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An analysis of Norwegian register data

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The effects of earlier income variation on mortality: An analysis of Norwegian register data

Kåre Bævre and Øystein Kravdal
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Several studies have shown a positive relationship between mortality and episodes of income decline, unemployment, or poverty shortly before death or in the more distant past. Our objective was to analyse the mortality effects of earlier income changes more generally, net of the overall level. We used Norwegian register data that included individual histories of annual labour income and focused on mortality among men aged 50–69 in 1990–2002. Men in this age group who, during the preceding 15 years, had experienced at least two substantial falls in income as well as at least one substantial increase, or vice versa, experienced an excess mortality of 17 per cent. For men who experienced fewer changes, there were only weak indications of excess mortality. Variation dominated by falls in income did not have a more adverse effect than variation dominated by rises.

Keywords: mortality; income; income variation; life course; Norway; longitudinal; men; change

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Introduction

An inverse relationship between the chance that a person of a certain age dies and his or her income a few years earlier has been established in many studies (e.g., Martikainen et al. 2009). The relationship is thought to reflect the causal effects of material disadvantages resulting from low income and the associated psychosocial stress, as well as selection. Much attention has also been devoted to health and mortality among persons who have recently experienced income decline, in particular as a result of unemployment (e.g., Strully 2009). Furthermore, there has been an increasing interest in examining the importance of income levels and income changes further back in time, which may be considered part of a broader effort to learn about the health implications of experiences and exposures in earlier stages of the life course (e.g., Ben-Shlomo and Kuh 2002). In studies of earlier income, various measures of the lifetime income level have been included in the regression models (Duleep 1986; Menchik 1993; Wolfson et al. 1993; McDonough et al. 1997; van Ourti 2003; von Gaudecker and Scholz 2007; Duggan et al. 2008; Cristia 2009), and some authors have examined effects of the number of income falls or the number of spells of poverty (e.g., McDonough et al. 1997, 2005; McDonough and Berglund 2003; for earlier studies, see the review in Benzeval and Judge 2001).

A few investigators have also estimated how various measures of health status are influenced by earlier income changes more generally, in particular by also considering income increases. For example, Tåhlin (1989) reported effects of income change over the previous 3 years on circulatory diseases, Lundberg and Fritzell (1994) studied the effects of changes in absolute and relative income over a 10-year period on two health outcomes at the end of the period, and Benzeval and Judge (2001) measured the effects of income decline and income increase over the 6 years preceding their study. The last-mentioned study showed that decline had an adverse effect and an increase had no effect. Income at the start of the period was included in these three studies, which means that the effect of increase (decline) also captured the effect of high (low) current income.

According to a recent study by Prause et al. (2009), psychological depression was more prevalent among those with earlier income volatility, measured as the variance of logged annual earnings. The interpretation of such a result is not straightforward.

Note that studies addressing how changes in income affect changes in health (Gunasekara et al. 2011) are part of a rather different research tradition.
These analyses aim to control for common individual determinants of income and health that are unobserved and constant, using a fixed-effects or difference-in-difference approach. In such designs, the aim is to identify the effect of the (current or lagged) income level through the relationship between changes in income and changes in health. The focus on income changes is purely instrumental, and there is no interest or focus on any substantive effect of the change itself.

The aim of our study was to add to knowledge of the effects of earlier income changes on mortality, effects we believe to be considerably more complex than is reflected in reports of previous studies. Our analysis focused on the impact of changes over and beyond their effects through the income level. This distinction is lacking in many existing studies, which often do not condition on the income level when estimating effects of income change. In consequence, the resulting estimates are somewhat hard to interpret. For example, to some extent the effects of income falls can reflect the fact that individuals who have had many falls have had a generally low overall income level, or at least currently have a relatively low income level. Furthermore, we considered not only income falls but also income rises, which have received little attention in previous studies. Taking income change in both directions into account is valuable even if the main goal is to assess the impact of income falls. In particular, an observed income decline may either be the end of a peak or the start of a trough, so that what seem to be the effects of income declines may actually also reflect the effects of income variation more generally, including increases. This fact seems not to have been fully appreciated in earlier studies.

