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Comparing Subjective and Objective Measures of Health: Evidence from Hypertension for the Income/Health Gradient

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Comparing Subjective and Objective Measures of Health: Evidence from Hypertension for the Income/Health Gradient

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Abstract

Economists rely heavily on self-reported measures of health status to examine the relationship between income and health. In this paper we directly compare survey responses to a self-reported measure of health that is commonly available in nationally-representative individual and household surveys, with objective measures of the same health condition. Our particular focus is on hypertension, which is the most prevalent health condition in Western countries. Using data from the Health Survey for England, we find that there is a substantial difference in the percentage of adult survey respondents reporting that they have hypertension as a chronic health condition compared to that from repeated measurements by a trained nurse. Around 85% of individuals measured as having hypertension do not report having it as a chronic illness. Importantly, we find no evidence of an income/health gradient using self-reported hypertension, but a large (about 14 times the size) gradient when using objectively measured hypertension. We also find that the probability of false negative reporting, that is an individual not reporting to have chronic hypertension when in fact they have it, is significantly higher for individuals living in low income households. Given the wide use of such self-reported chronic health conditions in applied research, and the asymptomatic nature of many major illnesses such as hypertension, diabetes, heart disease and cancer at moderate and sometimes very elevated levels, we show that using commonly available self-reported chronic health measures is likely to lead to an underestimate of true income-related inequalities in health. This has important implications for policy advice.

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1. Introduction

The relationship between income and health, and any underlying causal mechanisms, is a hotly debated topic (see, for example, Deaton and Paxson, 1998; Smith, 1999; Chase, 2002). In examining this topic, economists have relied heavily on self-reported measures of general health status and, to a lesser extent, self-reported chronic health conditions. One of the main factors used to justify the use of such measures is that self-reported health is a significant predictor of future functioning and mortality within countries (see, for example, Idler and Angel, 1990; Idler and Kasl, 1995; Idler and Benysmini, 1997; van Doorslaer and Gerdtham, 2003; Frijters et al., 2005b). Recent studies using self-reported measures of general health status and panel data have found only a weak role for increased income leading to improved health (see, for example, Adams et al., 2003; Meer et al., 2003; Contoyannis et al., 2004; Frijters et al., 2005a; Lindahl, 2005). However, if such self-reported measures suffer from some amount of reporting error, this has implications for the literature and consequently also policy aimed at ameliorating income inequalities.

The extent to which there can be reporting error in self-reported health is thus an important issue. Such error can occur for a number of reasons (see Murray and Chen, 1992). Survey respondents may report their health differently depending on their socially driven conceptions of what 'health' means, their expectations of their own health, their use of healthcare, and their comprehension of the actual survey questions asked (Bago d'Uva et al., 2006). These factors are problematic because they are likely to vary systematically with observed demographic and socio-economic characteristics such as education and income and it is these same characteristics that are most widely used to assess what the relationship between income and health is or whether inequalities in health exist (see, for example, van Doorslaer et al., 1997). It is also widely understood that individuals can (consciously) misreport their health given clear financial incentives to do so. For example, where receipt of welfare payments is conditional on health status, individuals have an incentive to report their health or extent of disability to be worse than it really is. This poses problems for empirical studies of the relationship between health status and labour market outcomes (see, for example, Stern, 1989; Bound, 1991; Currie and Madrian, 1999; Lindeboom et al., 2006; Kapteyn et al., 2006)[1].

There have been two main approaches used to tackle this potential measurement problem. One is to 'purge' self-reported general health measures of reporting error using other measures of health typically available in survey data that are still self-reported, but are seen to be more objective (Baker et al., 2004). Most commonly, these are self-reported chronic health measures. These studies then use the residual variation from a regression of self-reported general health on self-

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[1] For example, Kapteyn et al. (2006) found that much of the difference in self-reported work disability between the U.S. and the Netherlands is due to different reporting thresholds in the two countries.

reported chronic health conditions to examine the extent of any reporting heterogeneity. Lindeboom and van Doorslaer (2004) found some evidence of reporting bias by age and gender, but not income, using Canadian data and the constructed McMaster Health Utility Index as their more objective measure. Hagan et al. (2006) undertake a similar exercise focusing on the effect of self-reported health on mortality using British data.

It is not, however, clear that these more objective health measures are not also subject to reporting error. A recent paper by Baker et al. (2004) sheds some light on this issue by matching a wide range of self-reported chronic health conditions to records of public healthcare usage in Canada. They found clear evidence that such conditions are subject to a large amount of systematic reporting error, leading to large attenuation biases when used as explanatory variables. They also found that false negative reporting, where individuals had used medical services but not reported a matched health condition in the survey, were around 50% for most chronic conditions examined.[2]

A recent development has been to examine variation in the reporting of hypothetical health-related 'vignettes' by survey respondents. These are intended to represent fixed levels of latent health so that all variation can be attributed to reporting behaviour (Salomon et al., 2004). The assumption underlying this method is that individuals rate the hypothetical vignettes relating to someone else in exactly the same way as they would rate their own health. There is also the concern that the vignettes may not represent fixed levels of health. Using this approach Bago d'Uva et al. (2006) found evidence of reporting differences by income using data from China, India and Indonesia. In fact, the hypothesis of homogenous reporting across all socio-demographic characteristics was rejected for all countries and all health domains. This reporting error acted to reduce the estimated income/health gradient using self-reported general health as the outcome variable. One explanation proposed by the authors is that higher income groups may have higher expectations about their health and therefore report their health as lower than it would be if viewed by an individual with low income.

The extent and impact of reporting error, in particular with respect to the income/health gradient, therefore remains contentious. In this paper, we attempt to contribute to this literature by more directly investigating the differences between self-reported and actual health by matching self-reports of an important health condition, namely hypertension (or high blood pressure), to precise clinical measures of that same condition. We do this using detailed data drawn from the

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[2] Baker et al. (2006) match survey data for 1996/7 NPHS survey respondents living in Ontario to self-reported chronic illness diagnosed by a healthcare professional to public healthcare expenditure records recorded over the previous five years. Some 66% of survey respondents were able to be matched to the public healthcare records. Importantly, no matching to private healthcare was undertaken, and there exists a considerable possibility of mis-match due to the difficultly (discussed in their paper) in exactly matching a health condition to the actual health codes used by the public healthcare system in Ontario. Moreover, this form of matching is not able to shed any light on the issue of undiagnosed chronic health conditions, as individuals will not have sought medical advice if they had mild or no symptoms. This is particularly an issue for health conditions such as diabetes and hypertension.

Health Survey for England (HSE), which contains information from both survey respondents and an interview by a trained nurse. Unlike Baker et al. (2004) our data does not have the possibility of error arising from the need to match separately collected public healthcare records with survey data, as our clinical measures of the condition are taken from individuals at the same time (within 2 weeks) as they are asked questions about their health. The limitation of our study is that we are only able to focus on hypertension, as it is the only condition where we can exactly match self-reported with objective measures.[3] However, hypertension is the most prevalent chronic health condition in Western countries and is a major risk factor for cardiovascular disease. Moreover, hypertension is often called the 'Silent Killer', because it is typically asymptomatic at moderate and even highly evaluated levels of blood pressure. This makes the issue of undiagnosed hypertension a major public health concern. In addition, the asymptomatic nature of hypertension at moderate and sometimes advanced levels is shared by many of the most prevalent chronic health conditions including diabetes, cardiovascular disease and many types of cancer. This means that individuals are simply not aware that they have such a condition (often until it is too late) and so self-reported general health measures would not capture this aspect of poor health. However, the asymptomatic nature of hypertension also means that our study will obtain estimates of reporting error towards the upper-bound.

Using the matched information from individual questionnaires and nurse interviews, we investigate if there are differences in the estimated relationship between socioeconomic characteristics, with a particular focus on income, and the probability of having hypertension using self-reported compared to objective measures. We then examine whether there are systematic reporting differences by socio-economic characteristics, by estimating a model of false negative reporting. In addition to standard demographic controls, we are also able to control, given the broad topics covered by the HSE, for the use of hypertensive medication, the severity of the disease, individual lifestyle choices and the availability and use of healthcare.

2. Key facts about hypertension

Hypertension or elevated blood pressure is an extremely prevalent health condition, with the worldwide prevalence estimated to be as high as 1 billion individuals. In the US alone, it is

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[3] In principal we can also exactly match individuals self-reports of having diabetes as a chronic health condition with a clinical measure of diabetes (glucose) taken in the nurse interview. No other measures except hypertension and diabetes have a direct correspondence between what is asked in the individual questionnaire and what can be measured from the nurse interview (or later tests conducted on blood and saliva samples taken by the nurse). However, unlike blood pressure measurements that are simple to conduct, data on glucose is only collected from a small sub-sample of the HSE in only selected years. We do not use the diabetes information in this paper because of a major selection issue that results in a very low prevalence rate in the HSE. In particular, the problem is that individuals (in the selected sub-sample of the total sample) are required to fast for 24 hours before the nurse interview so that an accurate measure of insulin can be obtained. The problem is that individuals who already know that they have diabetes have no incentive to agree to the fast. Such a problem does not arise with measuring blood pressure.

estimated that some 50 million adults currently have high blood pressure (BP) that warrants some form of medical treatment (JNC7, 2004). While hypertension can occur in childhood and adolescence, the condition is mostly an adult concern, partly arising from the need for the heart to pump harder as the body ages.

