this paper, we identify a distinct and non-mutually exclusive second form of *ex-ante* moral hazard that runs in the opposite direction from the one identified by Ehrlich and Becker (1972).

The presence of a population with a given chronic condition within the general population induces research efforts by firms to develop pharmaceutical and other products to treat the diseases caused by the chronic condition. The resulting innovations benefit all people who are afflicted with any of those diseases. This yields a positive externality: people do not account for this induced innovation effect when they make the decisions that lead them to develop the chronic condition. In other words, this mechanism causes people to devote an inefficiently high level of self-protection.

As an empirical example of this externality, we analyze the innovation induced by the obesity epidemic. Obesity is associated with an increase in the incidence of many diseases. The induced innovation hypothesis is that an increase in the incidence of a disease will increase technological innovation specific to that disease. The empirical economics literature has produced substantial evidence in favor of the induced innovation hypothesis.

We first estimate the association between obesity and disease incidence. We then show that if these associations are causal then the magnitude of the induced innovation externality of obesity roughly coincides with the Medicare-induced health insurance externality of obesity. The current subsidy for obesity therefore appears to be approximately optimal for

people who are covered with private insurance before old-age. We also show that the pattern of diseases for the obese and for the normal weight are similar enough that the induced innovation externality of obesity on normal weight individuals is positive as well.¹

In our analysis we do not assume that there exists a free lunch in pharmaceutical innovation. Instead, we assume that the pharmaceutical reward system is optimal from the consumers' perspective in the following sense: the benefit to consumers from the additional innovation induced by any marginal increase in the reward for pharmaceutical innovation is equal to the marginal increase in the reward for pharmaceutical innovation.²

2 Background

In this section, we provide cursory reviews of the extensive literatures that touch on our argument. These include the clinical literature on the consequences of obesity, the health economics literatures on the medical costs associated with obesity and on the external effects of obesity in a pooled health insurance context, and the economics literature on the induced innovation effect.

2.1 Obesity, Disease, and Health Expenditures

Americans are increasingly overweight or obese.³ The proportion of adults classified as obese increased from 12.0% in 1991 to 20.9% in 2001 (Mokdad et al., 1999, 2003; Wang and

¹In this paper, we ignore any *ex-post* moral hazard induced by obesity. There are two reasons why this decision is justifiable. First, the elasticity of demand for health care is larger (in absolute value) for those without chronic conditions (Manning et al., 1987; Bajari et al., 2006). Second, Lakdawalla and Sood (2006) show that when it comes to pharmaceutical expenditures, there may not be any *ex-post* moral hazard at all – co-payments make out-of-pocket prices close to marginal cost.

²We do not aim to settle the debate on whether patent duration is set at the right level for the reward system to satisfy this property. Rather, the conclusions can be adjusted according to the reader's beliefs about this contentious issue.

³Body mass index (BMI) is the standard measure used to determine an appropriate weight in the medical literature. BMI is weight, measured in kilograms, divided by height, measured in meters, squared. Individuals with a BMI between 25 and 30 are considered overweight, while those with a BMI of 30 or more are considered obese (National Institute on Health, 1998). Henceforth, we use BMI and body weight interchangeably.

Beydoun, 2007).

Obesity is associated with an increased risk of a range of chronic conditions, including diabetes, hypertension, heart disease, and stroke (Kasper et al., 2004). In some cases, there are solid biochemical and physiological reasons to suppose that the association is causal, such as in the case of diabetes. In other cases, the evidence is murkier. Associations such as these arise for many reasons, not all of them medical. Here, we do not attempt to settle (nor are we capable of settling) the debate over whether there is a causal relationship between obesity and any particular chronic condition with which obesity is associated. Instead, our aim is to show that if the effect of obesity on disease incidence is causal and obesity therefore has a negative Medicare-induced public health insurance externality then obesity has also a positive induced innovation externality. The Medicare-induced negative public health insurance externality of obesity is therefore not a sufficient rationale for policies that are directed toward reducing obesity.

Not surprisingly, expected health care expenditures are higher for obese individuals than for normal weight individuals. A large number of studies document this fact. The vast majority of these studies use convenience samples consisting of individuals from a single employer or a single insurer (Elmer et al., 2004; Bertakis and Azari, 2005; Burton et al., 1998; Raebel et al., 2004). There are also studies of obesity-related medical expenditure differences in an international setting. Both Sander and Bergemann (2003), in a German setting, and Katzmarzyk and Janssen (2004), in a Canadian setting, find higher medical expenditures for obese people.

There are a few studies that use nationally representative data. Finkelstein et al. (2003) use data from the linked National Health Interview Survey (NHIS) and Medical Expenditure Panel Survey (MEPS). They estimate that annual medical expenditures are \$732 higher for obese than normal weight individuals. On an aggregate level, approximately half of the estimated \$78.5 billion in medical care spending in 1998 attributable to excess body weight

was financed through private insurance (38%) and patient out-of-pocket payments (14%). Sturm (2002), using data from the Health Care for Communities (HCC) survey, finds that obese individuals spend \$395 per year more than non-obese individuals on medical care. Thorpe et al. (2004) also use MEPS data, but they are interested in how much of the \$1,100 increase between 1987 and 2000 in per-capita medical expenditures is attributable to obesity. Using a regression model to calculate what per-capita medical expenditures would have been had 1987 obesity levels persisted to 2000, they conclude that about \$300 of the \$1,100 increase is due to the rise in obesity prevalence.

This is a large literature, which space constraints prevent us from surveying in more detail. The many studies that we do not discuss here vary considerably in generality – some examine data from a single company or from a single insurance source – though they all reach the same qualitative conclusion that obesity is associated with higher medical care costs.⁴ None of this literature attempts to address whether the relationship between obesity and associated health care expenditures are causal. We do not attempt to settle this issue here and, for the same reasons outlined above on the link between obesity and disease incidence, we do not need to settle it.

2.2 Health Insurance, *Ex Ante* Moral Hazard, and Induced Innovation

That obesity is associated with higher health care expenditures is only a necessary first step in establishing the traditional *ex-ante* welfare loss from obesity through health insurance. In the case of employer-provided health insurance, for instance, Bhattacharya and Bundorf (2005) show that differences in wages between obese and non-obese workers with employer-provided health insurance undo nominal risk pooling between the workers. Without no pooling, there is no externality. This argument does not extend to public insurance, such as Medicare,

⁴Some of the studies we reviewed, but arbitrarily do not discuss here include Bungam et al. (2003), Musich et al. (2004), Quesenberry et al. (1998), Thompson et al. (2001) and Wang et al. (2003).

where there is clearly pooling, an induced transfer from thinner to heavier, and no wage mechanism to undo it. Even in the case of public insurance, though, obese individuals are likely to pay higher out-of-pocket medical expenditures because of cost-sharing in insurance coverage. Being obese therefore imposes costs on the person holding the weight.

Bhattacharya and Sood (2007) show that, in pooled health insurance, if the elasticity of body weight with respect to the transfer from thinner to heavier individuals (induced by insurance) is zero, there is no welfare loss from the *ex-ante* externality. Unless the subsidy induced by insurance causes someone to become heavier, the insurance transaction is a costless transfer. With the exception of Rashad and Markowitz (2006), there has been little work attempting to measure the size of this key elasticity.

To date, we are not aware of any work that has attempted to estimate the size of the externality caused by *ex-ante* moral hazard through the induced innovation effect. Lakdawalla and Sood (2007) examine the effect of extending drug insurance on welfare through induced innovation. In comparison, we focus on the ex-ante moral hazard effect of induced innovation. We also distinguish between what the effect is on different demographic groups, such as normal weight individuals and the obese.

Our analysis is based on the induced innovation hypothesis put forward by Hicks (1932) and Schmookler (1966). Empirical investigations of the induced innovation hypothesis in the pharmaceutical industry include Acemoglu and Linn (2004), Finkelstein (2007), Lichtenberg and Waldfogel (2003), and our companion paper (Bhattacharya and Packalen, 2008), which all find support for the induced innovation hypothesis. Our companion paper also finds evidence of obesity-induced pharmaceutical innovation. Newell et al. (1999) and Popp (2002) find support for the induced innovation hypothesis in the energy sector.

Our analysis is also related to the studies on preference externalities by Waldfogel (2003) and George and Waldfogel (2003).⁵ These studies examine the effect that the racial char-

⁵These contributions in turn build on the theoretical contributions by Hotelling (1929), Spence (1976a,b) and Dixit and Stiglitz (1977) on market size and product variety.

acteristics of the population within a market have on the supply of radio programming and newspapers. While these studies focus on the effect of population characteristics on product variety, we seek to determine the effect of preference externalities both on the overall welfare as well as on the welfare of the obese and the normal weight separately. Furthermore, in our case the preference externality is determined by consumers' decisions rather than inherent characteristics (to extent that body weight is in fact a decision).

3 An Induced Innovation Externality Model

Our analysis of the induced innovation externality is based on four principles. First, the extent of innovation of drug therapies for a disease depends on the size of the entire worldwide potential market for pharmaceuticals for the disease. Second, the induced innovation externality of obesity is calculated as the effect that a marginal increase in obesity in the United States has on the consumer surplus of the population in the United States. This definition facilitates a direct comparison of the induced innovation externality of obesity with the Medicare-induced health insurance externality of obesity. We therefore ignore the induced innovation externality that a marginal increase in obesity in the United States has on consumers in the rest of the world. Third, we assume that pharmaceutical producers accurately forecast any marginal increase in obesity prevalence and hence such an increase immediately affects the rate of pharmaceutical innovation. This assumption is not crucial for our results because only a small fraction of the lifetime induced innovation externality of obesity is due to the effect that obesity has on an individual's annual pharmaceutical expenditures before the individual reaches mid-age. Fourth, we assume that the pharmaceutical reward system is privately optimal for the consumers in the United States in the sense that a marginal increase in the annual reward for pharmaceutical innovation yields an equivalent increase in the annual stream of consumer surplus from pharmaceutical innovation that is captured by the population in the United States.

Both body weight and age have a strong impact on a person's annual pharmaceutical and other health care expenditures, and the effects vary across diseases. Let $E_{t,i}(\textit{normal})$ and $E_{t,i}(\textit{obese})$ denote the mean annual expenditures on drug therapies for disease i for normal weight and for obese individuals, respectively, at age t . Let \bar{E}_i denote the average annual expenditures on drug therapies for disease i . The potential market size for drug therapies for disease i is $N_{WORLD} \times \bar{E}_i$, where N_{WORLD} is the size of the world-wide population. Measuring the potential market size by expenditures rather than disease incidence allows for obesity to influence pharmaceutical expenditures both through the effect that obesity has on disease incidence and through the effect that obesity has on the intensity at which an individual consumes drug therapies for a disease conditional on having that disease.

The reward that pharmaceutical firms receive annually from an individual for inventing drug therapies that treat the disease i and that are introduced either before or during a given year is a fixed share $R_{PATENT} \times (1 - R_{MC})$ of the individual's annual expenditures $E_{t,i}$ on drug therapies that treat disease i . The coefficient R_{PATENT} is the share of the pharmaceutical revenue that is captured by brand-name drugs. The factor $(1 - R_{MC})$ is the share of the revenue for brand-name drugs that the pharmaceutical firms receive in excess of variable (production, marketing, and general administration) costs.

We assume that the consumer surplus $V_{t,i}$ that an individual at age t receives from new drug therapies for the disease i is a fixed percentage R_{CS} of the reward for innovation that the pharmaceutical firms receive from the individual for new drug therapies for the disease i . Pharmaceutical innovation therefore increases the individual's lifetime expected consumer surplus annually by

$$V_{t,i} = R_{CS} \times R_{PATENT} \times (1 - R_{MC}) \times E_{t,i} \tag{1}$$

at age t .

Consider now the effect of one person becoming obese. For this individual the incidence of disease i changes from $E_{t,i}(\textit{normal})$ to $E_{t,i}(\textit{obese})$. This change in the disease incidence

changes the potential market size for new drug therapies that treat the disease i . This in turn changes the rate of innovation of drug therapies for the disease i . We denote the associated percentage change in the rate of innovation of drug therapies for the disease i by ΔI_i .

We divide the change in the rate of innovation, ΔI_i , into two separate effects: the composition effect and the general rate of innovation effect. The composition effect is the effect that the change in the disease incidence has on the relative allocation of pharmaceutical R&D across diseases and on the associated the rate of innovation for the disease i relative to all other diseases. The general rate of innovation effect is the effect that the change in the disease incidence has on the overall level of pharmaceutical R&D and on the associated general speed of pharmaceutical innovation.

The composition effect is given by $\Delta M_i^R \times \varepsilon_c$, where ΔM_i^R is the percentage effect that the change in the disease incidence has on the relative potential market size of drug therapies for the disease i :

$$\Delta M_i^R \equiv \frac{\frac{\bar{E}_i \times N_{WORLD} + E_{t,i}(obese) - E_{t,i}(normal)}{\sum_i [\bar{E}_i \times N_{WORLD} + E_{t,i}(obese) - E_{t,i}(normal)]} - \frac{\bar{E}_i \times N_{WORLD}}{\sum_i \bar{E}_i \times N_{WORLD}}}{\frac{\bar{E}_i \times N_{WORLD}}{\sum_i \bar{E}_i \times N_{WORLD}}}, \quad (2)$$

and where ε_c is the associated reward-elasticity of the composition of innovation.

The general rate of innovation effect is given by $\Delta M \times \varepsilon$, where ΔM is the percentage effect that the change in the disease incidence has on the total pharmaceutical market size:

$$\Delta M \equiv \frac{\sum_i [E_{t,i}(obese) - E_{t,i}(normal)]}{\sum_i \bar{E}_i \times N_{WORLD}}, \quad (3)$$

and where ε is the associated reward-elasticity of innovation.

The total innovation effect ΔI_i of the change in the disease incidence can therefore be written as

$$\Delta I_i = \Delta M_i^R \times \varepsilon_c + \Delta M \times \varepsilon, \quad (4)$$

where generally $\varepsilon_c \geq \varepsilon$.⁶ We assume that $\varepsilon > 0$. The equality $\varepsilon_c = \varepsilon$ holds in the special case that the allocation of R&D resources for each disease is independent of the demand for R&D resources for the innovation of drug therapies for all other diseases.