We seek to contribute both theoretically and empirically to an understanding of the effects of income change on mortality and divide the paper into two main parts accordingly. In the first part of the paper we analyse theoretically how income change, through various mechanisms, may produce effects on mortality that are far from self-evident. The arguments build on common ideas about the material and psychosocial effects of economic resources. We take these ideas one step further by incorporating ideas from consumer theory on how consumption at a certain point in time depends on the income trajectory, and by making an assumption about the individual’s own past being a relevant reference point in the psychosocial pathway. Additionally, we build on widely accepted notions about diminishing health returns to consumption and long-term health implications of earlier health and health behaviour.

In the second part of the paper we report the use of Norwegian register data to estimate the effects of income change, given the income level. The data we used are very rich in that they included complete cohorts and allowed us to consider income changes over a longer period (15 years) than commonly used in such investigations. As we discuss in the theory section, we would ideally have studied the role of both individual and household income, but our data allowed only the former. Because men have been the main wage earners, especially during the first decades covered by the data, the development over time in individual income has been more similar to the development in household income for men than for women. We have therefore chosen to study men exclusively. The second main limitation of our data is that we were not able to identify those who had retired. To exclude the majority of the retired, we set an upper age limit at age 69 (see elaboration below).

More specifically, we estimated discrete-time hazard regression models for mortality of men aged 50–69 in 1990–2002. The models included the number of income rises and falls over the preceding 15 years, or alternatively the standard deviation from trend (see definitions and their motivation below). While much of the existing literature on income decline has focused on the most dramatic reductions, such as those caused by unemployment or movement into poverty (which is generally uncommon in Nordic countries), our measures capture more moderate changes as well.

**Part 1: Possible reasons for the effects of earlier income changes**

**General ideas**

Our arguments about the effects of earlier income changes rest on four general ideas or assumptions. Firstly, a person’s consumption of health-promoting goods is positively influenced by his or her income at that point and negatively affected by uncertainty about future income. Secondly, consumption or income relative to certain standards or expectations may also have a health effect through a psychosocial pathway. Thirdly, the health influences of income are likely to be concave. Finally, health and health behaviour at any point in an individual’s life probably have long-term implications. Below, we elaborate on these four ideas and the arguments behind them.

*Material or consumption effects.* We assume that (net) consumption of health-promoting goods increases
with income, what economists call a normal good. While it is possible that a person with more resources may spend more on cigarettes, alcohol, or other types of non-healthy consumption (e.g., Ruhm 2007; Apouey and Clark 2009), there is much evidence of the positive effects of more resources on lifestyle (e.g., Reeves and Rafferty 2005; Qi et al. 2006), and these positive effects are generally assumed to dominate. The rich may additionally have better access to some health services (van Doorslaer et al. 2006).

The standard economic life-cycle theory for consumption builds on two fundamental assumptions, in addition to the general one of rationality (see, for example, Attanasio 1999). One is that agents are forward-looking, that is, they take expectations about future income into account. The second is that agents, in addition to preferring more consumption in each period (with declining marginal utility), also prefer smooth consumption paths. In an ‘ideal setting’, without any form of credit constraints or uncertainty about future income, the implications of these two assumptions is that consumption will be at a constant level, corresponding to an ‘expected lifetime income’. For example, when income is low compared to the average lifetime income, a person may benefit from savings made when incomes were higher (in anticipation of this low-income period), or borrow against the expected higher income in the future. In other words, according to this version of the theory, current consumption is not directly influenced by current income, but only indirectly through its effects on expected lifetime income.