A salient aspect of the condition for our analysis is that moderate, and even high levels of elevated BP, are typically asymptomatic. It is this aspect of the condition, as for mild diabetes or cardiovascular disease, which makes it particularly problematic if individuals are simply unaware that they have hypertension. Undiagnosed hypertension is therefore a major public health issue in Western countries. It is only at a severely elevated level of BP that an individual may experience some symptoms, which can include headaches, an increase in heart rate and a general feeling of ill health. Importantly, the relationship between BP and the risk of coronary vascular disease is continuous and independent of other risk factors. The higher the blood pressure, the higher the risk of a heart attack, heart failure, stroke, and kidney disease. It is estimated that approximately 7.1 million deaths per year in the US may be attributable to hypertension including death from heart disease, stroke, diabetes, chronic kidney disease and dementia (JNC7, 2004).

In addition to increasing with age, hypertension has a strong hereditary link (JNC7, 2004). Moreover, a number of other important causal factors for hypertension have been identified in the medical literature. These include excess body weight, excessive levels of dietary sodium intake, excessive alcohol consumption, smoking, reduced physical activity and inadequate intake of fruits and vegetables (JNC7, 2004). As we will see in our data, the prevalence of these lifestyle choices is high in the English population. In the US about 30% of adults are either overweight or obese and the figure for the UK is 25% (Flegal et al., 2002).

The positive aspect of hypertension is that it is treatable, and control of the condition is associated with favourable trends in the morbidity and mortality associated with the disease.[4] Primatesta and Poulter (2006) have estimated that at least 45,000 fatal and non-fatal cardiovascular episodes could be prevented each year by treating all uncontrolled hypertensive adults in England alone. Recommended treatments are drug therapy combined with lifestyle modification. Low levels of hypertension can be controlled with one drug; higher levels require two (or more) antihypertensive agents selected from different drug classes. Suggested lifestyle modifications include weight loss programmes and changes in diet to reduce sodium intake. Lifestyle modification has been estimated to provide substantial benefits. For example, weight loss of as little as 4.5kg reduces BP and/or prevents hypertension in a large proportion of overweight persons. Likewise, a low sodium eating plan has BP effects similar to a single drug therapy (JNC7 2004).

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[4] In the US, since 1972, age-adjusted death rates from stroke and coronary heart disease have declined by approximately 60 and 50 percent respectively and these benefits have occurred independent of gender, race or socio-economic status. JNC7 (2004) links these to higher treatment rates of BP.

Levels of hypertension are therefore related to age, hereditary predisposition, lifestyle choices and medical treatment. Poor control of BP has been argued to be related to both physician and patient attitudes. In the US, certain groups such as young men are particularly unlikely to adhere to treatment regimes, while women are more likely than men to know they have hypertension, to have it treated and to have it managed (Burt et al., 1995).

In clinical practice and hypertension research, blood pressure is typically calculated by measuring the pressure of an inflated cuff placed around the upper arm. This test provides two pieces of information: Systolic BP (SBP) measures blood pressure when the heart beats and Diastolic BP (DBP) measures blood pressure between beats. Both are measured in millimetre of mercury (mmHg). The combined use of these two measures is the most commonly used method to diagnose hypertension. The recent medical literature on hypertension provides the following cut-offs: 'Normal' BP is diagnosed when SBP is less than 120 and DBP is less than 80; 'Prehypertension' is having a SBP of 120-139 or a DBP of 80-89; 'Stage 1 Hypertension' is having a SBP of 140-159 or a DBP of 90-99; and 'Stage 2 Hypertension' is having a SBP greater or equal to 160 or a DBP greater or equal to 100 (JNC7, 2004).

3. Data, definitions, sample characteristics and simple bias calculations

3.1 The Health Survey for England

Our data source is the Health Survey for England (HSE), which was commissioned by the Department of Health, and carried out by the Joint Health Surveys Unit of Social and Community Planning Research, and the Department of Epidemiology and Public Health at University College London. Beginning in 1992, the HSE is an annual survey and is designed to monitor trends in the nation's health. The unit of survey in the HSE is the household, and information is collected from both adults and children living in England (children aged 12-15 complete a questionnaire, while a parent provides information about younger children). Importantly, information is collected through a combination of a face-to-face interview, a self-completion questionnaire and a medical examination (including various measurements such as height and weight, and the taking of a blood and saliva sample for clinical tests) conducted by a trained nurse. Using the Postcode Address File as a sampling frame, the HSE is considered to be representative of England: additional details of the sampling procedure can be found in Prescott-Clark and Primatesta (1998).

In this paper, we pool data from the 1998 and 2003 HSE's. In both of these years, additional information was collected from respondents relating to the risk factors for Cardiovascular Disease (CVD). This provides us with additional information relating to hypertension that we utilise in our empirical models. We focus on adults aged 25+ at the time of interview, which provides a total sample of 27,000 adults. We exclude adults aged less than 25 because the incidence of

hypertension for this group is extremely low. When we focus on respondents for whom we have observed valid blood pressure measurements, this gives a working sample of just over 18,600 adults (more details provided below). The size of the sample was larger in the 1998 than 2003 HSE, so 55.9% of our working sample comes from 1998. The average age is 51.8 years, 44.7% are male, 65.2% are married or co-habiting, 14.6% hold a degree or equivalent level qualification, 58.5% are employed either full or part-time, and 27% are retired. The average pre-tax household income is £27,007[5] and the sample is fairly evenly distributed across the English regions. In terms of health-related characteristics, 23.1% are clinically obese as measured by the nurse (i.e. their BMI≥30), 22.1% are smokers, 16.3% report to drink alcohol on a daily basis, 22.3% report that they regularly participate in vigorous exercise or sports, and 12.6% report eating fried food at least 3 times each week.

3.2 Self-reported and objective measures of hypertension

The HSE provides contemporaneous and directly comparable, self-reported and objective measures of the same health condition, namely hypertension. At the start of the HSE individual questionnaire, respondents are asked:

"Do you have any long-standing illness, disability or infirmity? By long-standing I mean anything that has troubled you over a period of time?"

Each respondent can report up to six such conditions, and these are grouped together by the data organisers into 42 categories. Category number 17 is hypertension or high blood pressure, which we use to create a binary self-reported measure of hypertension (SR1). We select this measure because this type of question, asking respondents about their chronic health conditions, is common in household surveys and it is widely used by researchers as a measure of health status.[6] Further, we want to compare a commonly available measure of health with a clinical measure of the same condition to assess the consequences of having to rely on such subjective health

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[5] The main measure of income that we use is current total pre-tax annual household income, which is provided in 31 bands in the HSE data, ranging from less than £520 to more than £150,000. To get a continuous measure of household income we took midpoints of these bands and deflated them (to 2000 prices) using the UK average earnings index according to the month in which the interview was conducted. Hence, we have a pseudo-continuous measure with over 700 potential values (31 bands * 12 months * 2 years) for total household income, which we then convert into natural logarithms for use in the statistical analyses. We also conduct some robustness tests later in the paper using alternative functional forms for household income.

[6] Note that if there are individuals who are aware that they have hypertension but do not consider it a chronic illness, our measure will underestimate individual's knowledge of their hypertensive status. However, the aim of this paper is to evaluate the reporting error that exists using a commonly available measure of health rather than establishing hypertension prevalence rates.

information to estimate the income/health gradient or to help 'purge' self-reported general health status from reporting error (see, for example, Case et al., 2002).

The HSE also contains another self-reported hypertension measure, where the conditions of 'long-standing disability or infirmity' are not posed in the question. Respondents are asked "Have you ever had your blood pressure measured by a doctor or nurse?" If the answer was "Yes", they were then asked, "Thinking about the last time your blood pressure was measured, were you told it was.., (1) Normal, (2) higher than normal, (3) lower than normal, or (4) were you not told anything?" While we provide some statistics for this alternative self-reported measure we do not use it in our empirical models of the income/health gradient or false negative reporting because it is not available in most surveys and so is not generally used in the literature on purging measures of self-reported health or income-health gradients. In addition, there is also a clear timing issue. Only 64% of the sample reported having their BP tested sometime in the last 12 months, just below 10% reported that it is longer then five years ago that they were last tested and 3.3% reported never to have had their BP tested. Moreover, we want to compare having currently measured hypertension by a nurse with contemporaneous self-reported hypertension (and contemporaneously measured socioeconomic characteristics).[7]

At the end of the individual interview (e.g. on page 63 of the 2003 questionnaire), respondents were asked if they agreed to a visit with a qualified nurse in order to "collect more medical information and carry out some measurements". Some 90.9% agreed to this visit. Of those who agreed, 90.3% actually had the nurse interview (or 82.1% of total sample). Virtually all nurse interviews were conducted within two weeks of the initial face-to-face interview.