When the rate of innovation changes by ΔI_i the associated change in the stream of consumer surplus from pharmaceutical innovation for disease i is $V_{t,i} \times \Delta I_i$ for an individual with annual pharmaceutical expenditures $E_{t,i}$. The total induced innovation externality of the marginal increase in obesity over all diseases is therefore $\sum_i V_{t,i} \times \Delta I_i$ for an individual with annual pharmaceutical expenditures $E_{t,i}$. Using the expressions (1) and (4) for $V_{t,i}$ and ΔI_i , respectively, this induced innovation externality be rewritten as

$$Externality_t = \sum_i E_{t,i} \times R_{PATENT} \times (1 - R_{MC}) \times R_{CS} \times (\Delta M_i^R \times \varepsilon_c + \Delta M \times \varepsilon). \quad (5)$$

The expression (2) for the effect that the marginal increase in obesity has on the relative potential market size for drug therapies for disease i can be rewritten as

$$\Delta M_i^R = \left[\frac{E_{t,i}(obese) - E_{t,i}(normal)}{\bar{E}_i \left(1 + \frac{E_{t,i}(obese) - E_{t,i}(normal)}{\bar{E}_i \times N_{world}}\right)} - \frac{\sum_i (E_{t,i}(obese) - E_{t,i}(normal))}{\sum_i \bar{E}_i \left(1 + \frac{E_{t,i}(obese) - E_{t,i}(normal)}{\bar{E}_i \times N_{world}}\right)} \right] \times \frac{1}{N_{WORLD}}, \quad (6)$$

which implies that

$$N_{WORLD} \times \Delta M_i^R \approx \left[\frac{E_{t,i}(obese) - E_{t,i}(normal)}{\bar{E}_i} - \frac{\sum_i (E_{t,i}(obese) - E_{t,i}(normal))}{\sum_i \bar{E}_i} \right] \quad (7)$$

when N_{WORLD} is large. Solving the equality (7) for ΔM_i^R and substituting the resulting expression for ΔM_i^R as well as the expression (3) for ΔM into the expression (5) for the obesity externality yields the following expression for the induced innovation externality of

⁶While the exact effect is $\Delta I_i = (1 + \Delta M_i \times \varepsilon) (1 + \Delta M_i^R \times \varepsilon_c) - 1$ we omit the term $(\Delta M_i \times \varepsilon) \times (\Delta M_i^R \times \varepsilon_c)$ because this term is small compared to the terms $\Delta M_i \times \varepsilon$ and $\Delta M_i^R \times \varepsilon_c$ when ΔM_i and ΔM_i^R are small.

obesity:

$$\begin{aligned}
Externality_t = & \sum_i R_{CS} \times R_{PATENT} \times (1 - R_{MC}) \times E_{t,i} \times \frac{1}{N_{WORLD}} \\
& \times \left[\left(\frac{E_{t,i}(obese) - E_{t,i}(normal)}{\bar{E}_i} - \frac{\sum_j (E_{t,j}(obese) - E_{t,j}(normal))}{\sum_j \bar{E}_j} \right) \right. \\
& \left. \times \varepsilon_c + \frac{\sum_j (E_{t,j}(obese) - E_{t,j}(normal))}{\sum_i \bar{E}_j} \times \varepsilon \right]. \tag{8}
\end{aligned}$$

Consider now the effect of a one percent increase in the pharmaceutical reward in every disease category from the subpopulation of N_{US} individuals. This increases the total pharmaceutical reward by $\frac{N_{US}}{N_{WORLD}}$ percent for all diseases. As the relative market sizes across disease categories do not change, the rate of pharmaceutical innovation and the benefit from pharmaceutical innovation increase by $\varepsilon \times \frac{N_{US}}{N_{WORLD}}$ percent for all diseases. By the definition of R_{CS} the average benefit from pharmaceutical innovation is R_{CS} times the pharmaceutical reward. For the subpopulation of N_{US} individuals the cost of the one percent increase in the pharmaceutical reward the subpopulation is therefore $1/R_{CS}$ percent of the total benefit that the population of N_{US} individuals receives from pharmaceutical innovation.

Because we assume that for a subpopulation of N_{US} individuals, where $N_{US} < N_{WORLD}$, the pharmaceutical reward system is privately optimal in the sense that a marginal increase in the reward for pharmaceutical innovation from the subpopulation yields an equivalent increase in the total consumer surplus for the subpopulation, the cost of the one percent increase in the pharmaceutical reward from the subpopulation of N_{US} individuals (which is $\frac{1}{R_{CS}}$ percent of total benefit from pharmaceutical innovation) must equal the benefit of the increase for the subpopulation of N_{US} individuals (which is $\varepsilon \times \frac{N_{US}}{N_{WORLD}}$ percent of the total benefit from pharmaceutical innovation). That is, the equality

$$\frac{1}{R_{CS}} = \varepsilon \times \frac{N_{US}}{N_{WORLD}} \tag{9}$$

must hold.

Solving the expression (9) for R_{CS} and substituting the resulting expression into the expression (8) yields the following expression for the induced innovation externality of obesity:

$$\begin{aligned}
Externality_t &= \frac{1}{N_{US}} \times R_{PATENT} \times (1 - R_{MC}) \\
&\times \sum_i E_{t,i} \left[\frac{E_{t,i}(obese) - E_{t,i}(normal)}{\bar{E}_i} \times \frac{\varepsilon_c}{\varepsilon} \right. \\
&\quad \left. + \frac{\sum_j (E_{t,j}(obese) - E_{t,j}(normal))}{\sum_j \bar{E}_j} \times \left(1 - \frac{\varepsilon_c}{\varepsilon}\right) \right]
\end{aligned} \tag{10}$$

Substituting the average expenditures \bar{E}_i for $E_{t,i}$ in the expression (10) for the externality and denoting $E_t(normal) \equiv \sum_i E_{t,i}(normal)$ and $E_t(obese) \equiv \sum_i E_{t,i}(obese)$ gives the externality on a person with average pharmaceutical expenditures:

$$Externality_t(average) = \frac{1}{N_{US}} \times R_{PATENT} \times (1 - R_{MC}) \times [E_t(obese) - E_t(normal)]. \tag{11}$$

The total induced innovation externality of obesity on the subpopulation of N_{US} individuals is N_{US} times the average externality. The total externality is therefore given by

$$Externality_t(total) = R_{PATENT} \times (1 - R_{MC}) \times [E_t(obese) - E_t(normal)]. \tag{12}$$

The expressions (11) and (12) for the average externality and total externality, respectively, show that neither the average externality nor the total externality depend on the prevalence of obesity in the population or the two innovation elasticities ε and ε_c . Instead, both externalities depend only on the total effect that the marginal increase in obesity has on the reward that pharmaceutical companies receive for successful innovation. This result is a consequence of the assumption that the reward system is optimal from the consumers' perspective: the share $R_{PATENT} \times (1 - R_{MC})$ of the additional revenue

$[E_t(obese) - E_t(normal)]$ is reward for pharmaceutical innovation and the reward must equal the total benefit $Externality_t(total)$ for the consumers from the associated increase in innovation. In section 6 we calculate the total externality at each age after estimating $E_{t,i}$, $E_{t,i}(normal)$ and $E_{t,i}(obese)$ and calibrating the parameters R_{PATENT} and R_{MC} .

Because the pattern of disease incidence is different for the normal weight than it is for the obese, the benefit from the marginal increase in obesity varies by body weight. We therefore also calculate the magnitude of the induced innovation externality by body weight. Let $E_i(normal)$ denote the average pharmaceutical expenditures of the normal weight for disease i . Substituting $E_i(normal)$ for $E_{t,i}$ in the expression (10) for the externality gives the induced innovation externality of the marginal increase in obesity at age t on the average normal weight person:

$$\begin{aligned}
Externality_t(normal) &= \frac{1}{N_{US}} \times R_{PATENT} \times (1 - R_{MC}) \times \sum_i E_i(normal) \\
&\times \left[\frac{E_{t,i}(obese) - E_{t,i}(normal)}{\bar{E}_i} \times \frac{\varepsilon_c}{\varepsilon} \right. \\
&\left. + \frac{\sum_j (E_{t,j}(obese) - E_{t,j}(normal))}{\sum_j \bar{E}_j} \times \left(1 - \frac{\varepsilon_c}{\varepsilon}\right) \right].
\end{aligned} \tag{13}$$

Similarly, letting $E_i(obese)$ denote the average pharmaceutical expenditures of the obese for disease i and substituting $E_i(obese)$ for $E_{t,i}$ in the expression (10) for the externality gives the induced innovation externality of the marginal increase in obesity at age t on an average obese person:

$$\begin{aligned}
Externality_t(obese) &= \frac{1}{N_{US}} \times R_{PATENT} \times (1 - R_{MC}) \times \sum_i E_i(obese) \\
&\times \left[\frac{E_{t,i}(obese) - E_{t,i}(normal)}{\bar{E}_i} \times \frac{\varepsilon_c}{\varepsilon} \right. \\
&\left. + \frac{\sum_j (E_{t,j}(obese) - E_{t,j}(normal))}{\sum_j \bar{E}_j} \times \left(1 - \frac{\varepsilon_c}{\varepsilon}\right) \right].
\end{aligned} \tag{14}$$

In section 6 we calculate the externality on the normal weight $Externality_t(normal)$ and the externality on the obese $Externality_t(obese)$ for different values of the ratio $\frac{\varepsilon_c}{\varepsilon}$.

4 Data

We use the Medical Expenditure Panel Survey (MEPS) data from years 1996-2005 to estimate disease incidence, pharmaceutical expenditures and total health care expenditures by age and Body-Mass Index (BMI) group. Because MEPS from years 1996-2000 does not include BMI information we use the National Health Interview Survey (NHIS) data from years 1996-2000 and the match between the NHIS data and the MEPS data to find the BMI information for individuals during years 1996-2000. In the data, each subject is followed for two years, except in panel 10 which started in 2005. The data consists of 262,958 observations on 149,737 individuals.

We estimate disease incidence from the self-reported data in the MEPS. In MEPS the diseases are coded by the International Classification of Diseases, Ninth Revision (ICD-9). We use the MEPS data also to estimate total health care expenditures and total pharmaceutical expenditures. To estimate pharmaceutical expenditures by the therapeutic category of drugs we match the MEPS data on pharmaceutical expenditures by individual drugs (which are reported by the subject and the subject's pharmacy) to the National Ambulatory Medical Care Survey (NAMCS) data by drug name. We use the NAMCS data from years 1995, 2000, and 2005.⁷ We only match the drugs in NAMCS that have only one therapeutic category. In some cases we combine therapeutic categories when the drugs in the original categories

⁷For each drug mention in NAMCS we assign the therapeutic category in NAMCS from the 2005 NAMCS if a therapeutic category exists for the active ingredient in the 2005 NAMCS. For active ingredients without a therapeutic category in the 2005 NAMCS we assign the therapeutic category in NAMCS from the 2000 NAMCS if a therapeutic category exists for the active ingredient in the 2000 NAMCS. For active ingredients without a therapeutic category in the 2005 NAMCS and in the 2000 NAMCS we assign the therapeutic category in NAMCS from the 1995 NAMCS if a therapeutic category exists for the active ingredient in the 1995 NAMCS.

may be used to treat the same diseases.⁸

5 Obesity and Disease Incidence

In this section we report the association between obesity and disease incidence by disease as well as the association between obesity and pharmaceutical expenditures by the therapeutic category. The effect of obesity varies greatly by age, race and sex. We therefore form a composite measure of the association of obesity and disease incidence. Namely, for each disease we estimate the association between obesity and the incidence of the disease for a randomly chosen person.

Let r_t denote the share of individuals in the age group t , and let $\mu_{t,i}(normal)$ and $\mu_{t,i}(obese)$ denote the incidence of disease i for the normal weight individuals in the age group t and for obese individuals in the age group t , respectively. Within each age group we also allow the disease incidence to vary by sex, race (black/non-black), insurance status (private/non-private) and year (linear trend). However, for notational convenience we omit these subscripts here.

The incidence of the disease i for a randomly chosen normal weight individual is $\sum_t r_t \times \mu_{t,i}(normal)$ and the incidence of the disease i for a randomly chosen obese individual is $\sum_t r_t \times \mu_{t,i}(obese)$. An estimate of the association between obesity and disease incidence can therefore be obtained by calculating

$$Effect_i \equiv \frac{\sum_t r_t \times \mu_{t,i}(obese) - \sum_t r_t \times \mu_{t,i}(normal)}{\sum_t r_t \times \mu_{t,i}(normal)} \times 100\% \quad (15)$$

for each disease i . If the estimated associations are causal effects, then the estimates measure the effect that the obesity of a randomly chosen individual has on the incidence of the disease

⁸We combine therapeutic categories with less than 200 observations in MEPS to therapeutic category "Other". We also assign unmatched drugs to the therapeutic category "Other". In total, approximately 15% of pharmaceutical expenditures in the MEPS data are assigned to the "Other" category.

i for that individual.

We also construct an estimate of the share of disease incidence that is associated with obesity by calculating

$$Share_i \equiv \frac{\sum_t r_t \times \bar{\mu}_{t,i} - \sum_t r_t \times \mu_{t,i}(normal)}{\sum_t r_t \times \bar{\mu}_{t,i}} \times 100\%, \quad (16)$$

where $\bar{\mu}_{t,i}$ is the average incidence of the disease i in the age group t and is defined as

$$\bar{\mu}_{t,i} \equiv s_t^{NORMAL} \times \mu_{t,i}(normal) + s_t^{OVERWEIGHT} \times \mu_{t,i}(overweight) + s_t^{OBESSE} \times \mu_{t,i}(obese), \quad (17)$$

where s_t^{NORMAL} , $s_t^{OVERWEIGHT}$ and s_t^{OBESSE} denote the share of the normal weight, the overweight, and the obese, respectively, in the age group t .

We divide the population into the following age groups: 0-18, 18-35, 35-50, 50-65 and 65+. We classify individuals with BMI 18.5-25 as normal weight, individuals with BMI 25-30 as overweight, and individuals with BMI 30-50 as obese. For individuals in the age group 0-18 we do not construct separate estimates of the disease incidence by body weight.

The estimated associations between obesity and disease incidence are calculated using the MEPS data. The results are shown in Figures 1.1-1.18 (all figures are in the Appendix).⁹ The ICD-9 disease classification contains 18 disease classes. Each of the figures shows the results for all diseases within one disease class.¹⁰ We also calculate the effect of obesity on pharmaceutical expenditures by the therapeutic category of drugs using the matched MEPS and NAMCS data. The effects by the therapeutic category are calculated by replacing the disease incidence parameters $\bar{\mu}_{i,j}$, $\mu_{i,j}(normal)$, $\mu_{i,j}(overweight)$ and $\mu_{i,j}(obese)$ in the expressions (15), (16) and (17) with the corresponding measures of pharmaceutical expenditures $\bar{E}_{t,i}$, $E_{t,i}(normal)$, $E_{t,i}(overweight)$ and $E_{t,i}(obese)$ for each body weight group

⁹The 99% confidence intervals (CI) are calculated using cluster-robust standard errors with clustering at the subject level.