The ability to smooth consumption can be limited by credit constraints, with the consequence that consumption tends to vary more with changes in annual income. Furthermore, with uncertainty about future conditions, expected lifetime income will be revised in light of new information, which in turn will affect consumption. For example, an unanticipated reduction of income will lead to a downward revision of expected lifetime income, and thus a reduction in consumption. Note that an anticipated income change will give no such effect. Moreover, the reduction will be larger if income is expected to stay low for several years than if the income decline is expected to be short-lived (for a more thorough discussion see, for example, Jappelli and Pistaferri 2010). Additionally, uncertainty about future income may reduce consumption by inducing precautionary saving. The standard prediction is that the amount of precautionary savings rises with the level of uncertainty, that is, for a given level of expected lifetime income, one will consume less the more uncertain the future income (see, for example, Caballero 1990).

**Psychosocial effects.** There is also a large literature describing or building on a psychosocial pathway from income to health outcomes. The idea is essentially that a feeling of deprivation or inferiority compared to some reference group may be a psychosocial stressor that can have direct physiological consequences, for example through immune or neuroendocrine mechanisms (Sapolsky 2005; Cohen et al. 2007; Pham-Kanter 2009). The stressor may also operate more indirectly through unhealthy coping practices such as smoking (Wilkinson 1999; Marmot and Wilkinson 2001). It should be noted, however, that the effects of relative income have not always shown up in empirical investigations, and in fact may be very difficult to separate from the effects of absolute income with the type of data that have been available for most studies (e.g., Lorgelly and Lindley 2008; Gravelle and Sutton 2009). Some authors have also argued that the effects of the supposedly mediating variable—psychosocial stress—are particularly difficult to identify, or have questioned the link between relative position and psychosocial stress (Macleod and Smith 2003; Lynch et al. 2004).

Assuming that psychosocial mechanisms have some importance, it is not obvious what the most relevant reference group would be (Pham-Kanter 2009; Subramanyam et al. 2009). Furthermore, it is not obvious whether the comparison should be based on current income (and consumption), income level in recent years, or income expectations for the near future. Nor is it obvious whether it is the individual’s own income or the household income that is most relevant. We return to this issue of individual vs. household income later.

In our discussion below, we simply refer to the possibility that individuals who currently earn little compared to the national average may suffer from some psychosocial stress (in addition to material effects discussed above). An idea even more central to our argumentation is that an individual may compare current income (or consumption) with his or her own income at an earlier time, and perhaps especially with income in the most recent period. This idea has a quite long history in the social sciences (e.g., Clark et al. 2008).

Furthermore, it seems plausible that economic uncertainty can be a psychosocial stressor with many of the same effects on health. There is a large literature showing that job insecurity is strongly
associated with poorer health outcomes (see, e.g., Ferrie et al. 2005; Burgard et al. 2009; Lázló et al. 2010). Income variability can in several situations be tightly connected to job insecurity, but there are also reasons to expect similar stress effects from the more general economic insecurity embodied in income variation.

**Concavity.** There is a growing research literature on the shape of the relationship between recent income and health outcomes (Ecob and Smith 1999; Fritzell et al. 2004; Mackenbach et al. 2005; Rehkopf et al. 2008). The results are not fully consistent, but the majority of studies report that the relationship is not uniformly linear. Rather, the contribution to better health from a given increase in income tends to be higher at lower levels of income than at higher levels, that is, the function is concave. Some studies find more extreme versions with a threshold value beyond which there is little or no effect of additional income.

**Long-term effects.** It is a core idea in life-course epidemiology that health and health behaviour in one period have implications for later health and mortality (e.g., Ben-Shlomo and Kuh 2002). This is, of course, a central premise for our argumentation as well, although for simplicity we do not always point that out explicitly. More precisely, the effects of income on health and health behaviour discussed above probably have consequences for mortality many years later. Stated differently, mortality in any given year depends on the accumulated effects of earlier health and health behaviour and thus a long income history. On the other hand, income in the most recent years is still likely to be more important than income in earlier years.