A key component of the nurse interview was the taking of repeated blood pressure (BP) measurements. A BP reading was taken three times in the interview, and of those who had the nurse interview, valid BP measurements were collected from 84.9% of respondents (or 69.7% of total sample). This gives us our working sample of 18,600, for whom we observe both self-reported and nurse measured hypertension.[8] Note that an 'invalid' BP measurement occurred if a respondent

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[7] Another question was used by Banks et al. (2006) as a measure of 'lifetime' hypertension prevalence in the 2003 HSE. Respondents are asked, "Do you now have, or have ever had, high blood pressure". If the answer was "Yes", respondents were then asked, 'Were you told by a doctor or nurse that you had high blood pressure?" Just over 25% (25.8%) of our sample report a positive reply to this question, which corresponds to the 32% reported by Banks et al. (2006) for their sample of 40-70 year olds in the 2003 HSE. As with the SR2 measure, we do not use this lifetime prevalence measure in our empirical models because we are looking at the relationship between self-reported beliefs of currently having hypertension with currently measured hypertension by a nurse. For example, only 59% of individuals reporting positively to the above question were measured by the nurse to currently have 140/90 hypertension in our sample. Similarly, 26% of respondents reporting never to have been told by a doctor or nurse that they had high blood pressure are measured by the nurse to be hypertensive. Also, like SR2 this lifetime prevalence measure is not commonly available in individual or household surveys. For example, in the UK context, while self-reported chronic health conditions are reported in the British Household Panel Study, the UK's Quarterly Labour Force Survey and the UK's General Household Survey, no other measure of self-reported (not objectively measured) conditions is available.
[8] There does not appear to be any selection on the main observable characteristics. For example, 44.7% of the total sample are male compared to 44.3% of the working sample; the average age of the total sample is 51.1 compared to

had eaten, smoked, drunk alcohol or undertaken vigorous exercise in the last 30 minutes, and that the majority of the invalid cases arise arose because a respondent had recently eaten. Blood pressure measurements were not taken from pregnant women. As is standard in the medical literature, we use the average of the 2nd and 3rd blood pressure readings, which allows for the possibility that the first measurement might be higher than usual (e.g. because of initial interview nerves, or because of the initial physical exertion before the interview begins). It is likely that this average BP reading will still contain some measurement error. For example, measurement error can arise from inaccurate equipment, incorrect testing procedures, or the use of a wrongly sized cuff.[9] There is no reason to think, however, that any error will be correlated with socio-demographic characteristics, and so it will not invalidate any of our main conclusions.

Following standard medical practice (see Section 2), we define a survey respondent in this paper as having at least Stage 1 hypertension if their SBP is greater than or equal to 140 or their DBP is greater than or equal to 90 ($\geq 140/90$). However, we also estimate models where we use the continuous SBP measure as our dependent variable. We also conduct a number of tests which show that our main results, with respect to socio-economic differentials in hypertension, remain robust to the exact measures used. In addition, in both the 1998 and 2003 HSE, respondents were also asked in the individual questionnaire, before the nurse survey was conducted, whether they have ever had their BP tested, and if so, how long ago. Only 3% reported that they had never had their BP tested. Information was also collected on whether individuals reported currently taking BP medication. We use this additional information as control variables in our empirical models.

3.3 The extent of hypertension and false reporting

Table 1 provides some descriptive statistics for hypertension in England from the HSE. The mean level of SBP in the sample is 134.9 mmHg and the mean level of DBP is 74.6 mmHg. Most importantly, only 7.1% of the sample reported that they currently had hypertension as a chronic illness, while 34.7% had clinical hypertension ($\geq 140/90$) as measured by the nurse. The raw correlation between our two measures is only 0.17. The level of false negatives in this context, which is the percentage of individuals who have measured hypertension but do not report currently having hypertension as a chronic condition, is extremely high at nearly 87%.

Alternatively using SR2, we see just over 11% of respondents reported that they were told by a doctor or nurse that they had higher than normal BP when last tested. The raw correlation between

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51.8 for the working sample; and the average annual pre-tax household income for the total sample is £27,128 compared to £27,007 for the working sample.
[9] There were, however, three different size cuffs available for the nurse to use: small adult cuff (17-25cm), standard adult cuff (23-33cm) and large adult cuff (31-40cm).

SR2 and clinical hypertension ($\geq 140/90$) is only a little higher at 0.22, and the false negative rate remains very high at 77%.[10]

Taken together, these results are suggestive of a substantial public health problem of undiagnosed hypertension in England since there are well-established long-term health consequences of hypertension and BP medication is very inexpensive and effective at reducing BP. Note that our use of self-reported chronic hypertension will overstate the extent of underdiagnosis.[11]

In contrast, the level of false positives (individuals who stated they had hypertension when in fact their blood pressure was lower than 140/90) was only 4% (or 6% using SR2). Baker et al. (2004) found similar low levels of false positives for hypertension using Canadian data, but lower levels of false negatives. The level of false negatives in Baker et al. (2004) varies considerably depending on the assumptions they make about the relevant time-period when matching data from self-reports to public healthcare records. The HSE data requires no matching and so cannot suffer from matching issues.

An alternative definition of hypertension sometimes used in the medical literature (see, for example, Primatesta and Poulter, 2006) is when an individual has measured BP $\geq 140/90$ and/or they are currently taking some form of BP medication. Some 13% of respondents in our sample reported that they were taking BP medication at the time of the individual interview. Given that only 7% report having hypertension, this suggests that many individuals who are taking BP medication incorrectly believe that their BP is at normal levels. If we use this alternative definition, the percentage with hypertension increases to 39.1% (from 34.7%) and the level of false negatives falls by about 3% (83.7% from 86.9%). The level of false positives also falls from 4% to 1%. The use of either of these two alternative measures of clinical hypertension does not, however, make any difference to the substantive results that we present.

The next three figures show descriptive statistics with respect to age, household income and region of residence, and the prevalence of hypertension in England. Figure 1 plots both self-reported and objective hypertension by age. As expected, both increase, but measured hypertension rises considerably faster with age than self-reported chronic hypertension. This is suggestive of undiagnosed hypertension becoming more of a problem as individuals' age. Importantly, the data also clearly reveal (Figure 2) a very large hypertension differential by household income, with

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[10] If we restrict our attention to those reporting that they have had their BP tested within the last years, 14.5% of the sample report being told that they have higher than normal BP by a doctor or nurse. Even with this restriction, we still get a false negative rate of 75%.

[11] Primatesta and Poulter (2006) report that about 62% of individuals who have measured hypertension are aware of the condition, using an awareness measure based on HSE respondents reporting that they have been told by a doctor or nurse at *some point* in their life that they had high blood pressure. However, it is not clear how this 'lifetime' measure relates to an individual's current awareness of having hypertension. Also, this is the same measure that Banks et al. (2006) use as their lifetime hypertension prevalence measure.

individuals living in households in the lowest quartile of income having roughly double the probability of being measured by the nurse as hypertensive. A much smaller differential is also evident for self-reported chronic hypertension, and taken together with the objective measure, suggests that undiagnosed hypertension might be more prevalent in poorer English households. Finally, Figure 3 presents the percentage of individuals with self-reported and objective hypertension by broad English region. There is some evidence of a general North-South divide with the highest prevalence of objectively measured hypertension being in the North East (42.2%) and Yorkshire (37.6%), and the lowest in London (28.5%). These are very large differences, especially if thought of in terms of actual population numbers: the North East would have around 300,000 less adults with hypertension if its prevalence was at the London level. No such regional differential, however, is observed for self-reported chronic hypertension. Most importantly, it is also clear from these figures that policy-makers could be easily mislead about inequalities in hypertension at the population level if they were to rely solely on the results of studies that used only a self-reported measure of chronic hypertension.

Amongst other hypotheses that we explore in our empirical models is whether or not these raw income and regional differences still remain after we have controlled for a large set of factors which could be driving this correlation including lifestyle choices, smoking, drinking, obesity; access and choices regarding healthcare, including time since having a BP test, whether currently on BP medication and the number of GPs per capita in the local area.

Finally, there is some positive news gained from looking at differences in self-reported and objective hypertension between 1998 and 2003.[12] If we looked at only self-reported hypertension the picture would seem negative: in 1998 only 5.5% of respondents reported having hypertension compared to 8.5% in 2003. If this was the only information we had available we might wrongly conclude that the prevalence of hypertension had increased over this 5-year period. However, over the same period objective hypertension fell from 37.1% to 31.1%, and the average measured systolic BP fell from 135.9 to 133.5 (75.5 to 73.3 for diastolic BP). Combining both these sources of information gives a more positive picture: awareness of hypertension has increased and the management of hypertension also improved over this period (also see Primatesta and Poulter, 2006).

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[12] Note that in the 2003 HSE, the blood pressure equipment was changed from Dinamap to Omron. However, for consistency purposes, the 2003 HSE reports Dinamap equivalent measurements that are calculated using a well established calibration factor (see Primatesta and Poulter, 2006). In this paper, we use Dinamap measurements from 1998 and Dinamap equivalent measurements from 2003.

3.4 Simple bias calculations

Error in self-reported health measures will lead to biased coefficient estimates when the self-reported measure is used either as an explanatory or dependent variable. While the primary focus of this paper is the differential in the estimated income/health gradient when subjective compared to objective hypertension measures are used, here we present some simple bias calculations when self-reported hypertension is used as an explanatory and dependent variable. To do this, we use the framework of Bound et al. (2001), which allows for a direct comparison with the results from previous validation studies.