¹⁰For each disease class we combine diseases with less than 100 observations in the MEPS with other such diseases to category "000 Other diseases in the disease class".

and age group combination. The estimated associations between obesity and pharmaceutical expenditures are shown in Figure 2.¹¹

The results show significant variation in the association between obesity and disease incidence both across diseases within each disease class and across all diseases. The variation in the association between obesity and disease incidence across diseases is important for two reasons. First, in our companion paper (Bhattacharya and Packalen, 2008) this variation enables us to identify the empirical effect of obesity on pharmaceutical innovation. Second, the variation implies that the induced innovation externality of obesity on the normal weight may be negative. This is because an increase in obesity will change the relative potential market sizes across diseases which in turn may shift resources toward diseases for which the incidence among normal weight individuals is relatively low compared to the average disease incidence across diseases for normal weight individuals.

The results also suggest several interesting results that to our knowledge have not been explored in the medical literature. We find that sexually transmitted diseases HIV, Herpes Simplex and Chlamydia (in disease class 1) are negatively associated with obesity. Second, malignant and non-malignant skin cancer (in disease class 2) are negatively associated with obesity. Third, contraceptive use (in the disease class 18 and as a therapeutic category) is negatively associated with obesity. We do not suggest that these are physiological consequences of obesity but rather that they result from behavioral changes that are caused the limiting effect that obesity has on an individual's choice set. Future work should explore whether these associations are indeed causal.

¹¹Within each age group we again allow the disease incidence to vary by sex, race (black/non-black), insurance status (private/non-private) and year (linear trend). To eliminate outliers we drop observations where pharmaceutical expenditures in a particular therapeutic category exceed \$10,000.

6 The Externality Calculations

We first calibrate the parameters R_{PATENT} and R_{MC} . Berndt (2001) reports that the share of off-patent generics is approximately 50% of the dispensed drug units. Because brand-name drugs cost more than generics we calibrate the share of the marginal pharmaceutical revenue that goes to brand-name drugs at $R_{PATENT} = 0.80$. Reinhardt (2001) cites estimates for the pharmaceutical industry that place marketing and general administration costs at 35% of revenue and manufacturing costs at 27% of revenue, but notes that firms in the pharmaceutical industry often manufacture also other goods than brand-name drugs. Estimating the share $1 - R_{MC}$ of the marginal revenue from brand-name drugs that is in excess of marginal costs is therefore difficult. We calibrate it at $1 - R_{MC} = 0.66$.

Using the calibrated values of the parameters R_{PATENT} and R_{MC} we first estimate the total induced innovation externality of obesity at each age using the expression (12) and MEPS data on total pharmaceutical expenditures.¹² As our later objective is to compare the induced innovation externality of obesity with the Medicare-induced health insurance externality of obesity for individuals who are covered by private insurance before old-age, for ages 0-65 we construct the estimates of pharmaceutical expenditures using data on only individuals who are covered by private insurance. For ages 65+ we construct the estimates from data on individuals who are covered by either public or private insurance.

The results are shown in Figure 3. Because the total externality is a fixed percentage of the obesity-induced increase in a person's annual pharmaceutical expenditures, the path of the externality follows the path of the increase in annual pharmaceutical expenditures that is due to obesity and thus increases sharply between ages 25 and 55. Overall, the estimate

¹²To eliminate concern over possible time effects in the pharmaceutical expenditures data we use only MEPS data from years 2002-2005 in the analyses in this section.

In the calculations in this section we use the following age groups: 0-18, 18-25, 25-30, 30-35, 35-40, 40-45, 45-50, 50-55, 55-60, 60-65, 65-70, 70-75, 75-80, 80+, and the following BMI groups: 18.5-25 (normal weight), 25-30 (overweight), and 30-50 (obese). In addition to allowing the expenditures to vary by age and body weight, we allow the expenditures to vary by sex and race (black/non-black).

of the total induced innovation externality of obesity as a function of age shows that while the magnitude of the externality that a marginal increase in obesity has on an individual depends greatly on the age of the individual, on average the magnitude of the externality is substantial.

We next calculate the average externality, the externality on the normal weight and the externality on the obese separately using the expressions (11), (13), and (14), respectively.¹³ For these calculations we use the matched MEPS and NAMCS data on pharmaceutical expenditures by the therapeutic category of drugs.

Figure 4.1 shows the results for the three externalities when the ratio of the reward-elasticity of the composition of pharmaceutical innovation (ε_c) and the reward-elasticity of total pharmaceutical innovation (ε) is set at $\frac{\varepsilon_c}{\varepsilon} = 2$. In this case the externality on other obese people is approximately 50% higher than the average externality, and the externality on the normal weight is positive and substantial at almost any age.¹⁴ Figure 4.2 shows the results for the three externalities when the ratio of the two innovation elasticities is set at $\frac{\varepsilon_c}{\varepsilon} = 4$. Even when the ratio of elasticities is set this high the externality on the normal weight is generally positive. Figure 4.3 shows the results for the three externalities when the ratio of the two innovation elasticities is set at an extreme $\frac{\varepsilon_c}{\varepsilon} = 8$. In this seemingly unrealistic case obesity now has a substantial negative externality on the normal weight.

We next calculate the cumulative induced innovation externality of obesity and compare it with the cumulative Medicare-induced health insurance externality of obesity. The present value of the cumulative total induced innovation externality of obesity from the initial age

¹³In these calculations calibrate the U.S. Population at $N_{US} = 300,000,000$.

¹⁴A possibility that is not taken into account in these calculations is that obesity might shift resources from research that potentially benefits everyone to obesity-specific research. We do not think that this is a significant issue for our purposes because while obesity accounts for roughly 10% of all health care expenditures, in 2005 among all publications in the MEDLINE database of biomedical publications less than 2% mention the word "obesity", the word "obese", the words "body mass index" or the acronym "bmi" in either the abstract or the title of the publication (and less than 1% if one considers only the title).

t_0 to the terminal age T is

$$CumulativeExternality(total) = \sum_{t=t_0}^T \beta^{t-t_0} \times Externality_t(total), \quad (18)$$

where β is the discount factor and $Externality_t(total)$ is the total externality at age t and is calculated using the expression (12). The present value of the cumulative Medicare-induced health insurance externality of obesity from the initial age t_0 to the terminal age T is

$$MedicareExternality = \sum_{t=\min\{t_0,65\}}^T \beta^{t-t_0} \times m \times [T_t(obese) - T_t(normal)], \quad (19)$$

where m is the share of the marginal health care expenditures paid by Medicare, and $T_t(normal)$ and $T_t(obese)$ are the average annual health care expenditures at age t for the normal weight and for the obese, respectively, and are estimated from the MEPS data. We also calculate the present value of the cumulative Medicare-induced insurance externality of obesity from pharmaceutical expenditures alone.¹⁵

We calibrate the discount factor at $\beta = 0.97$ and the initial age at $t_0 = 18$. The share of health care expenditures covered by Medicare for people aged 65 and over is approximately 50% in the MEPS data. While this average rate may not coincide with the marginal rate, we assume that for people aged 65 and over medicare pays 50% of the increase in health care expenditures that is caused by obesity by setting $m = 0.5$.¹⁶ We calculate the cumulative externalities as a function of the terminal age T .

The results are shown in Figure 5. For a person with terminal age 80, which roughly equals life expectancy, the present value of the (positive) cumulative induced innovation externality of obesity from pharmaceutical expenditures is much larger than the present value

¹⁵The Medicare-induced insurance expenditure for pharmaceutical expenditures alone is calculated as $\sum_{t=\min\{t_0,65\}}^T \beta^{t-t_0} \times m \times [E_t(obese) - E_t(normal)]$,

¹⁶This proportion is presumably higher now since Medicare started in 2006 to cover pharmaceutical expenditures through its Part D program.

of the (negative) Medicare-induced insurance externality from pharmaceutical expenditures and is similar in magnitude as the present value of the (negative) cumulative Medicare-induced public health insurance externality from all health care expenditures. Of course, the exact value of the induced innovation externality of obesity is sensitive to the assumptions about the parameters. However, we suspect that the conclusion that the magnitudes of the two opposing externalities of obesity are the same is robust. Moreover, we have ignored the induced innovation externality of obesity from all other medical expenditures than pharmaceutical expenditures.

7 Conclusion

In this paper we argue that an analysis of the *ex-ante* moral hazard should not stop at the disincentive effects of insurance on self-protective activities. To demonstrate that our argument is also quantitatively important we examine the obesity epidemic as an empirical example.

While the effects of obesity on the incidence of all individual diseases are not known, obesity is known to increase the health care costs for a person. It is also well known that given the health care costs of obesity and the existence of public health insurance programs obesity has a negative externality. Moreover, another commonly held view is that since obesity is at least to some degree the result of an individual's decisions and an individual does not bear the full costs of obesity, public policies aimed at increasing the costs of obesity for an individual may be justified. In this paper we have challenged this perspective on obesity.

Our analysis is based on the induced innovation hypothesis, which has broad empirical support. Any increase in obesity that increases the incidence of a disease increases the potential market size for new drug therapies for the disease and, by the induced innovation hypothesis, also the rate of innovation of drug therapies for the disease. The induced inno-

vation externality arises because this increase in innovation of drug therapies for the disease benefits all people who are afflicted with the disease.

Our results show that the magnitude of the induced innovation externality of obesity is substantial. We show that the present value of the cumulative induced innovation externality from pharmaceutical expenditures roughly coincides with the present value of the Medicare-induced health insurance externality from total health care expenditures. We also show that, while the externality on the normal weight is smaller than the average externality, it too is likely to be positive.

Our estimates of the associations between obesity and disease incidence replicate many findings in the medical literature but also reveal several interesting associations that to our knowledge have not been explored in the medical literature.¹⁷ Overall, the estimates show considerable variation in the association between obesity and disease incidence across diseases. We show that the average induced innovation externality of obesity is unaffected by this variation across diseases.

Finally, because preference externalities in health care have direct policy implications, identifying and quantifying other such externalities than the pharmaceutical innovation externality examined here is an important topic for future research.

¹⁷Namely, we show that obesity is associated with a decrease in the incidence of skin cancer, sexually transmitted diseases and contraceptive use. These associations are likely consequences of behavioral responses to obesity rather than direct physiological effects.

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Appendix

Figure 1.1: Associations between Obesity and Infections and Parasitic Diseases.



Figure 1.2: Associations between Obesity and Neoplasms.

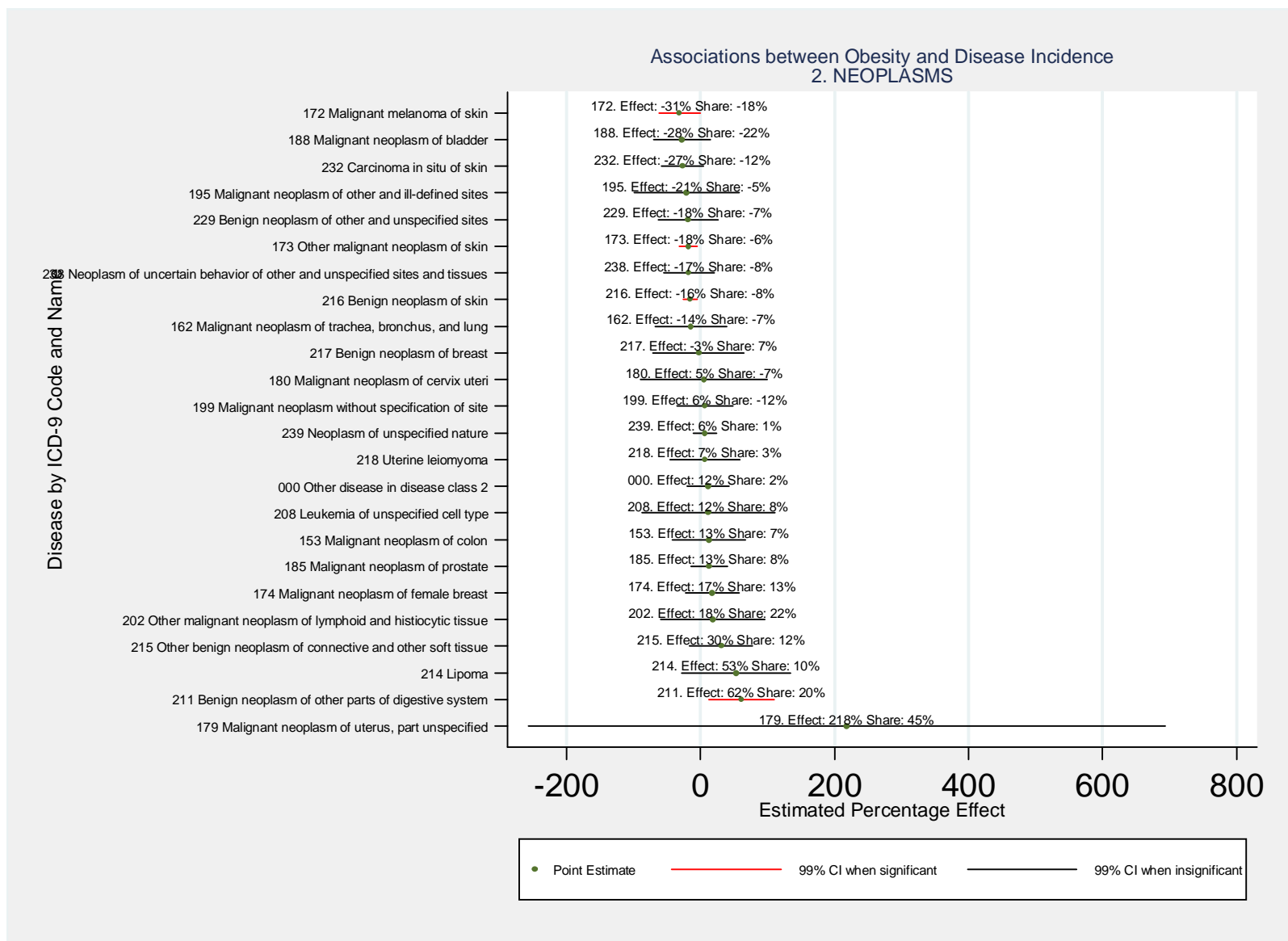


Figure 1.3: Associations between Obesity and Endocrine, Nutritional and Metabolic Diseases.