In the case where self-reported hypertension is used as the sole explanatory variable in a regression model, the proportional bias (minus the ratio of the bias to the true coefficient value) is equal to the coefficient from a regression of the error on self-reported health (denote this value as *?*).[13] If self-reported hypertension is used as a dependent variable (for example, in a probit model) and it is assumed that any measurement error is uncorrelated with the explanatory variables in the model, then the proportional bias in the marginal effects equal the sum of the false negative and false positive rates (denote this value as *d*).

Our estimate of *?* is 0.68. In other words, if self-reported hypertension is used as an explanatory variable instead of objective hypertension, the estimated coefficient will be 68% smaller than the true value. This estimate is much larger than the figure reported in Baker et al. (2004), who calculated that the proportional bias due to self-reported hypertension is 0.36 using Canadian data. Our estimate of *d* is 0.91. Again, this is substantially larger than Baker et al.'s estimate, which equals 0.46.[14] The difference between our proportional bias estimates and those reported in Baker et al. is a result of the much higher rate of false-negative reporting that we observe. One possible reason for this difference is the reliance by Baker et al. (2004) on matching subjective survey responses to past medical records and therefore a doctor's particular diagnosis. Our proportional bias estimates are also large compared with validation studies of other variables. For example, Card et al. (2004) investigated the accuracy of reported Medicaid coverage in the Survey of Income and Program Participation and found values of *?* and *d* equal to 0.20 and 0.18, respectively.

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[13] We follow other validation studies and limit our analysis to the scenario where self-reported hypertension is the only regressor. When this is not the case, the proportional bias becomes the coefficient from a regression of the measurement error on all the explanatory variables.

[14] Baker et al. (2004) do not provide an estimate of the bias when self-reported health is used as a dependent variable. However, the sum of the false negative and false positive rates given in their Table 1, under the column 'Narrow Mapping', equal 0.46.

4. Empirical results

4.1 The estimated health-income gradient

In this section we start by examining whether the lack of income gradient in self-reported chronic hypertension and the large gradient in measured hypertension, as well as the clear regional differentials, seen in the raw data are robust to controls for demographics, education, genetic predisposition, measures of location, employment, health and lifestyle. We begin by estimating simple probit and regression models that control for basic demographic characteristics and year of survey. We then extend the models to control for education, location and genetic predisposition. Finally, we add in employment status, obesity and measures of lifestyle. The estimates are presented in Tables 2 and 3. The Pseudo R^2 measure indicates a reasonable goodness-of-fit for each model, in the range of 0.25 to 0.31.

This large set of controls allows us to examine the impact of income after allowing for observables which are likely to be correlated with income and region. In addition, differences in awareness and incidence of hypertension across different social groups are of interest in their own right. For example, conditioning on employment status allows us to examine whether the 'justification' hypothesis, i.e. that reporting health problems is both a socially acceptable rationalisation of lack of labour market participation and one which allow individuals to access higher welfare payments (e.g. Kapteyn et al., 2006), may affect hypertension reporting. Conditioning on obesity, genetics and lifestyle allows us to examine whether individuals who are at greater risk are aware of their greater risk.

Table 2 presents the marginal effects of the estimated relationship between the self-reported and two objective measures of hypertension and income, controlling for only basic demographic variables. The two objective measures are the standard definition of hypertension and the level of systolic blood pressure as a measure of severity. The Table shows no income gradient for self-reported chronic hypertension but a clear negative gradient in both objective measures: individuals living in low income households are significantly more likely to have hypertension and also to have more severe hypertension. Its is important to note that the calculated marginal effect of a one-log point increase in household income is around 14 times larger (-0.002 compared to -0.028) when using objectively measured rather than self-reported hypertension. If we take the six log-point variation in household income observed in the data, this would mean a 16.8 percentage point difference in the probability of having recorded hypertension between the poorest and richest individuals.[15] If we estimate this model using SR2 as the binary dependant variable, that is the individual reporting to have been told that they had higher than normal BP when last tested, the

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[15] We have also run the models using diastolic BP as our objective measure. In this case, the coefficient on log household income is again negative and statistically significant (i.e. -0.242, t-stat=-2.02).

coefficient on log household income is -0.017 (*t*-stat=-4.88).[16] Therefore if we take SR2 to be to some extent *more* objective than SR1, as expected the coefficient estimate on income gets closer to that found using the clinical measure.

Note that we are treating income as exogenous in these models. We believe that this is a valid assumption because hypertension has a unique set of properties: it is typically asymptomatic except at extremely elevated levels, it is often undiagnosed and it can be treated very inexpensively. Given these characteristics, hypertension is unlikely to affect labour market behaviour and as a result is unlikely to affect an individual's income.

Table 2 also shows demographic differences in the self-reported and objective measures. Men do not report chronic hypertension, yet are considerably more likely to actually have measured hypertension than women. In contrast, individuals from ethnic minorities are more likely to report that they have hypertension, when in reality they have very similar actual rates to the rest of the population. The reporting behaviour of the married and non-married is not significantly different, although individuals who are married are less likely to have hypertension than those that are not married. The final set of coefficients in this table shows the change between the two survey years. As suggested by the raw data in Section 3, the prevalence of objective hypertension has fallen: for example, systolic blood pressure has fallen by just over 3 points. However, reported hypertension has actually risen.

Table 3 extends the set of controls. Extended Model 1 adds controls for education and genetic predisposition to hypertension as captured by parental deaths from cardiovascular disease. Importantly, the lack of income gradient in the self-reported measure and the gradient in objective measures remain, although the magnitude of the coefficient on household income for the objective measures is roughly halved. Conditional on income, education has no impact on self-reported hypertension but is negatively associated with objective measures. As expected given the medical literature, individuals with a family history of cardiovascular disease recognise their greater risk, but the impact of parental history on reporting is less than on the risk of actually having hypertension. The second three columns add controls for location, work status, obesity and life style. The first row shows that the income gradient changes very little allowing for these additional controls. Importantly, in terms of health inequalities in England, the coefficients on the controls indicate that the differences in self-reported and objective health by region seen in the raw data remain. While there are no significant differences in either self-reported or objective hypertension by rural or urban residence, there are significant and large differences between regions. Individuals outside the South East are less likely to report hypertension as a chronic illness, while in fact they have significantly higher objective levels.

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[16] These additional results are available on request from the authors.

The work status estimates give limited support to the idea that individuals may report this condition to justify non-participation in the labour market. Both non-participants and the disabled report higher rates of hypertension, while neither actually have higher rates. Being obese is associated with both reporting and actually having hypertension, but the estimated marginal effect of obesity on the chance of self-reporting is considerably lower than the effect on the probability of actually having the condition. Those who take vigorous exercise/sports and do not smoke are less likely to report that they have hypertension, while those who drink alcohol daily are not. In fact, alcohol consumption is positively associated with actual hypertension while the other behaviours are not.

In summary, while controlling for education, work, lifestyle, area of residence and genetics, approximately halves the estimated size of the association between income and hypertension, these controls do not change the basic picture that self-reports, as commonly used by researchers, are not income graded despite the fact that there is a strong negative relationship between income and objective levels of hypertension. The findings of significant regional differences in hypertension also remain after controlling for the extensive list of socio-economic variables.

4.2 Investigating false negatives reporting

The previous sections showed the difference in the prevalence of self-reported chronic hypertension versus objectively measured hypertension. Individuals may misreport for a variety of reasons including:

a. They had no symptoms and so have not sought medical advice;

b. They had symptoms and sought medical advice, but either the medical practitioner found no evidence of hypertension or did not tell them they had hypertension;

c. They were tested and told that they had high blood pressure, but did not report it as a chronic illness when asked in the individual questionnaire;

d. They were tested and prescribed BP medication, and so believe that they are no longer hypertensive when in fact they still are.

The importance of each reason will depend on individual attitudes and knowledge about health, the severity of hypertension, lifestyle and attempts to control hypertension, and the availability and response of medical care. In this section, we attempt to better understand the extent and reasons for reporting errors in self-reported chronic illnesses by explicitly modelling the role of observable characteristics on the propensity for an individual to misreport. Here we define a misreport to have taken place if SR = 0, but measured BP=140/90 i.e. a false negative report. In using this definition,

we do not focus on the individuals who incorrectly reported hypertension (the false positives). However, as Table 1 shows only 3.8 percent of individuals committed such an error.

The difficulty in modelling this reporting error is that false negative reporting can only occur for individuals who have measured hypertension BP=140/90. We do not observe whether a non-hypertensive individual would misreport if they were hypertensive. To estimate the impact of observables on an individual's potential to misreport, we use the Censored Bivariate Probit model introduced in Van de Ven and Van Praag (1981). This model consists of two latent equations, one describing the propensity to misreport (y_1^*) and the other describing the propensity for an individual to be measured as hypertensive (y_2^*):

$$y_{ji}^* = x_{ji}' \boldsymbol{b}_j + \boldsymbol{e}_{ji}, \ j = 1, 2$$

where the realisation of the latent variable y_1^* is denoted by y_1 and equals 1 if $y_1^* > 0$ and $y_2^* > 0$, and zero otherwise; x_{ji} are vectors of socio-demographic characteristics; and e_{1i}, e_{2i} are distributed bivariate normal with variance equal to one and covariance equal to $?$. The model is estimated by Maximum Likelihood. The non-zero covariance accounts for unobservable characteristics that affect both the propensity to misreport and the propensity to be measured as hypertensive. For example, this may arise if individuals with high discount rates are more likely to be hypertensive and to misreport, and individuals' discount rates are not directly observed.

For the model to be well identified, four dummy variables indicating whether the individual's mother and father died of cardiovascular disease before or after the age of 60 are excluded from the misreport equation. These variables are valid exclusions if they influence the probability of having hypertension but do not directly affect the probability of misreporting. Therefore we are using the fact that there is a strong hereditary component in hypertension for identification purposes. Statistical tests indicate that these instruments are highly significant in the hypertension equation and so the first assumption is satisfied (see Chi-squared statistics in Table 4). The second assumption cannot be directly tested; however, it may be violated if having a parent die of cardiovascular disease alters an individual's health-related behaviour (e.g. more frequent doctor visits) or the treatment received by a doctor (e.g. higher propensity to receive medication). The advantage given by the richness of the HSE data is that we are able to explicitly control for these possibilities by including in the misreport equation variables that represent time since last blood pressure test, whether the individual has been prescribed blood pressure medication and the severity of hypertension (as measured by systolic and diastolic values).

The marginal effects from the bivariate censored probit models and the associated z-statistics are presented in Table 4. Overall, the models appear to be well identified, the instruments included in the hypertension equation are statistically significant and the estimated correlation between the error terms of the two equations is positive and significant. The first column of the table examines the association with household income, allowing for basic demographics and change over time. The second allows for a more in-depth analysis of misreporting by adding controls for education, work status, region of residence, lifestyle, measures of the availability of medical services, measures of the use of medical services for hypertension, and the actual level of systolic blood pressure. Use of this wide ranging set of controls allows us to test whether any income gradient in misreporting is robust to behaviours of individuals or medical providers that are associated with income.

The first column of the Table 4 shows that the negative association between income and the propensity to misreport is robust to basic demographic controls. The differences between men and women seen in the previous section remains: in common with other studies we find men are significantly less likely to recognise they have the disease than women. Perhaps more surprisingly, those from ethnic minorities are less likely to report a false negative (though this is not robust to the large set of controls in the second column of estimates). The results also show a clear fall in misreporting over time. The time effect is robust to medical intervention. So it is not simply the result of an increase in the testing of blood pressure or the prescription of BP medication by GPs. The greater stress on primary care by the Labour administration post 1997, alongside general attempts to increase public awareness of health (for example, the '5 a day campaign' which seeks to increase fruit and vegetable consumption), may account for the rise in awareness, and the fall in actual prevalence, of hypertension[17].

The next set of results allows for the other controls. For this condition, there is only weak evidence of differences in false reporting by education (conditioning on income). Nor does the justification hypothesis appear to have an effect on reporting behaviour. Both these results are rather different from those found looking at the differences in reporting behaviour relative to broader medical conditions (for example, the vignette analysis of Bago D'Uva et al. (2006) or the literature on employment and reported health status). The lack of impact of education may be because the HSE has better measures of income than other surveys and so the education parameter does not pick up some of the income effect, or it may be that there are smaller differences across education when we examine awareness of a specific condition rather than general health. The nature of hypertension probably accounts for the lack of importance of work status. If moderate hypertension is asymptomatic then it cannot limit ability to work, so will not be used to justify

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[17] In addition, in 2004, the UK government adopted a new performance framework for GPs intended to increase the extent of preventative care by linking payments to meeting targeting for preventative care. This post-dates the data used here.

being out of work. The final row of the first column shows the clear change in reporting behaviour between the surveys. The marginal effect is large – of the same order as the well known difference between males and females.

The results also show strong regional differences in awareness of hypertension that do not appear to be explained by either the observed characteristics of the individuals who live in those regions, their level of health, their lifestyles or the medical care they have received for hypertension. Individuals in all regions outside Greater London are more likely to report false negatives. Most of the regional differences are statistically significant and the effects not trivial. Individuals in the South East region, which is contiguous with London, are around 6 percentage points more likely to report a false negative, whilst those in the North East are 12 percentage points more likely than those who live in London.

Individuals who are at risk of higher hypertension because of their obesity are nearly 10 percentage points less likely to recognise that they have hypertension, controlling for diet, lifestyle and exercise (which themselves have no statistical impact on false reports). The general availability of medical care does not appear to affect misreporting, but specific medical intervention for hypertension does affect the propensity to misreport. The more recently an individual was tested for hypertension the less likely they are to report a false negative. The effects of recent testing are large: individuals who were last tested five years or more prior to the survey are nearly 20 percentage points more likely to false report compared to those tested in the last year. Those who are taking blood pressure medication are also less likely to report a false negative. Finally, those who have higher blood pressure are more likely to correctly report that they have hypertension.

In summary, our results show systematic differences across individuals in their awareness of having hypertension. In particular, those with low income, males, the aged, those living outside London (especially in the North East and Yorkshire), and individuals who are obese are less likely to recognise that they have the condition. Medical intervention directed at the detection or treatment of hypertension appears to significantly lower the risk of false reporting as does a rise in the awareness of hypertension.

4.3 Robustness tests

We have conducted a number of robustness tests by including additional control variables in the false negative selection model. Firstly, we have relaxed the functional form of household income by using both decile and quartile dummies instead of log household income, as well as including the actual income bands (grouped) as reported in the survey. Each of these more flexible forms suggests that log household income provides a good approximation. If we use simply income quartiles, for example, relative to being in the bwest quartile the estimated marginal reduction in

the probability of false negative reporting of being in income quartile 2 is -0.043 (t-stat=2.23), quartile 3 is -0.0584 (t-stat=2.41) and quartile 4 is -0.068 (t-stat=2.56).

We have also investigated whether controlling for stress, anxiety, depression and sleeplessness can explain away the income and region findings. It might be that low income is associated with high levels of stress that then leads to hypertension, and that living in some areas of England is more stressful than others. Including dummy variables for feeling unhappy, feeling under strain and suffering from sleeplessness (using information collected as part of the General Heath Questionnaire, GHQ12) in both the hypertension and false negative equations does not change at all our income or regional results, which remain statistically significant and large in magnitude.

In terms of capturing area differences in healthcare supply (i.e. the availability of medical personnel to measure blood pressure) we control in the model of false reporting for the number of GPs per capita at the (100) District Health Authority. We also tried a number of hospital supply measures including information on waiting times for elective surgery. As with GP per capita, we found that the estimated role of hospital supply measures is never statistically significant.

We have also tested the robustness of our false negative results to two alternative definitions of objective hypertension. If we follow Primatests and Poulter (2006) and define having hypertension as having measured BP at 140/90 or/and reporting currently taking BP medication, then the marginal effect for a one-log point change in household income (using Extended Model 3 controls) is -0.022 (t-stat=-2.12), and the marginal effects for living in the North East is 0.113 (t-stat=3.49) and Yorkshire is 0.070 (t-stat=2.51). Moreover, if we increase the required levels of measured BP necessary to be diagnosed with hypertension to having $SBP \geq 150$ (instead of ≥ 140) or $DBP \geq 95$ (instead of ≥ 90), then the equivalent marginal effects are -0.018 (t-stat=1.85), 0.091 (t-stat=2.44) and 0.074 (t-stat=2.19), respectively. Therefore, our main findings are robust to the exact definition of objective hypertension used to define false negative reporting.

There is some discussion in the medical literature that males over 50 years of age should have a higher cut-off of SBP and DBP to be considered hypertensive. Consequently, we have re-estimated the selection model both dropping males in this age group from the sample and also introducing a new cut-off of $SBP \geq 160$ and/or $DBP \geq 95$ for them. Again these different cut-offs make no substantive difference to our results. For example, when we drop males aged over 50 from the sample, the marginal effect on log household income increases to -0.029 (t-stat=2.33).

Finally, we have controlled for the possibility that hypertension might be correlated with a higher probability of having other health conditions. For example, it might be the case that individuals with a serious health condition report that condition but do not report a lesser condition. If this condition is hypertension this would lead to false negative levels that are too high. To test for this we have re-estimated the selection model (Extended Model 3 specification) with controls for

all the other chronic health conditions that are recorded in the HSE. Interestingly, we find that only those reporting having arthritis, respiratory problems and diabetes are significant less likely to false negatively report. However, our estimates on all the main socio-economic variables of interest remain virtually unchanged (e.g. the marginal effect on log household income is -0.028 (t-stat=2.39) rather than -0024 (t-stat=2.31).[18]

4.4 The relationship between self - reported health, general health and false reporting

The results above show that the asymptomatic nature of the condition leads to a strong income gradient in the reporting of false negatives. Here we investigate whether false negative reporting is also associated with the reporting of general health, using the measure commonly used in studies of income and health. We regress the self-reported general health measure collected in the HSE (which takes values from 1 to 5, where 5 is poorest health) against income, demographic measures and systolic blood pressure, plus two variables measuring awareness (or lack thereof) of hypertension. The first is coded 1 if the individual reports a false negative for hypertension, the second is coded 1 if the individual correctly reports they have hypertension. The omitted group is those individuals who do not have hypertension. Under the assumption that the general health measure will not reflect conditions that the individual is unaware of, the coefficient on the first variable should be zero. The coefficient on the second should be positive; those who are aware they have hypertension should, other things equal, rate their health as poorer. The results, shown in Table 5, support this hypothesis. Those who are unaware that they have hypertension rate their health no differently from those who do not have hypertension, whilst those who know they have hypertension rate their health as significantly worse. These results strongly hold even when we add in the full-set of demographic and socio-economic control variables as in Extended Model 2 in Table 3 (coefficient is now 0.420 with a t-stat of 9.37). As those who report incorrectly have lower income, this suggests that use of a general self-assessed health measure will systematically underestimate the strength of the (negative) income-health gradient.