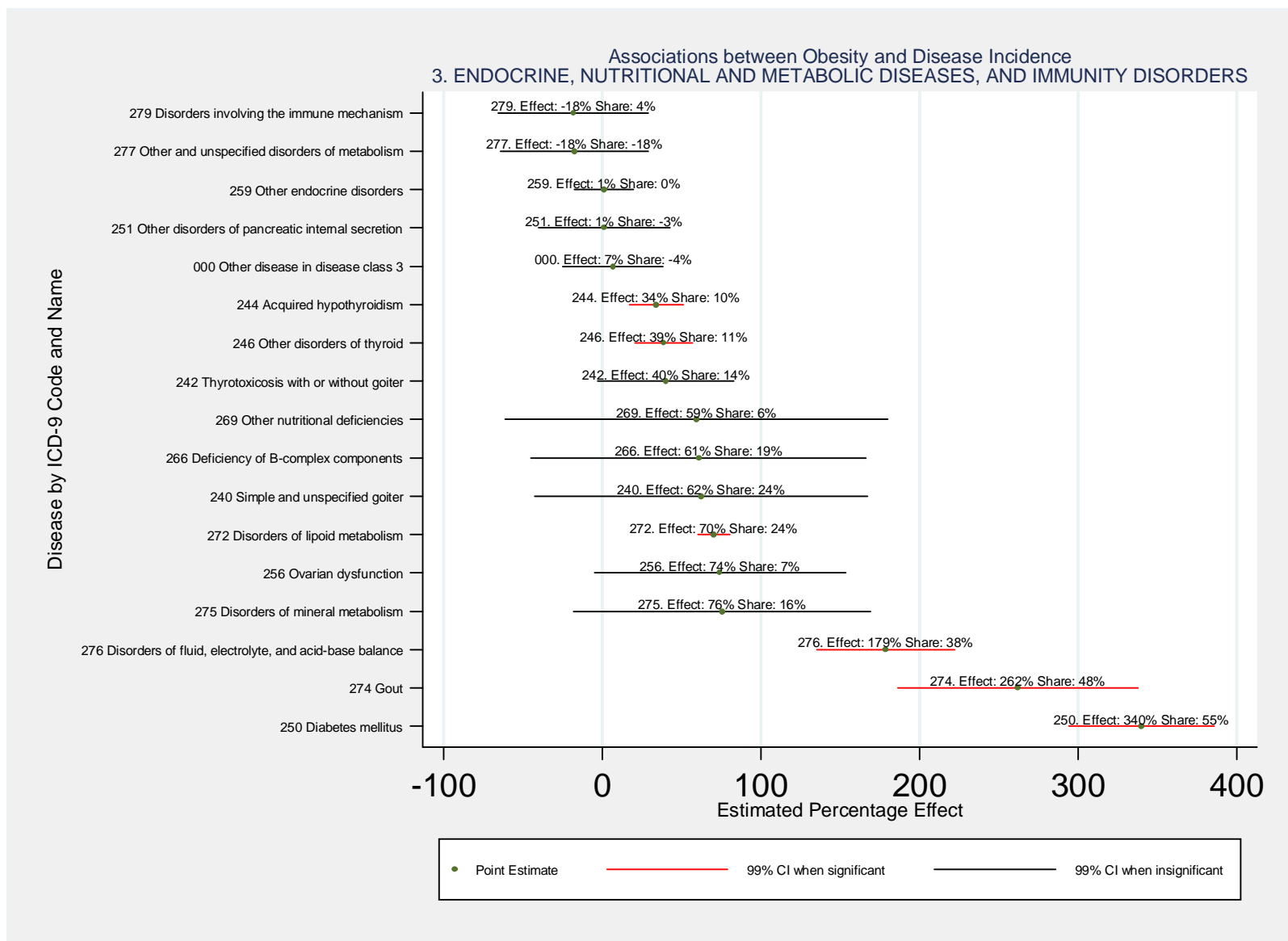


Figure 1.4: Associations between Obesity and Diseases of Blood and Blood-forming Organs.

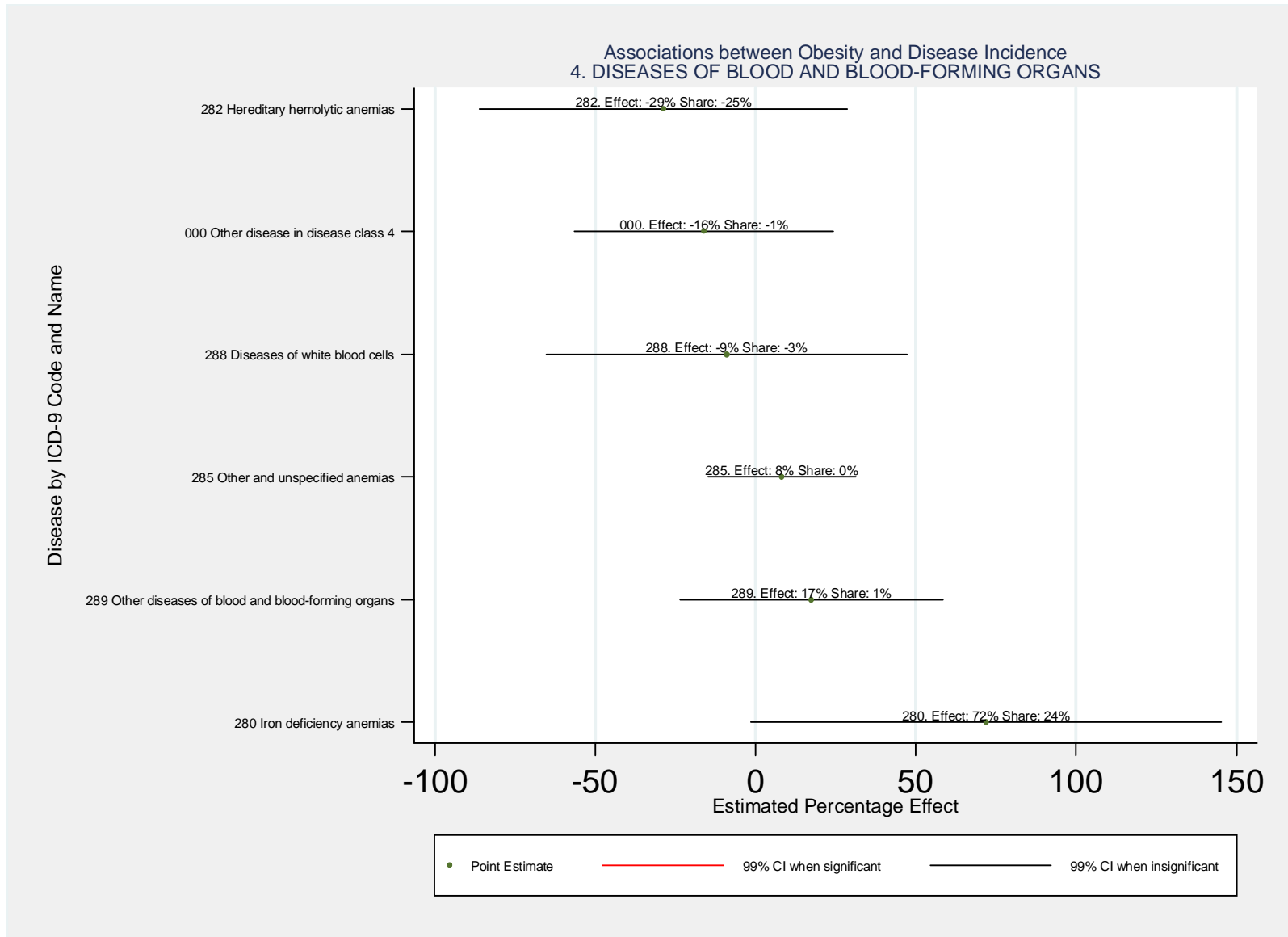


Figure 1.5: Associations between Obesity and Mental Disorders.

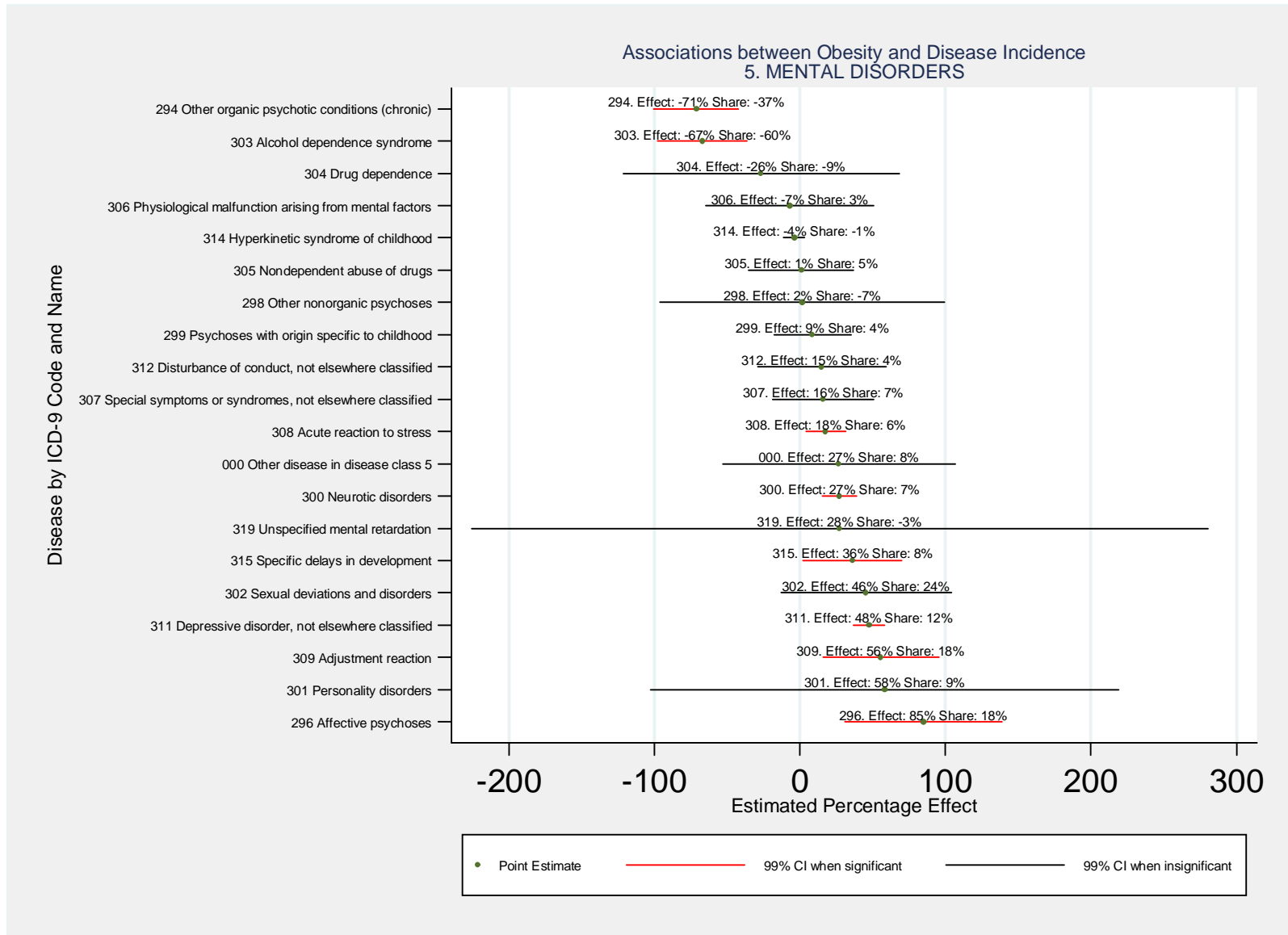


Figure 1.6: Associations between Obesity and Diseases of the Nervous System and Sense Organs.



Figure 1.7: Associations between Obesity and Diseases of the Circulatory System.

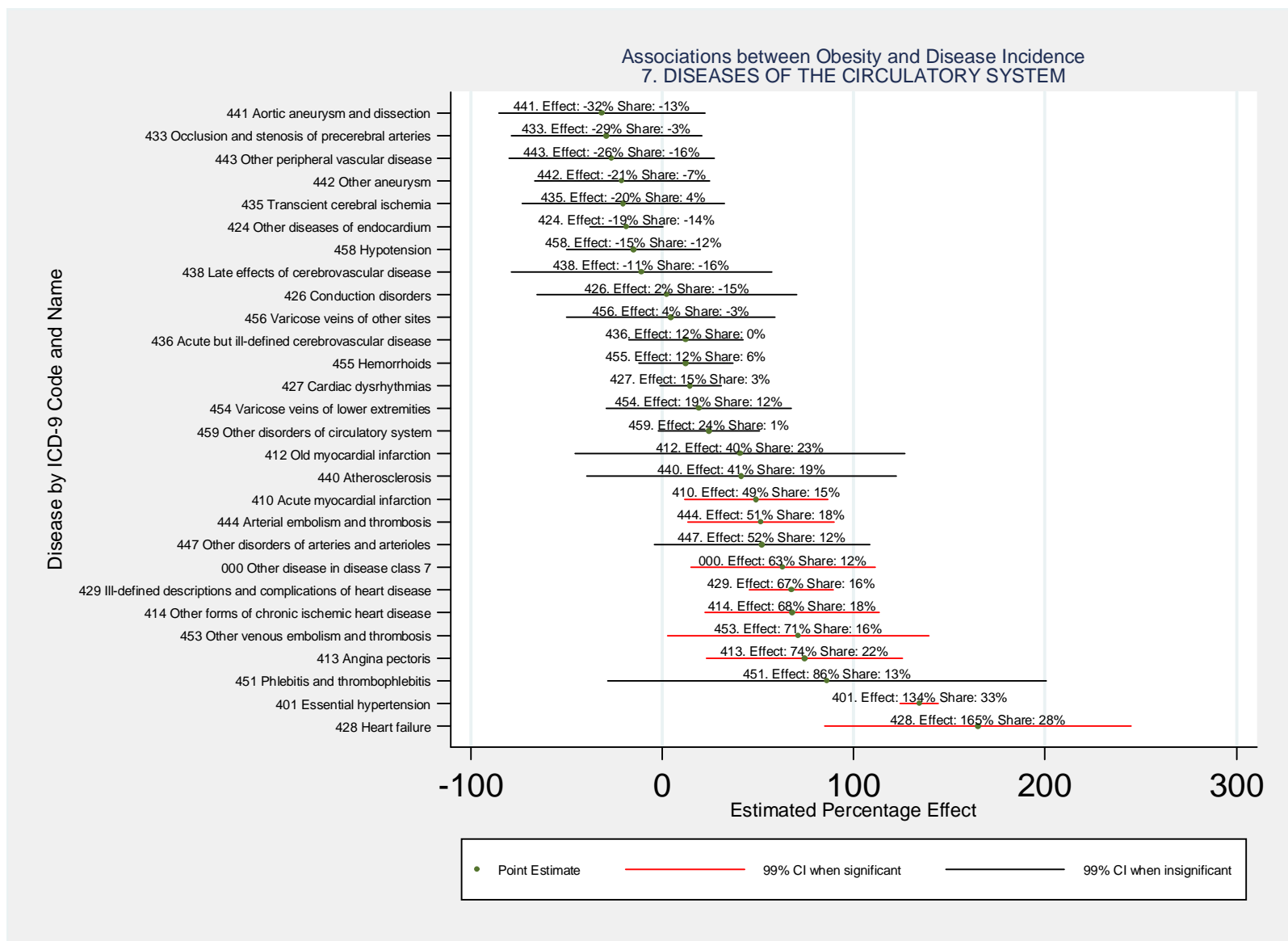


Figure 1.8: Associations between Obesity and Diseases of the Respiratory System.

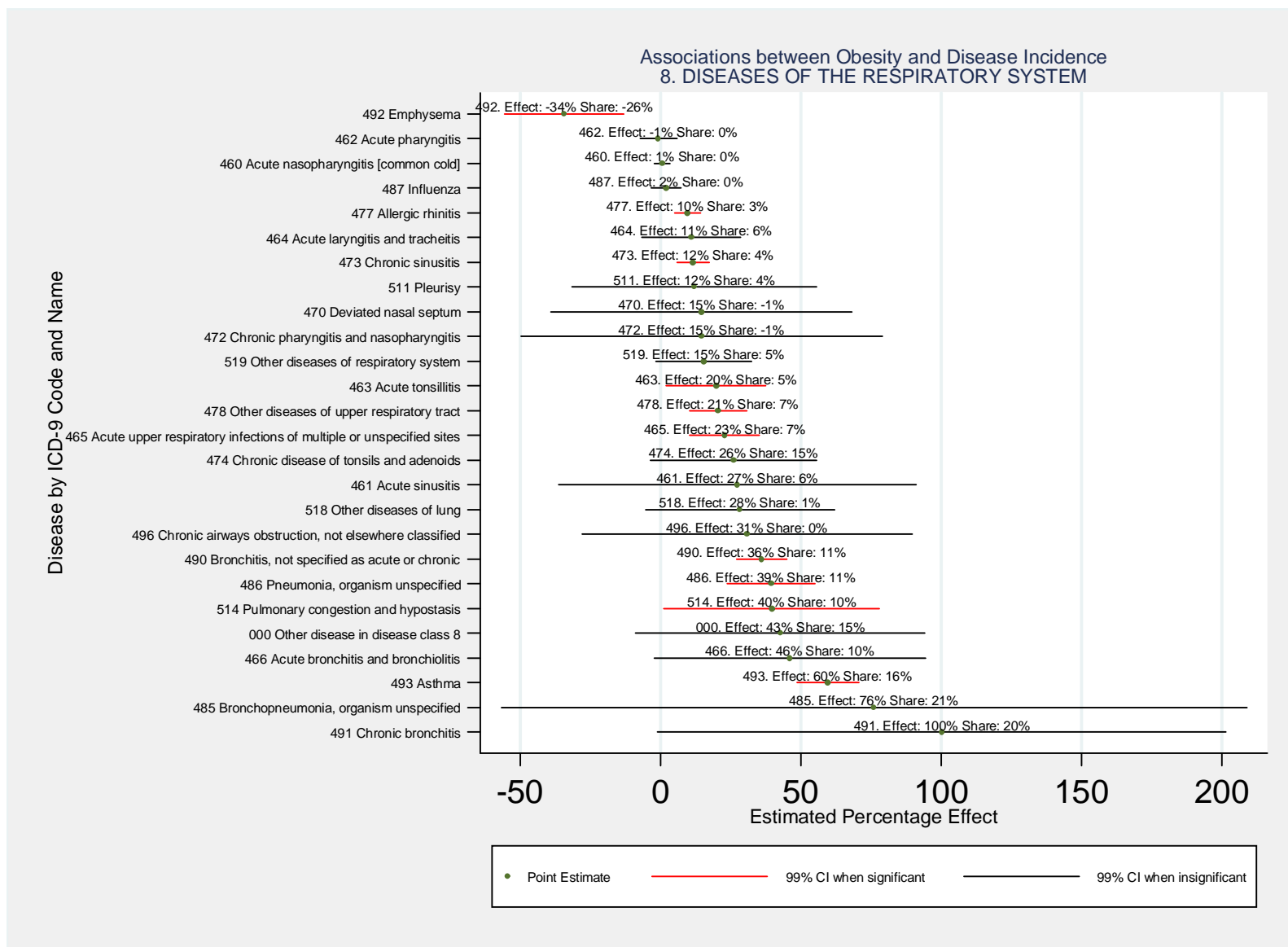


Figure 1.9: Associations between Obesity and Diseases of the Digestive System.

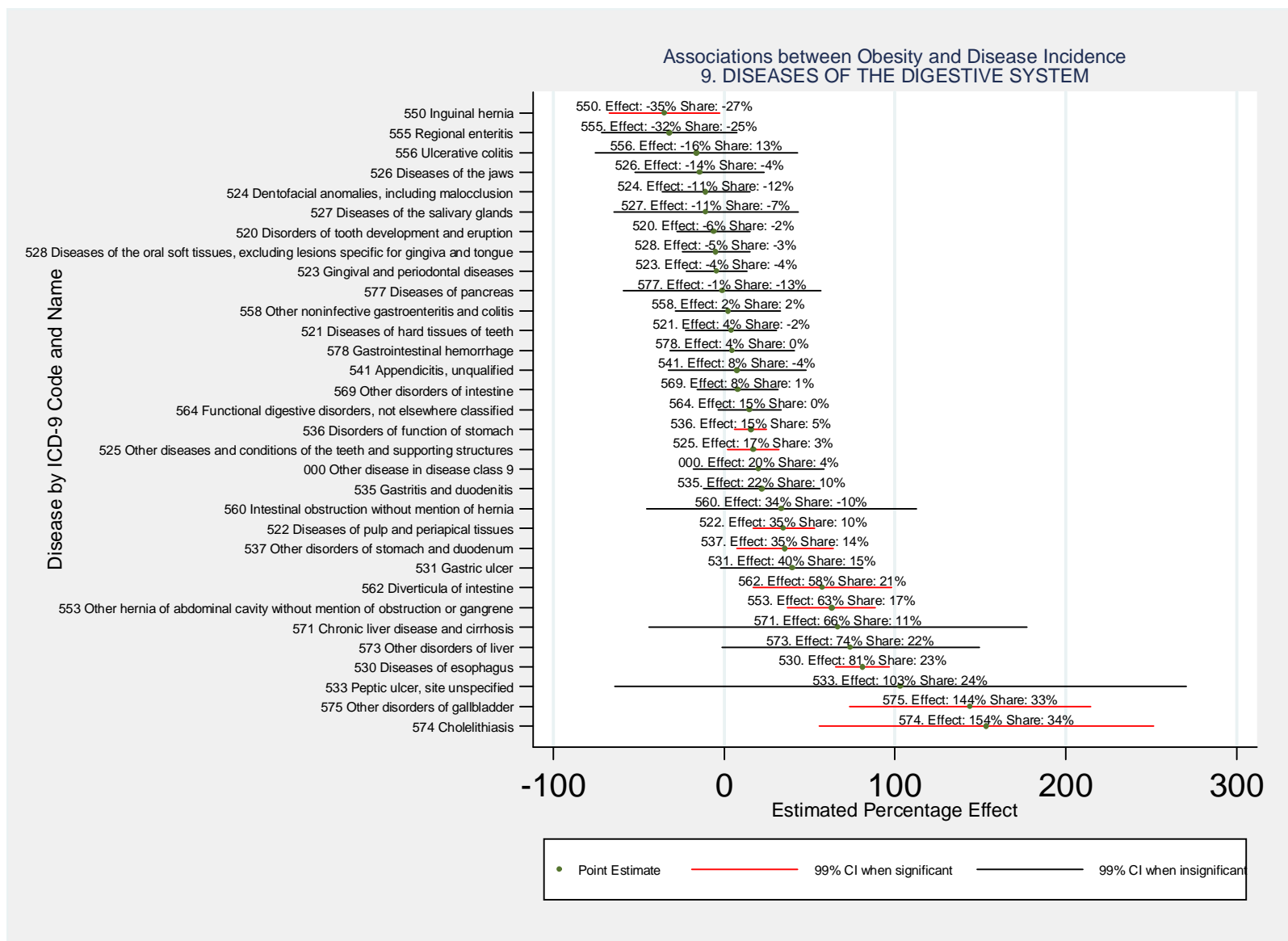


Figure 1.10: Associations between Obesity and Diseases of the Genitourinary System.

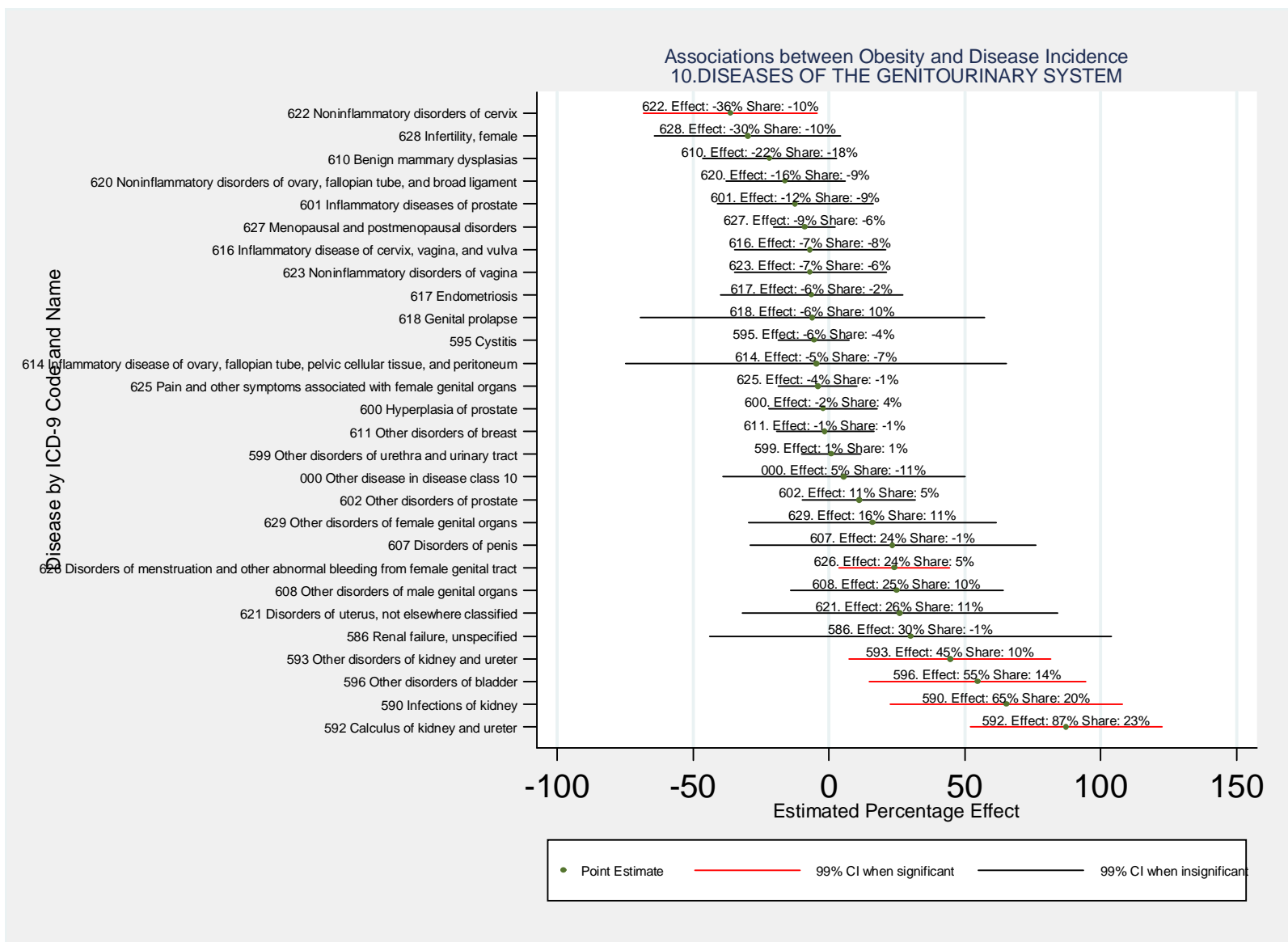


Figure 1.11: Associations between Obesity and Complications of Pregnancy, Childbirth, and the Puerperium.

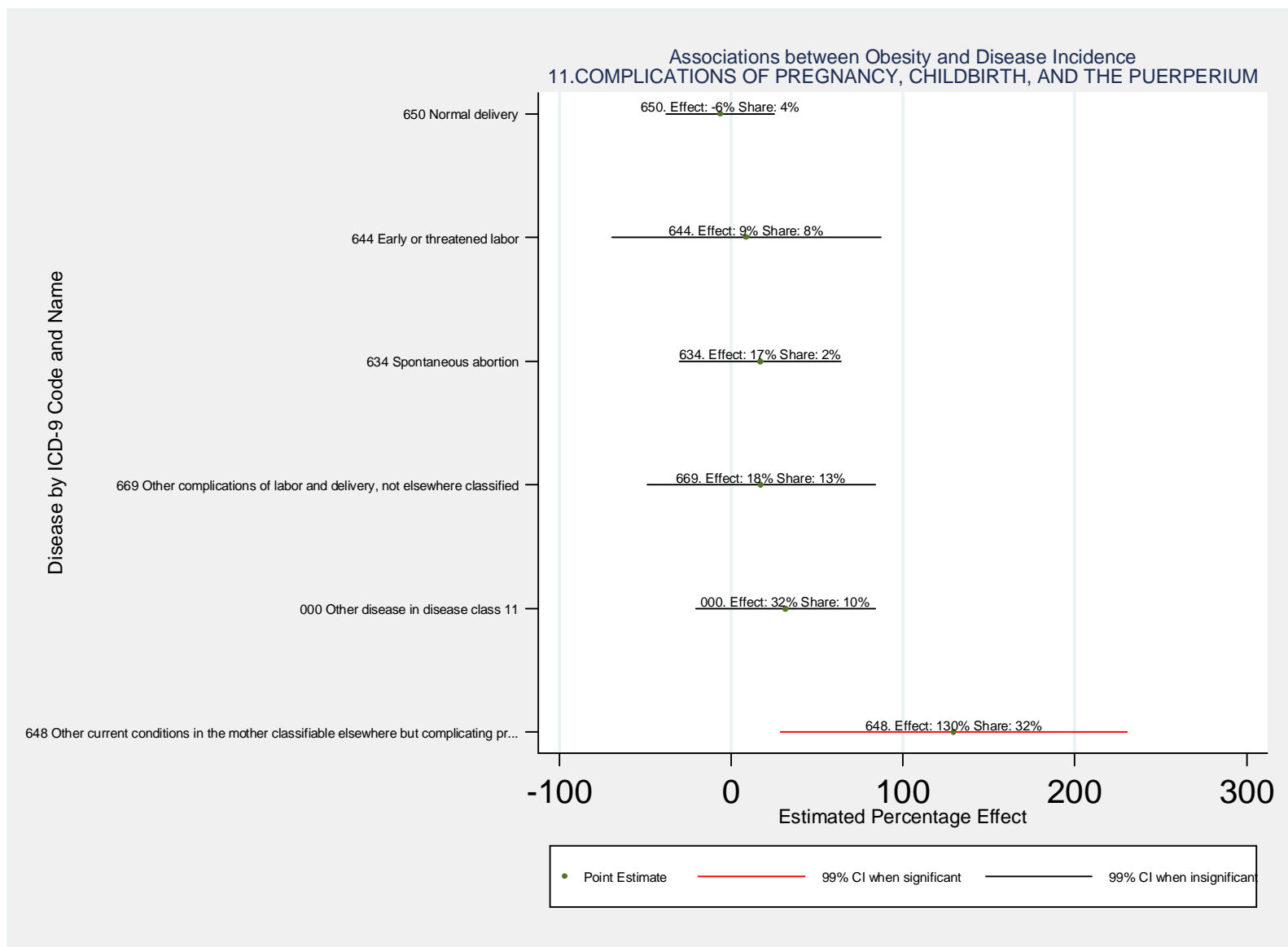


Figure 1.12: Associations between Obesity and Diseases of the Skin and Subcutaneous Tissue.