5. Conclusions

The use of self-reported general health status measures is widespread in the examination of the relationship between income and health. As a measure it captures what an individuals 'feels' about their own health at a given point in time, which may be important information for predicting individuals' behaviour and decisions. However, such a measure may be less appropriate in the

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[18] Note that the chronic health condition controls are self-reported and can suffer the same type of reporting error as we find for hypertensive. Also, for brevity we do not present the full set of estimates for each of these additional models. We are, however, happy to make them available upon request.

context of identifying health inequalities that should be of concern to policy-makers. This is because self-reported health measures can suffer from reporting error that is related to key socio-economic characteristics including income. An additional aspect of health important in measuring socio-economic inequalities is that many chronic health conditions that are partly socio-economically determined are asymptomatic at moderate and often advanced stages. This means that people may not know that they have such a condition, and consequently this is then not picked up in self-reported measures even though there are serious long-term health consequences of such illnesses. This applies to some of the most prevalent health conditions including diabetes, hypertension, cardiovascular disease and many cancers. Baker et al. (2004) suggest that reporting error occurs with respect to a wide-range of self-reported chronic health conditions.

The task then is to be able to establish the extent to which such errors are related to socio-economic characteristics, particularly income. In this respect, recent studies are mixed in their conclusions about whether using self-reported health leads to a good estimate of the 'true' income/health gradient, or whether there is a tendency to either under or over-estimate the relationship.

Using two waves of data from the Health Survey for England, we provide direct evidence on this issue by comparing survey responses to self-reported and objective measures of exactly the same health condition, namely hypertension. Hypertension is an important condition as it is highly prevalent in Western countries, and given its asymptomatic nature is often described as the 'Silent Killer'. The fact that hypertension is asymptomatic except at extremely elevated levels of blood pressure, and that BP medication is cheap (GP access is free at the point of delivery in the British NHS and pharmaceuticals are heavily subsidised for the poor) and effective, means that we are able to treat income as largely exogenous, because the issue of reverse causality is not relevant. This same aspect of the condition also means that we estimate the upper-bound in the extent of possible reporting error.

We find a large difference in the percentage of the sample who report having hypertension as a chronic illness (7.1%) relative to those who are measured to have the condition (34.7%), with the raw correlation between the two measures being only 0.17. The percentage of individuals committing a false negative report in this context, which is those reporting that they do not have chronic hypertension but are in fact measured by the nurse as being hypertensive, is extremely high at about 86%. Most importantly, we find no evidence of an income/health gradient in hypertension when we use the self-reported measure but a large and statistically significant gradient using objective measures. In fact, the size of the coefficient on log household income is around 14 times bigger for the objective measure, even after extensively controlling for demographic and socio-economic characteristics that might be expected to be correlated with income. This differential

cannot be explained by differences in obesity, lifestyle choices such as smoking, drinking, exercise and eating fried food, nor can it be explained by differential stress rates or access to health services.

We also examine the characteristics of individuals most likely to false negatively report, that is have measured hypertension but not report it when asked in the survey. Income is again an important explanatory variable, with each additional log point increase in household income reducing the probability of committing a false negative report by about 2.5 percentage points. Again, these differentials cannot be explained by differences in usage or access to medical services, nor differential usage of hypertension medication or differences in the severity of hypertension.

As reported in the recent literature using health 'vignettes', it is likely that studies that rely only on self-reported measures of health will tend to under-estimate the true extent of the income/health gradient. One reason is that health expectations are to some extent socially-driven with high income groups having higher expectations about what constitutes 'good' health. This means that they report their health as lower than it would be if the same level of health was viewed by an individual from a low income background. Given the asymptomatic nature of hypertension, we find the size of this under-estimate to be very large. Although it is towards the upper-bound of the size of reporting error, the fact that there are many serious health conditions that are asymptomatic at moderate and sometimes even advanced stages[19] means the issue we examine is not confined to hypertension alone. Our results therefore suggest that estimates of the income/health gradient which use self-reported measures underestimate the extent of the gradient; the importance of illnesses which are often asymptomatic in early stages suggests that the discrepancy between actual and reported ill health is an important topic for future research.

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[19] To get a lower-bound we would need to compare self-reported and objective measures of conditions where the symptoms are immediate and more obvious to the individual such as problems with eyesight, hearing or musculoskeletal pain.