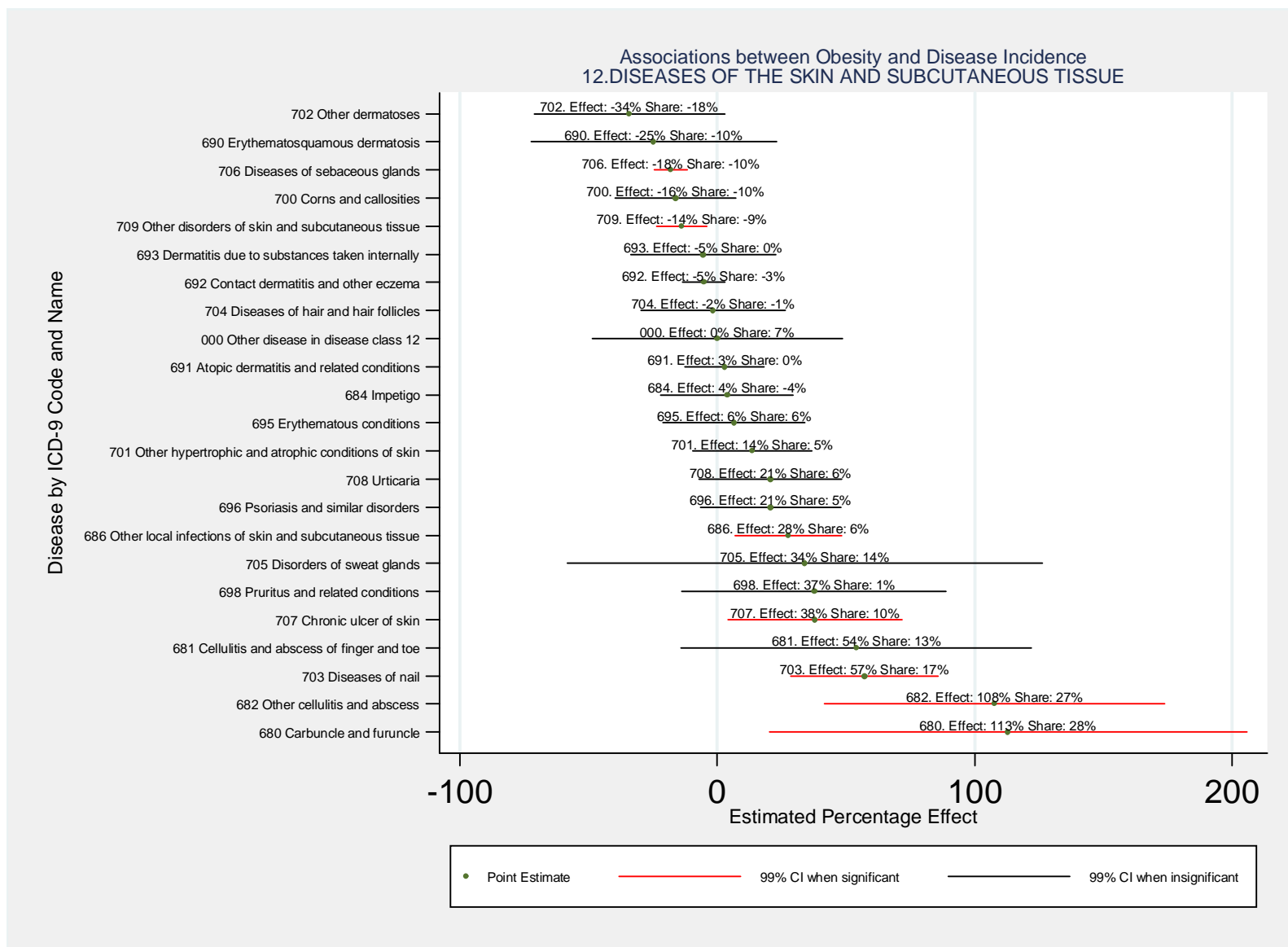


Figure 1.13: Associations between Obesity and Diseases of the Musculoskeletal System and Connective Tissue.

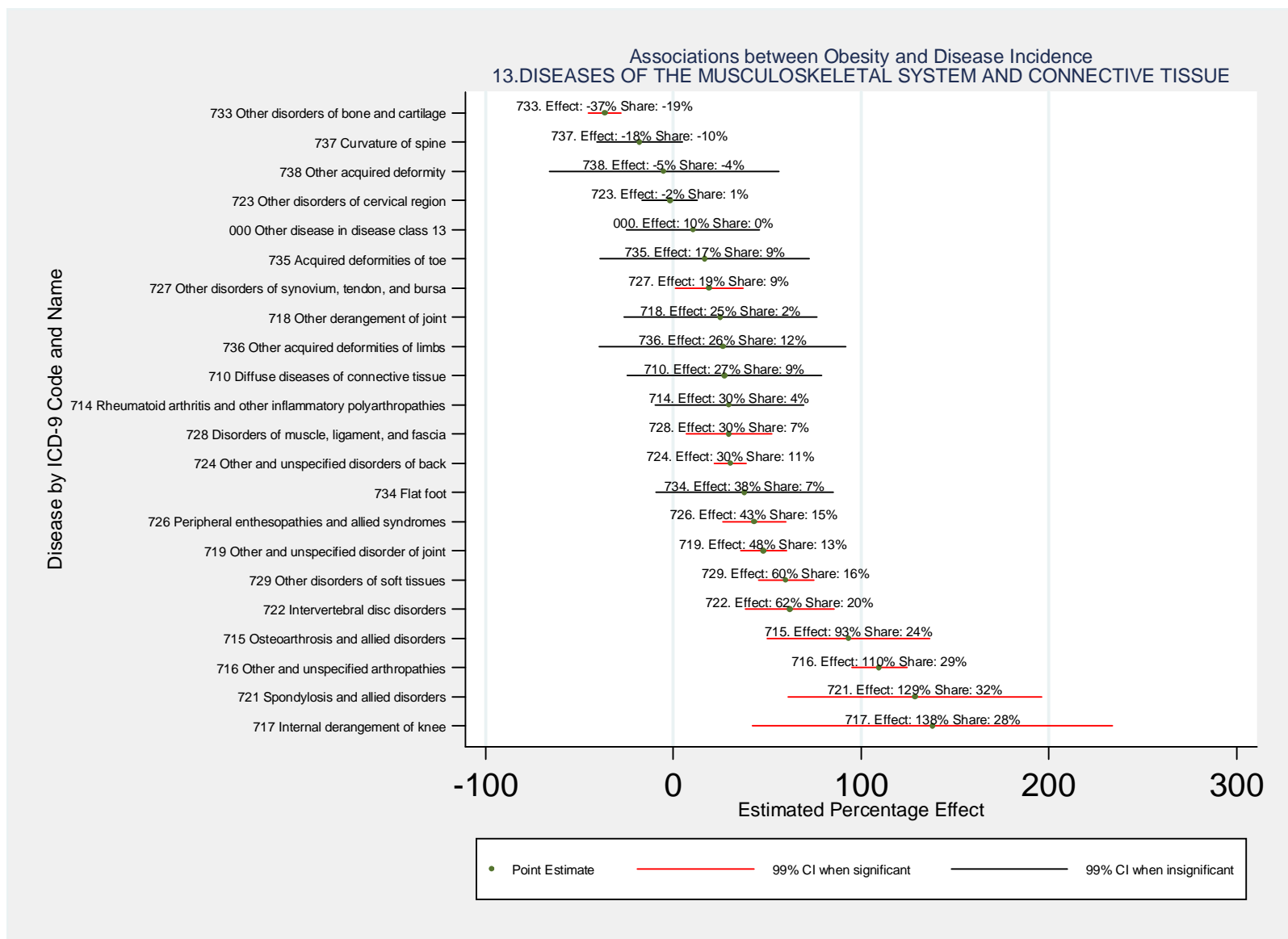


Figure 1.14: Associations between Obesity and Congenital Anomalies.

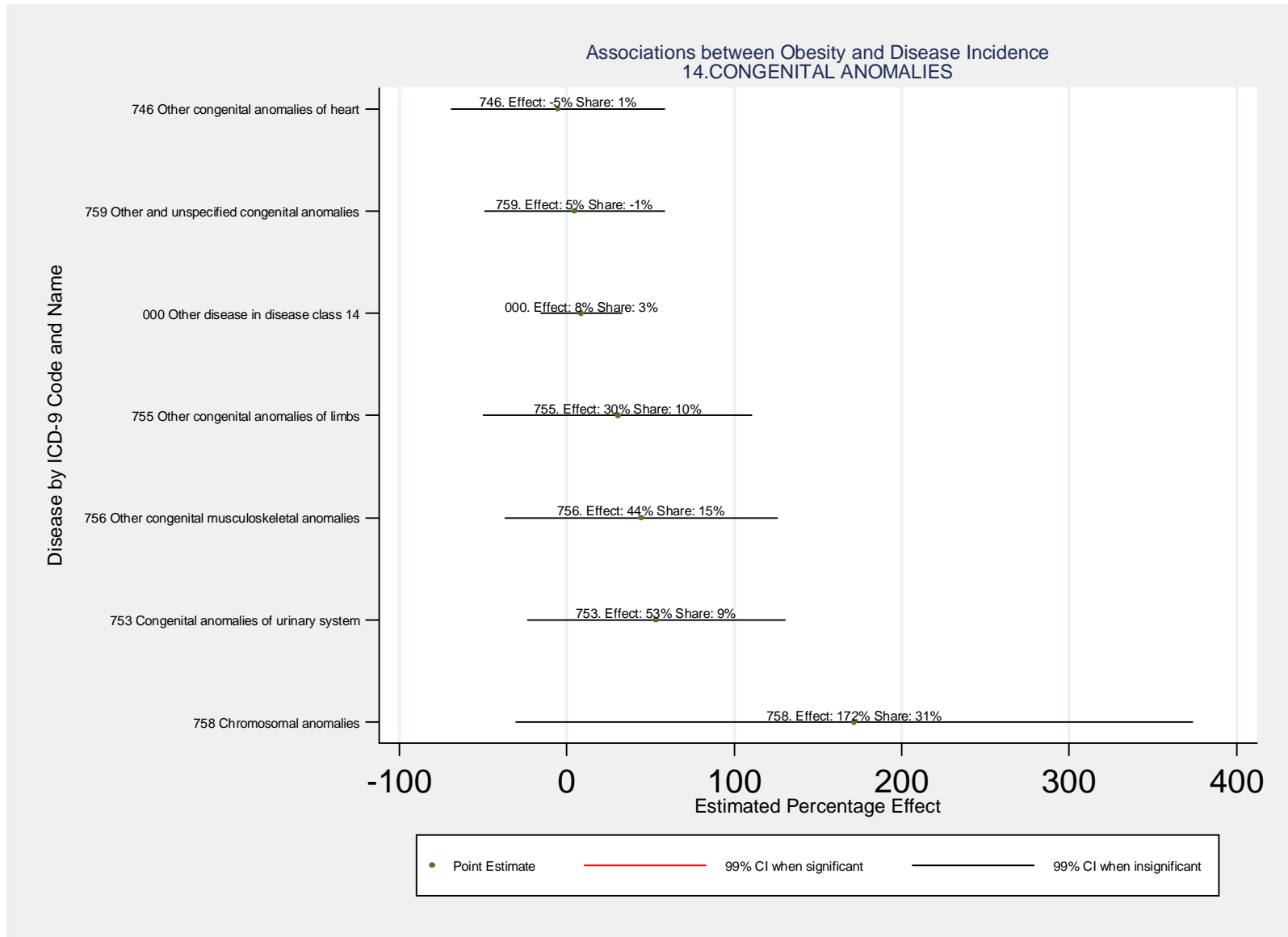


Figure 1.15: Associations between Obesity and Certain Conditions Originating in the Perinatal Period.

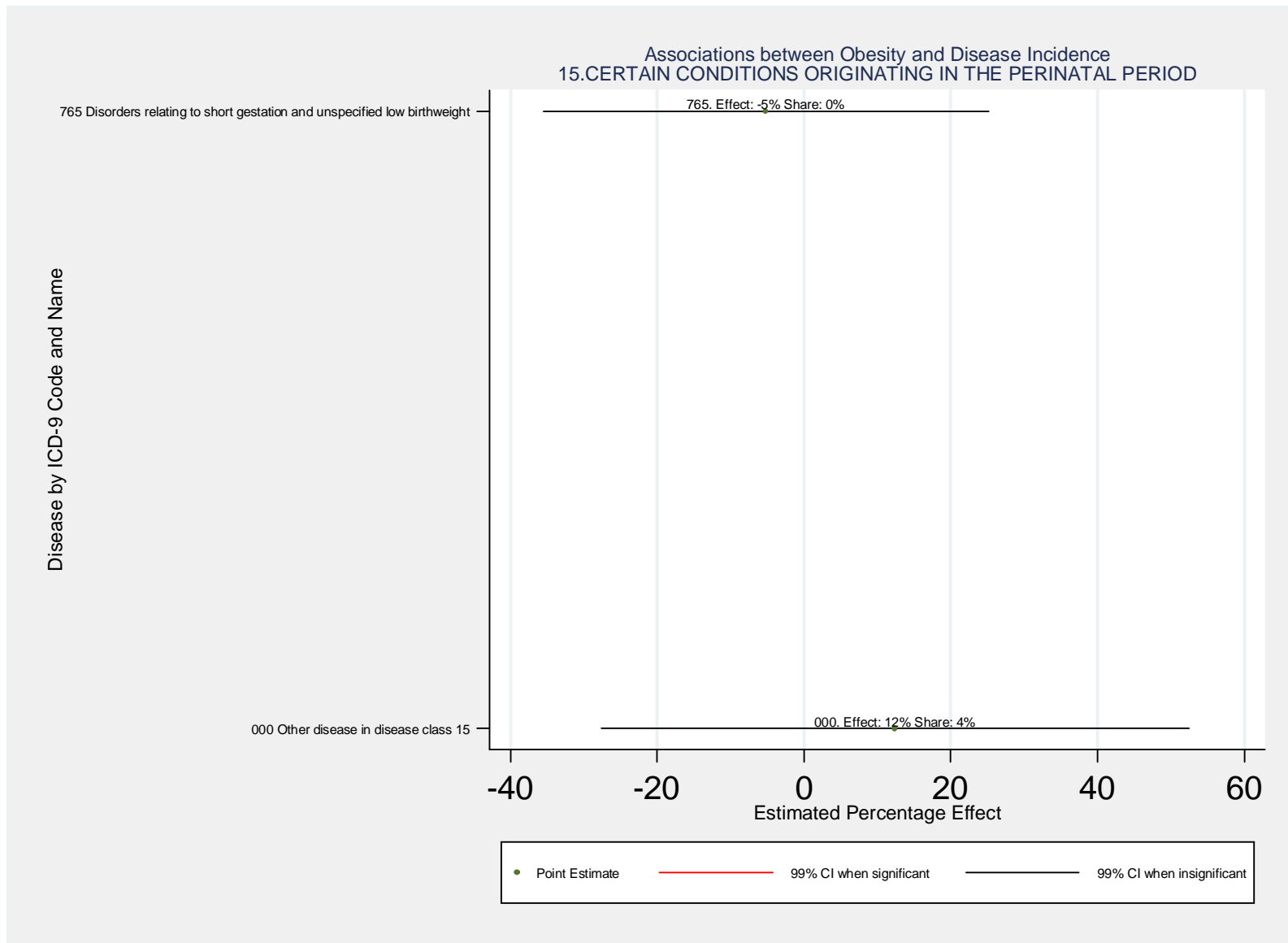


Figure 1.17: Associations between Obesity and Injury and Poisoning.