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Figure 1: Self-Reported Chronic Hypertension and Objective Hypertension by Age
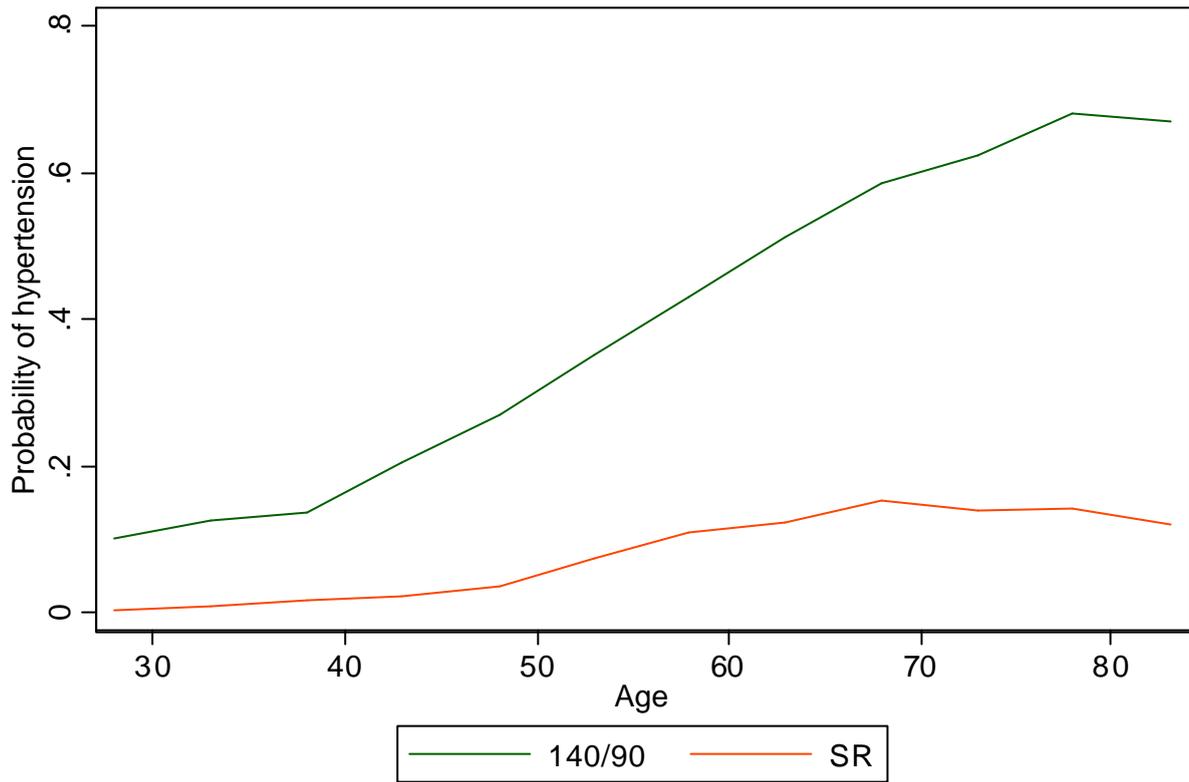
Figure 2: Self-Reported Chronic Hypertension and Objective Hypertension by Household Income Quartile
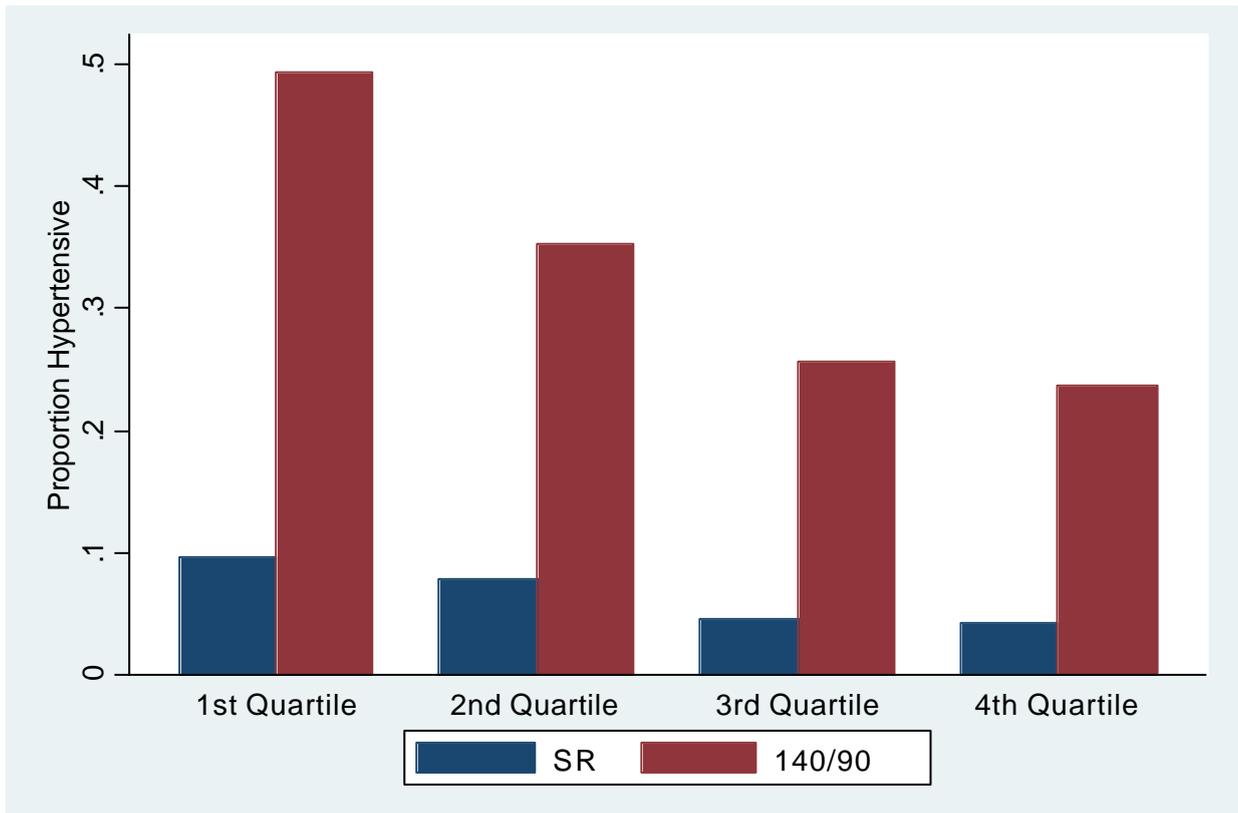
Figure 3: Self-Reported Chronic Hypertension and Objective Hypertension by England Region
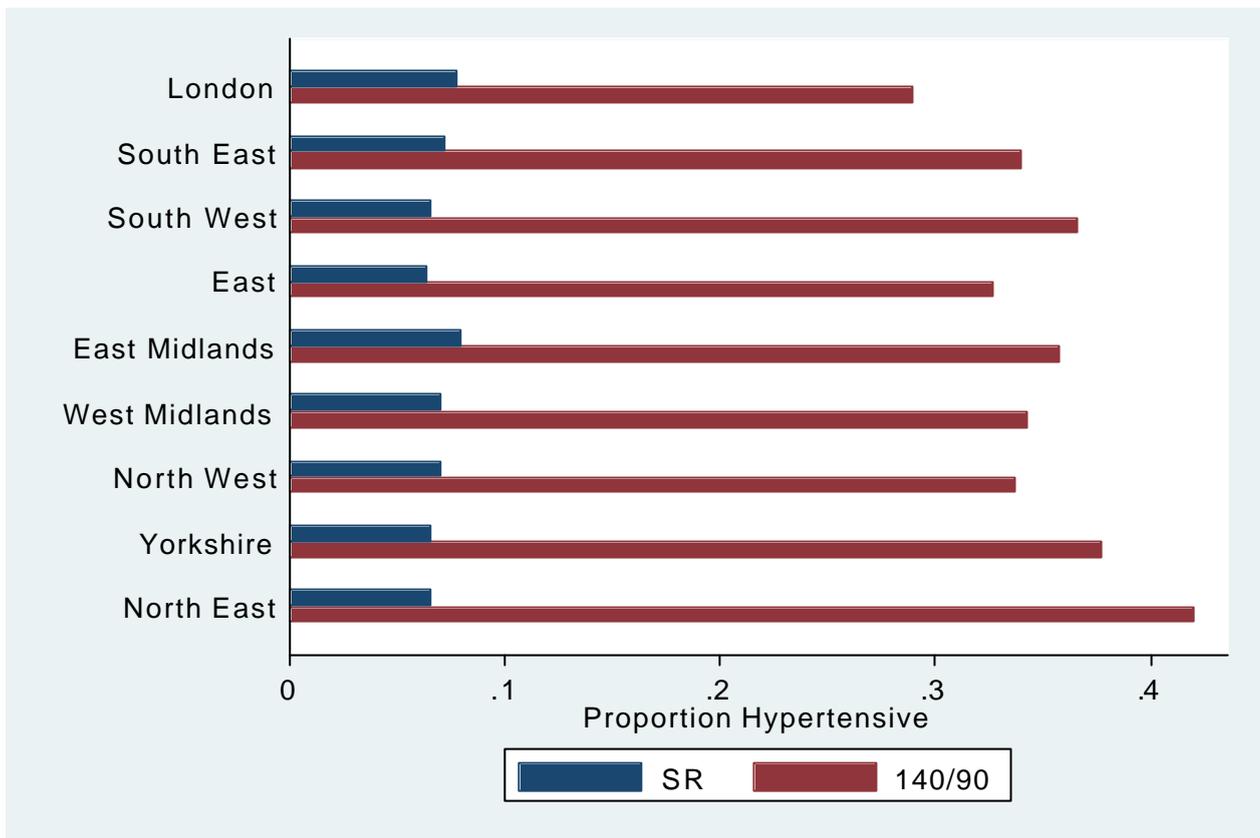
Table 1: Prevalence of Self-Reported Chronic and Objective Hypertension

Mean Systolic BP	134.9 mmHg
Mean Diastolic BP	74.6 mmHg
% BP measured ($\geq 140/90$)	34.7%
% Self-reporting Hypertension as a chronic illness (SR1) *	7.1%
% False Negative (SR1=0|BP $\geq 140/90$)	86.9%
% False Positive (SR1=1|BP<140/90)	3.8%
% Self-reporting Hypertension (SR2) *	11.1%
% False Negative (SR2=0|BP $\geq 140/90$)	76.8%
% False Positive (SR2=1|BP<140/90)	6.0%
% Reporting BP test in last 12 months *	64.1%
% Reporting taking BP Medication *	13.4%

Note: * means reported in the individual questionnaire prior to the nurse interview.

Table 2: Binary Probit and Regression Models of Self-Reported Chronic Hypertension and Objective Hypertension

	Probit Model SR		Probit Model 140/90		Regression Model Systolic	
	ME	|*t*|	ME	|*t*|	*ß*	|*t*|
Log real annual household income	**-0.002**	**0.73**	**-0.028**	**4.93**	**-0.974**	**5.23**
Age	0.012	13.40	0.022	12.55	0.425	7.51
Age squared	-0.009	11.69	-0.009	6.01	0.077	1.42
Male	-0.003	1.00	0.090	12.77	4.355	19.16
Black	0.060	4.10	0.004	0.13	-1.489	1.41
Asian	0.050	4.41	0.023	0.96	-0.123	0.16
Married	-0.009	1.31	-0.030	3.07	-1.064	3.43
Number of children in household	-0.003	0.92	-0.031	5.90	-1.229	10.10
Number of adults in household	-0.000	0.09	0.011	1.93	0.374	1.98
HSE 2003	0.018	6.24	-0.088	11.81	-3.229	12.84
Log Likelihood	-4124		-10153		-78626	
(Pseudo) R-Squared	0.286		0.287		0.248	
Sample	18658		18658		18658	

Notes: Marginal effects from binary probit models calculated at sample means. Standard errors adjusted for clustering at the household level in all models. Absolute *t*-statistics presented. Omitted categories: Female, white, not married, survey year 1998. Each model also includes a dummy for missing cases of household income.

Table 3: Extended Probit Models of Self-Reported Chronic Hypertension and Objective Hypertension

	Extended Model 1						Extended Model 2					
	SR		140/90		Systolic BP		SR		140/90		Systolic BP	
	ME	|t|	ME	|t|	ME	|t|	ME	|t|	ME	|t|	ME	|t|
Log real annual household income	-0.002	0.91	-0.014	2.23	-0.426	2.09	0.001	0.55	-0.013	2.04	-0.415	1.98
Age	0.011	12.35	0.020	11.23	0.349	6.06	0.010	11.39	0.019	10.31	0.282	4.72
Age squared	-0.008	10.77	-0.008	5.15	0.124	2.26	-0.007	9.87	-0.007	4.52	0.177	2.98
Male	-0.002	0.78	0.093	13.08	4.460	19.53	-0.002	0.75	0.086	11.01	4.010	15.61
Black	0.059	3.97	0.037	1.14	-0.047	0.04	0.060	4.06	0.044	1.32	0.026	0.02
Asian	0.042	3.82	0.041	1.65	0.662	0.84	0.037	3.58	0.053	2.09	1.023	1.28
Married	-0.005	1.32	-0.033	3.49	-1.266	4.09	-0.006	1.69	-0.036	3.73	-1.326	4.25
Number of children in household	-0.002	0.76	-0.030	5.70	-1.233	9.96	-0.002	0.83	-0.030	5.63	-1.181	9.43
Number of adults in household	0.000	0.05	0.008	1.45	0.268	1.43	-0.000	0.44	0.007	1.22	0.185	0.99
HSE 2003	0.017	6.22	-0.087	11.43	-3.109	12.32	0.015	5.41	-0.092	11.80	-3.250	12.68
Degree	0.002	0.43	-0.050	4.00	-2.001	5.10	0.006	1.16	-0.042	3.31	-1.616	4.04
Other higher qualification	0.005	0.92	-0.036	2.89	-1.503	3.70	0.008	1.58	-0.032	2.43	-1.198	2.89
A Levels or equivalent	-0.003	0.54	-0.022	1.49	-0.631	1.44	-0.001	0.16	-0.018	1.20	-0.401	0.92
O Levels or equivalent	0.003	0.84	-0.033	3.24	-0.915	2.77	0.006	1.43	-0.032	3.12	-0.813	2.45
Mother died of CVD aged less than 60	0.023	2.51	0.072	2.95	2.060	2.28	0.021	2.45	0.067	2.77	1.780	2.00
Mother died of CVD aged greater than 59	0.021	6.09	0.023	2.26	1.338	3.27	0.020	5.81	0.023	2.10	1.243	3.04
Father died of CVD aged less than 60	0.032	4.85	0.037	2.31	1.049	2.00	0.029	4.58	0.034	2.15	0.958	1.81
Father died of CVD aged greater than 59	0.010	3.19	0.022	2.46	0.832	2.42	0.010	3.29	0.023	2.47	0.846	2.48
North East	-0.014	2.11	0.102	4.78	3.933	5.92	-0.014	2.25	0.103	4.80	3.897	5.94
North West	-0.006	0.97	0.053	3.13	2.404	4.54	-0.006	1.05	0.052	3.07	2.335	4.47
Yorkshire	-0.009	1.54	0.078	4.36	2.608	4.66	-0.009	1.71	0.076	4.26	2.550	4.60
West Midlands	-0.006	1.05	0.048	2.62	1.980	3.41	-0.007	1.22	0.047	2.56	1.956	3.43
East Midlands	-0.003	0.45	0.065	3.62	2.429	4.28	-0.003	0.60	0.062	3.47	2.330	4.16
East	-0.010	1.66	0.032	1.80	1.108	2.03	-0.009	1.68	0.032	1.79	1.080	2.01
South East	-0.006	1.03	0.047	2.92	1.833	3.67	-0.005	1.01	0.048	2.97	1.848	3.76
South West	-0.010	1.84	0.053	2.99	2.110	3.70	-0.010	1.77	0.056	3.15	2.218	3.93
Reside suburbs	0.005	1.19	0.000	0.01	0.316	0.81	0.005	1.17	-0.001	0.08	0.244	0.63
Reside rurally	-0.001	0.23	-0.001	0.04	0.462	1.03	-0.002	0.39	-0.004	0.27	0.355	0.80

Table 3: (Continued)

Working part-time	-	-	-	-	-	-	-0.006	1.38	-0.031	2.64	-1.322	3.80
Unemployed	-	-	-	-	-	-	0.011	0.95	-0.033	1.22	-1.777	1.94
Non participant	-	-	-	-	-	-	0.013	2.32	-0.005	0.35	-0.486	0.94
Disabled	-	-	-	-	-	-	0.015	2.09	-0.024	1.28	-0.604	0.85
Student	-	-	-	-	-	-	0.013	0.71	-0.095	2.15	-2.461	1.92
Retired	-	-	-	-	-	-	0.006	1.23	0.005	0.34	-0.192	0.36
Doctor or registered nurse	-	-	-	-	-	-	-0.011	1.44	-0.025	1.06	-1.322	1.77
Obese (BMI$\geq$30)	-	-	-	-	-	-	0.035	10.27	0.141	15.05	5.502	17.78
Smoker	-	-	-	-	-	-	-0.008	2.20	-0.002	0.19	-0.059	0.19
Drink alcohol daily	-	-	-	-	-	-	0.004	1.23	0.041	3.95	1.281	3.60
Vigorous sports/exercise regularly	-	-	-	-	-	-	-0.009	2.39	-0.015	1.56	-0.513	1.88
Eats fried food regularly	-	-	-	-	-	-	-0.003	0.76	0.010	0.90	0.677	1.84
Log Likelihood	-4080		-10103		-78521		-3988		-9914		-77929	
(Pseudo) R-Squared	0.292		0.293		0.253		0.310		0.313		0.270	
Sample	18658		18658		18658		18658		18658		18658	

Notes: Marginal effects from binary probit models calculated at sample means. Standard errors adjusted for clustering at the household level in all models. Absolute *t*-statistics presented. Omitted categories: Female, white, not married, survey year 1998, less than 'O' level as highest qualification, mother did/had not died of CVD, father did/ has not dies of CVD, lives in Greater London, resides in city location, works full-time, not a doctor or registered nurse, is not obese, non-smoker, drinks less than every day, does not undertake regular vigorous sports/exercise and does not regularly east fried food. Each model also includes a dummy for missing cases of household income, and a dummy control for BMI missing.

Table 4: Heckman Probit Selection Models of False Negative Reporting

	Basic Model		Extended Model 3	
	ME	|*t*|	ME	|*t*|
Log real annual household income	-0.024	2.89	-0.024	2.31
Age	-0.003	0.45	0.010	1.88
Age squared	0.008	1.49	0.000	0.09
Male	0.102	9.39	0.086	6.54
Black	-0.103	2.20	-0.024	0.43
Asian	-0.072	1.84	-0.009	0.22
Married	-0.000	0.02	-0.018	1.09
Number of children in household	-0.025	2.38	-0.034	3.15
Number of adults in household	0.001	0.11	0.003	0.28
HSE 2003	-0.127	9.33	-0.118	9.02
Degree	-	-	-0.037	1.79
Other higher qualification	-	-	0.002	0.10
A Levels or equivalent	-	-	0.005	0.20
O Levels or equivalent	-	-	-0.010	0.66
North East	-	-	0.129	3.77
North West	-	-	0.059	2.14
Yorkshire	-	-	0.076	2.62
West Midlands	-	-	0.052	1.76
East Midlands	-	-	0.066	2.22
East	-	-	0.056	1.87
South East	-	-	0.068	2.55
South West	-	-	0.069	2.32
Reside suburbs	-	-	-0.039	1.82
Reside rurally	-	-	-0.019	0.83
Working part-time	-	-	0.005	0.27
Unemployed	-	-	0.039	0.94
Non participant	-	-	-0.009	0.40
Disabled	-	-	0.001	0.03
Student	-	-	-0.063	0.96
Retired	-	-	0.003	0.20
Doctor or registered nurse	-	-	0.000	0.01
Obese (BMI$\geq$30)	-	-	0.090	4.74
Smoker	-	-	0.014	0.80
Drink alcohol daily	-	-	0.020	1.24
Vigorous sports/exercise regularly	-	-	0.011	0.64
Eats fried food regularly	-	-	-0.006	0.33
Log GP per capita	-	-	-0.010	0.18
BP tested 1 -3 years ago	-	-	0.137	4.28
BP tested 3 – 5 years ago	-	-	0.147	2.92
BP tested 5+ years ago	-	-	0.168	2.70
BP never tested	-	-	0.115	2.09
Currently taking BP medication	-	-	-0.300	4.74
Systolic BP			-0.002	2.96

Rho	0.896	0.943
Log Likelihood	-12482	-11516
Wald Test (Rho=0) Chi-squares (1)	23.04	25.18
Test of 1st stage 'instrument' power Chi-squared (4)	39.87	21.28
Sample	18658	18658

Notes: Unconditional Marginal effects from Heckman Probit Selection models calculated at sample means. Standard errors adjusted for clustering at the household level in all models. Absolute *t*-statistics presented. Omitted categories: Female, white, not married, survey year 1998, less than 'O' level as highest qualification, mother did/had not died of CVD, father did/ has not dies of CVD, lives in Greater London, resides in city location, works full-time, not a doctor or registered nurse, is not obese, non-smoker, drinks less than every day, does not undertake regular vigorous sports/exercise and does not regularly east fried food, BP tested in last 12 months, and not currently taking any BP medication. Each model also includes a dummy for missing cases of household income, and a dummy control for BMI missing.

Table 5: Ordered Probit Model of Self-Reported General Health Status

	Basic Model	
	b	*|t|*
Log real annual household income	-0.320	23.27
Age	0.192	5.17
Age squared	-0.007	2.18
Male	0.007	0.49
Black	0.168	2.39
Asian	0.284	5.63
Married	-0.064	2.93
Number of children in household	-0.018	1.66
Number of adults in household	0.094	7.39
140/90 = 1, SR=1 (Individual reports having chronic hypertension)	0.449	10.25
140/90 = 1, SR=0 (Individual does not report having chronic hypertension)	0.021	0.77
Systolic BP	-0.001	1.67
HSE 2003	-0.040	2.22
Log Likelihood	-22638	
(Pseudo) R-Squared	0.121	
Sample	18658	

Notes: Standard errors adjusted for clustering at the household level in all models. Omitted categories: Female, white, not married, does not have 140/90 hypertension and survey year 1998.