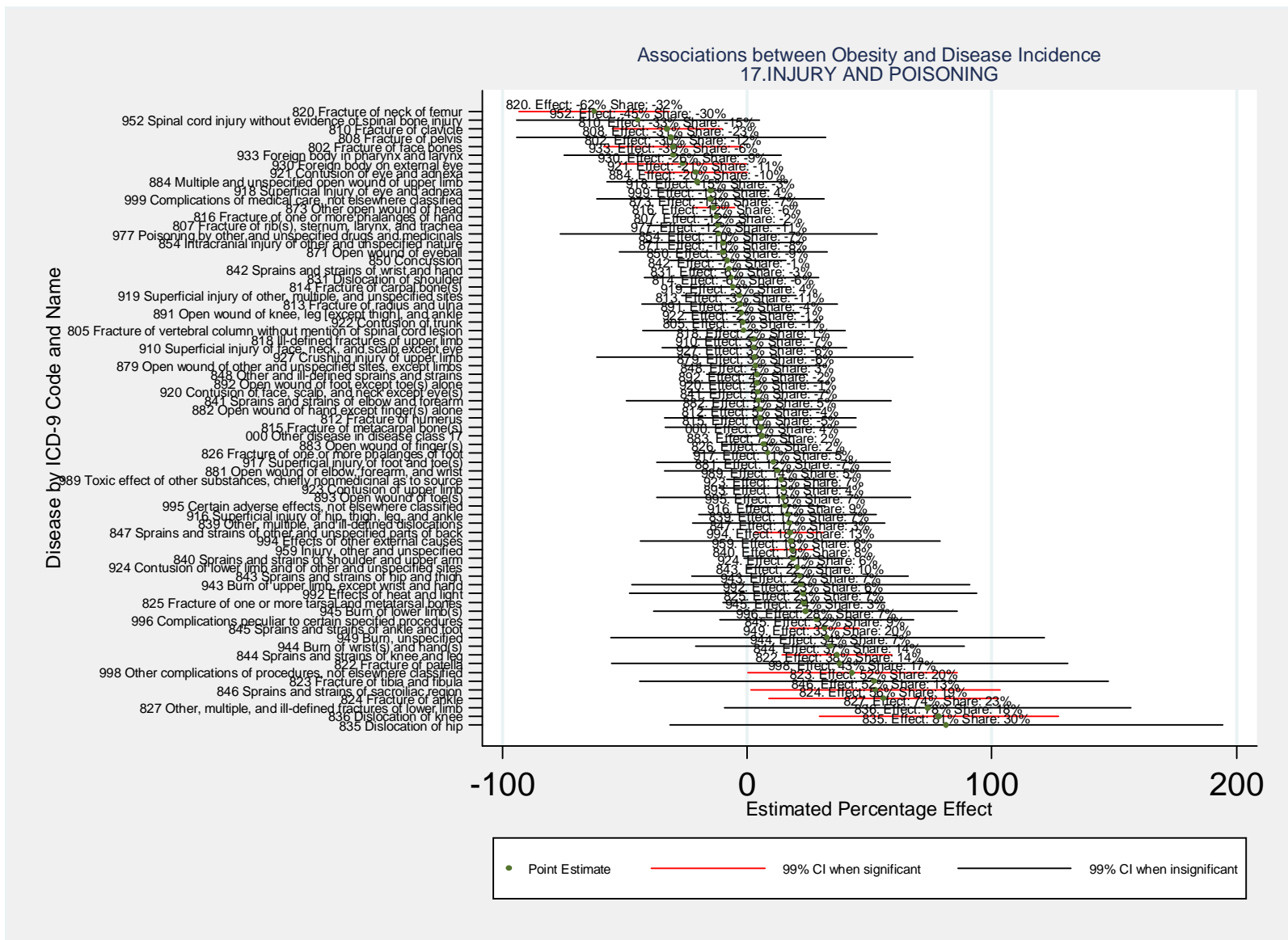


Figure 1.18: Associations between Obesity and Factors Influencing Health Status and Contact with Health Services.

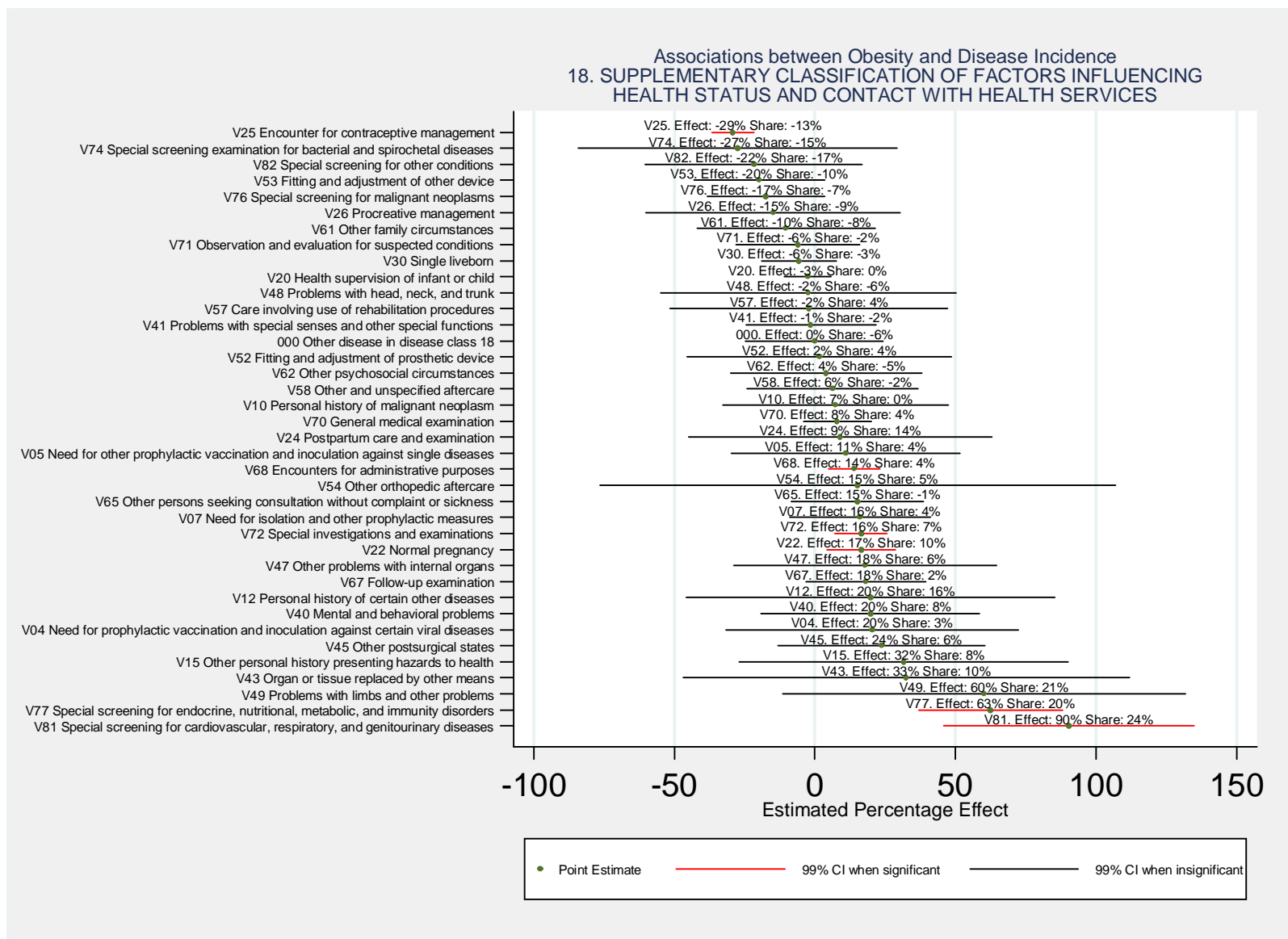


Figure 2: Associations between Obesity and Pharmaceutical Expenditures by Therapeutic Category.

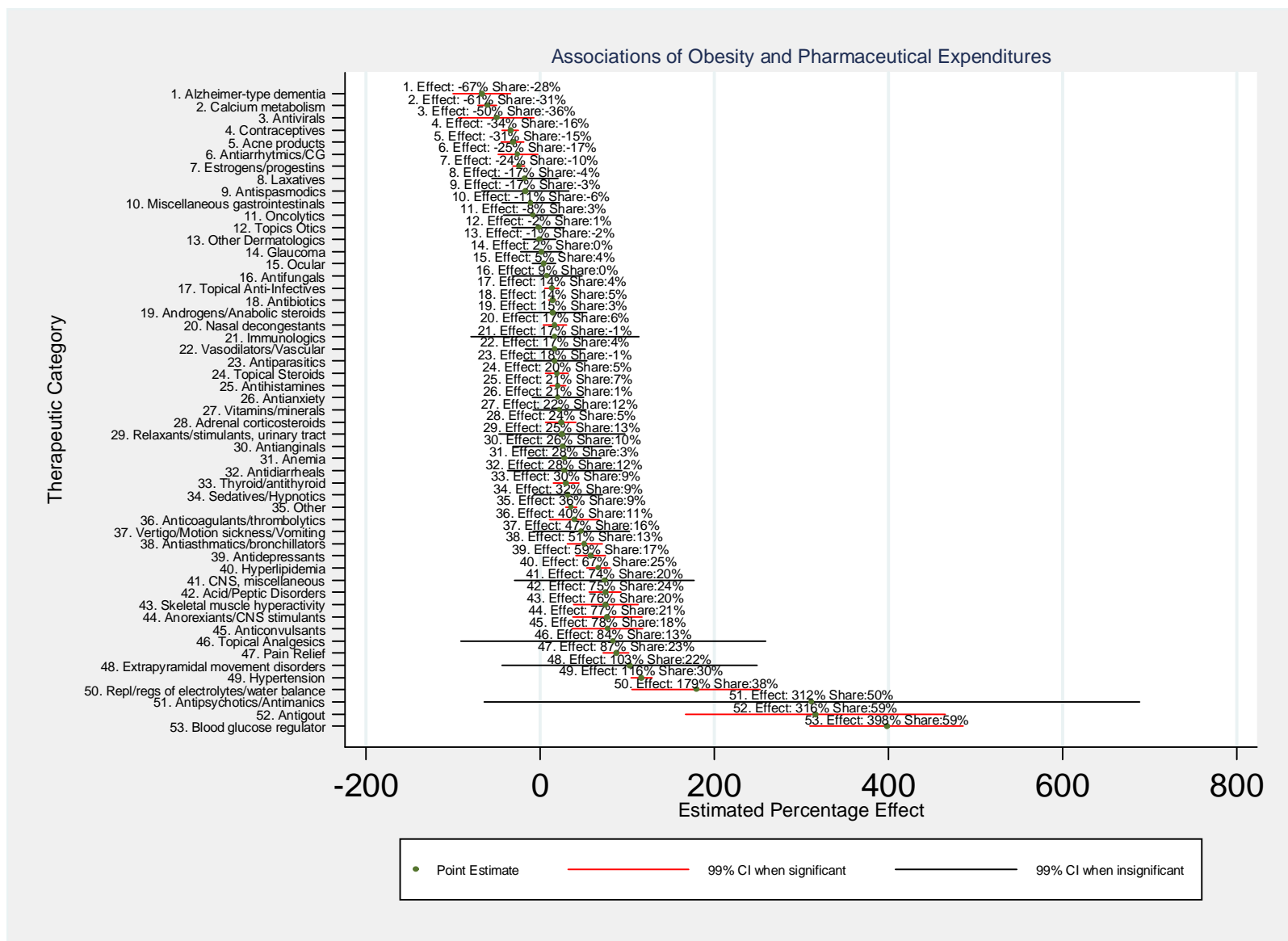


Figure 3: Total Induced Innovation Externality of Obesity.

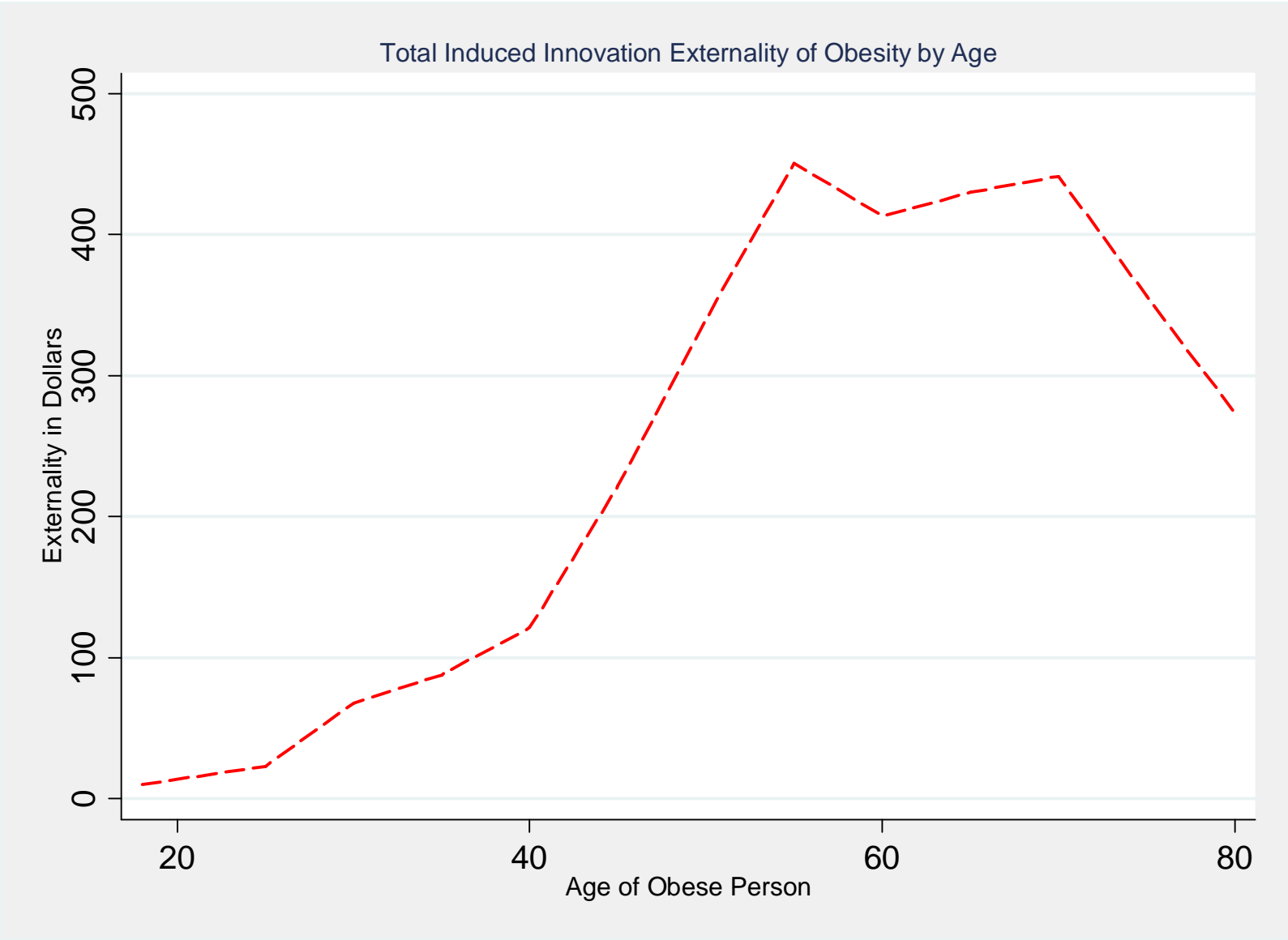


Figure 4.1: Induced Innovation Externalities when the Ratio of Innovation Elasticities is set at $\frac{\epsilon_c}{\epsilon} = 2$.

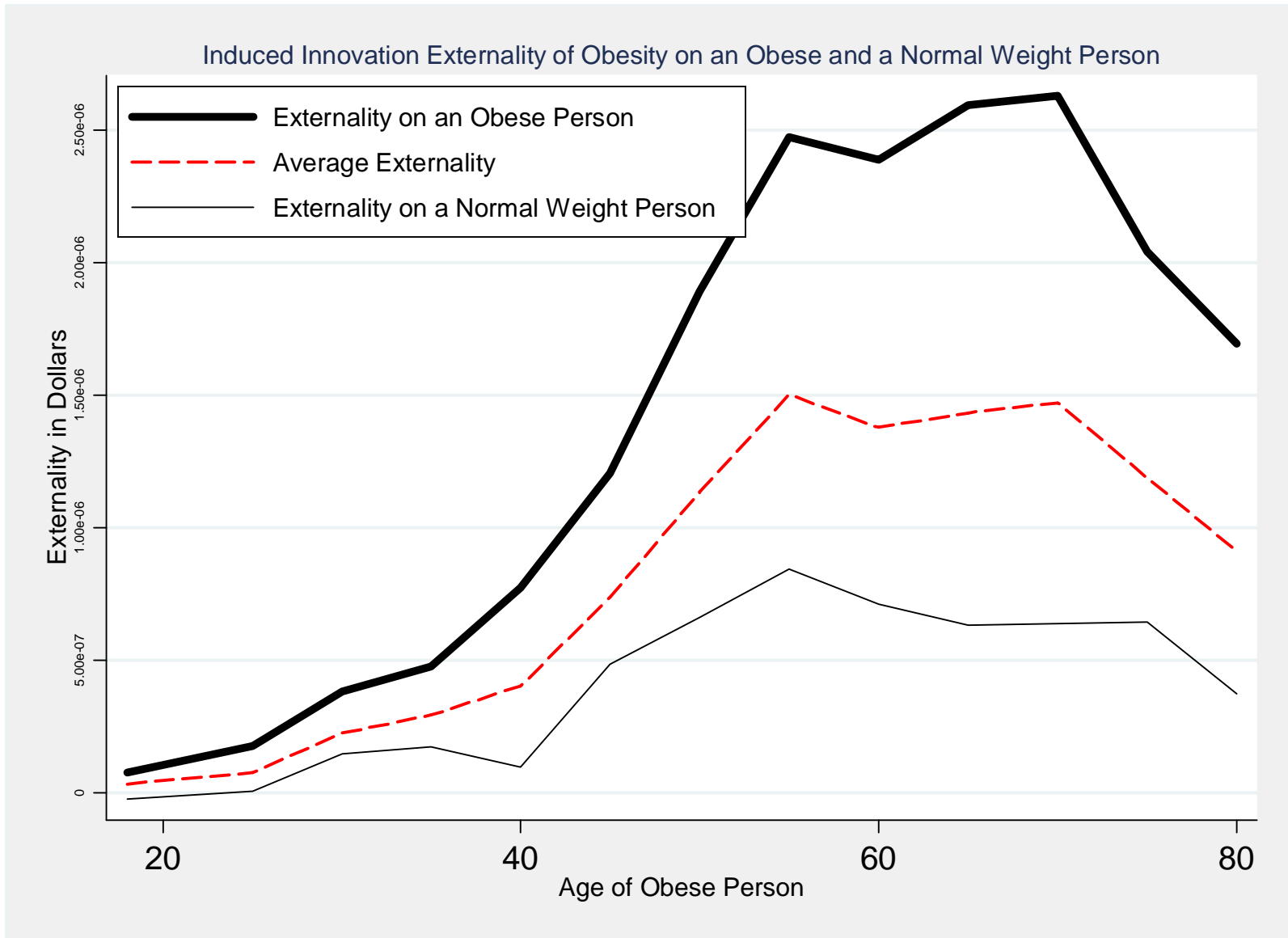


Figure 4.2: Induced Innovation Externalities when the Ratio of Innovation Elasticities is set at $\frac{\epsilon_c}{\epsilon} = 4$.

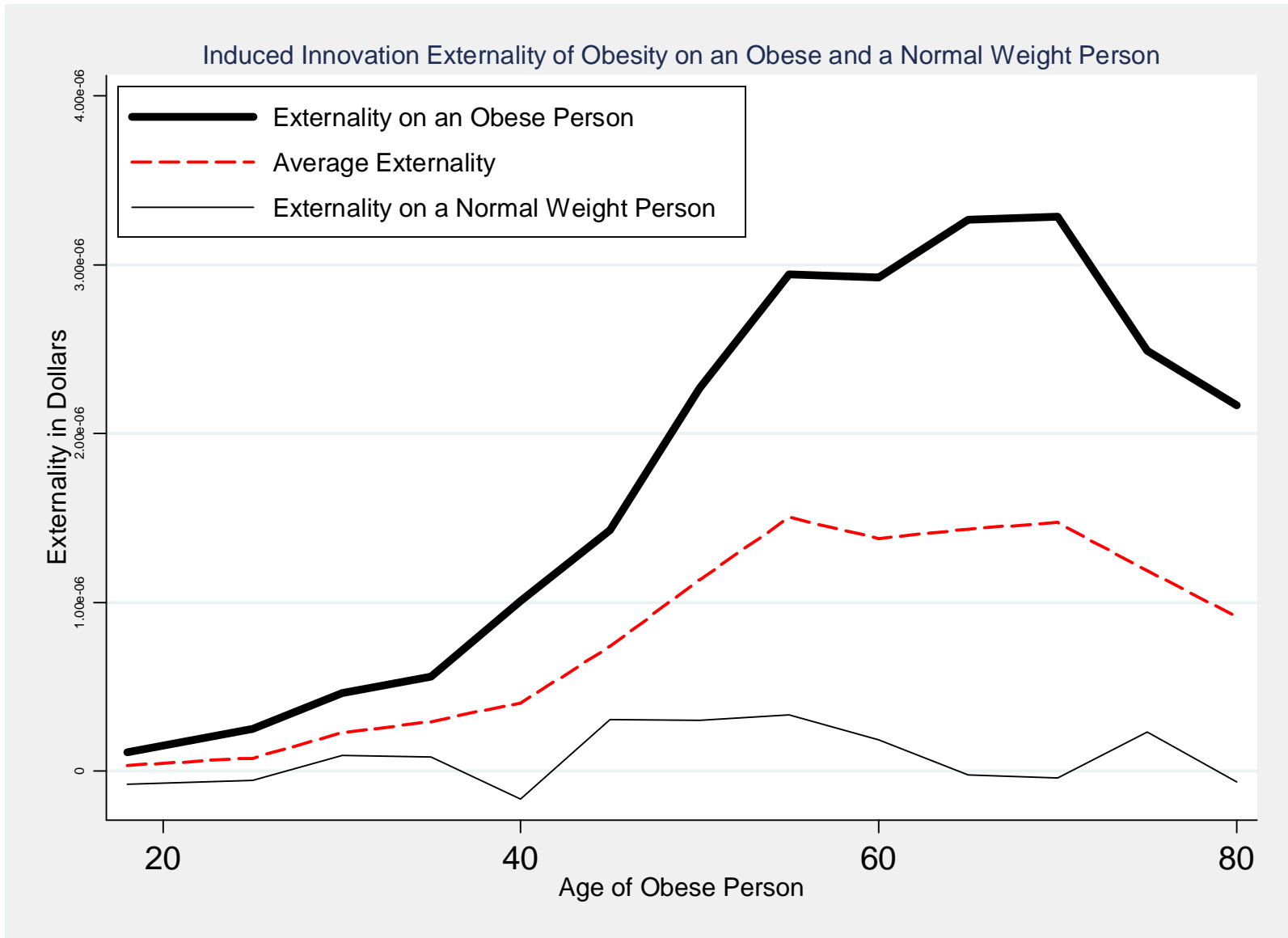


Figure 4.3: Induced Innovation Externalities when the Ratio of Innovation Elasticities is set at $\frac{\epsilon_c}{\epsilon} = 8$.

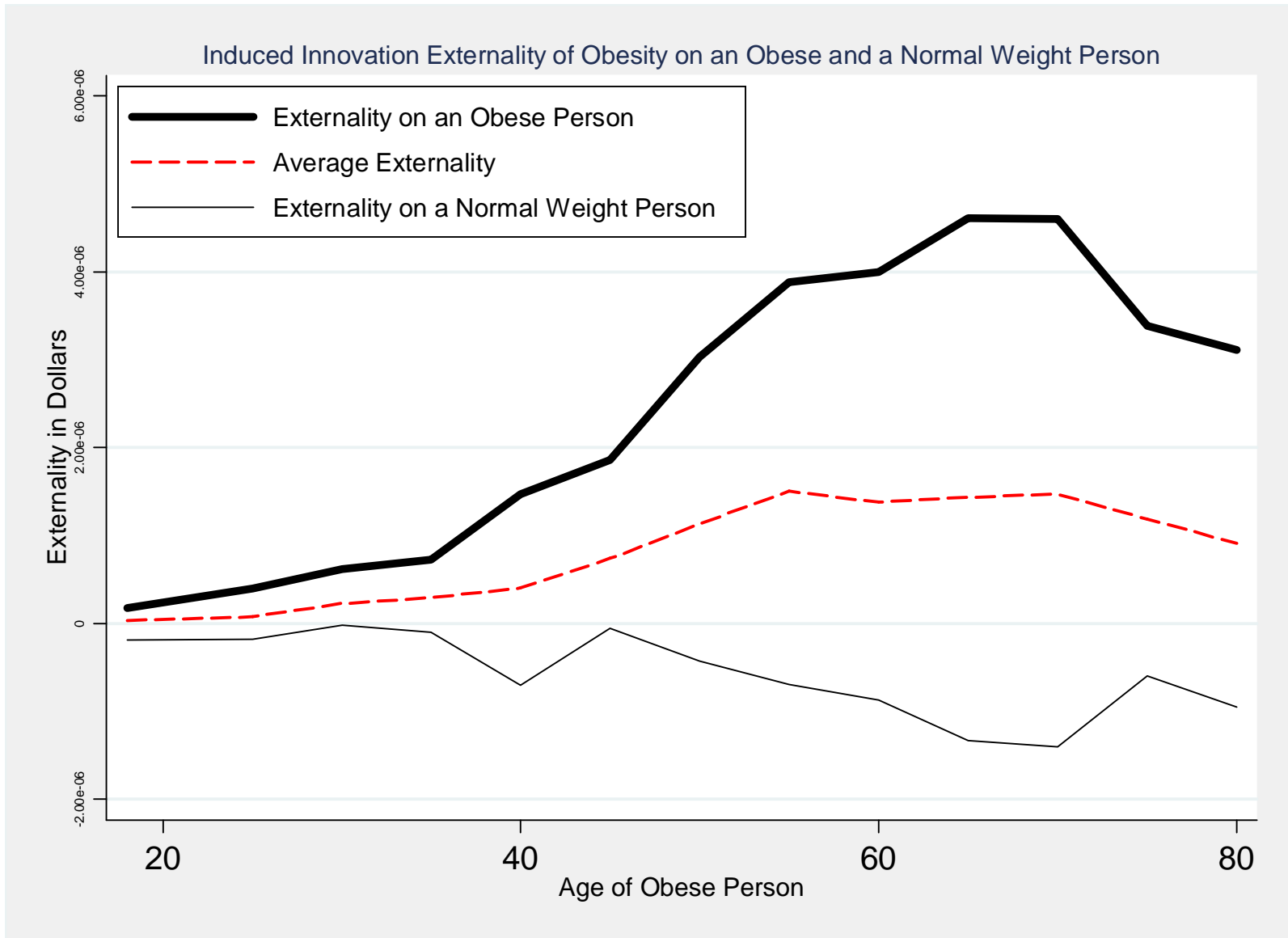


Figure 5: Comparison of the Total Induced Innovation Externality and the Medicare-Induced Health Insurance Externality.