**Possible effects of income variation**

We now explain how income changes may affect mortality, given the general ideas just presented, and identify three main causal pathways (summarized in Table 1). By ‘change’ we mean a substantial difference compared not only to one particular year, but to a longer period that may reflect the income level that, to some extent, the individual has become used to and may expect for the future. Such differences are most likely to have implications for consumption and be relevant for psychosocial stress mechanisms. We return to the precise operationalization later.

**Three main causal pathways.** The experience of an income change in either direction will generally increase uncertainty about future incomes, at least if the change is unanticipated. As pointed out earlier, it is possible that uncertainty may induce psychosocial stress that is detrimental to health. Uncertainty may also lead to precautionary saving and thus a lower level of consumption of health-promoting goods. It seems plausible to suppose that the more changes a person has experienced, the stronger the feeling of uncertainty. These effects make up the first causal pathway as indicated in the first row of Table 1.

The second pathway follows from the assumed concavity of the relationship between income and health. To illustrate by an example, we consider two individuals with the same average income. One has had a constant income, while the other has experienced periods with income below the average balanced by years with income correspondingly much above the average. Under the concavity assumption, the latter person will have the highest mortality, because what he or she has gained in health during years with higher income (through material or psychosocial effects) will not compensate for the larger disadvantages experienced in the years with lower income. In general, given the average income level in earlier years, mortality is lower if income has been constant at this level than if it has varied. (Formally, this is just an application of Jensen’s inequality: the mean of a concave function is smaller than the function evaluated at the mean.)

When we compare individuals with the same average income, both those who have experienced a substantial fall in income and those who have experienced a substantial rise are likely to have had more periods below and above this average than others, and should therefore have higher mortality. We emphasize that the effect is qualitatively the same for falls and rises, as indicated by the positive signs in the second row of Table 1, but the size of the effect may be different. The exact functional form of the relationship between income and mortality, such as the degree of concavity and whether there are thresholds, determines whether there is such a difference between falls and rises in size of effect. For the same reasons, it is not possible to give precise predictions for the additional effects of having experienced multiple income changes.

The third pathway applies only if psychosocial stress is affected by comparisons with own income levels in the past. An income fall then has an additional detrimental effect on mortality because it entails a feeling of deprivation relative to earlier
years, while an increase lowers mortality because it entails a relative improvement (indicated by the respective signs in the third row of Table 1). One might speculate whether the advantage from an increase might be smaller than the corresponding disadvantage from a fall (as indicated by the parentheses around the negative sign in the third row). The implication would then be that income variation characterized by just as many falls as increases in income would raise mortality compared to a situation with stable income.

In summary, two mechanisms produce the detrimental health effects of both an income rise and an income fall (though not necessarily equally strong), conditional on average income. For both these mechanisms it is sufficient that there is either a material or a psychosocial effect as described above. The third mechanism is asymmetric and produces a beneficial effect of an income rise that in principle might outweigh the adverse effects. Thus, taking everything into account, our expectations are as follows:

(i) A positive effect on mortality of being classified as having experienced an income fall.
(ii) An uncertain effect of being classified as having experienced an income rise. The effect is most likely to be positive, though not necessarily as large as that associated with income falls, and it may even be negative if the intertemporal relative income mechanism dominates.
(iii) The effects in (i) and (ii) will be additive. Those who have experienced frequent income variation, that is, either multiple falls and rises, or combinations of the two, are likely to have particularly high mortality. (This is indicated in the third column of Table 1.)

Individual and household income. In the theoretical analysis above, we used the term income in the abstract since the arguments and predictions do not hinge on the exact nature of the income concept. We will now be more specific.

Most people live much of their lives in a household that includes other persons. Of course, a person’s own income and the total income of his or her household usually do not develop in exactly the same way over time. Incomes may even move in opposite directions, such as when one partner works extra hours in an attempt to compensate for an income loss suffered by the other. For what we called the material consumption effects, household income is probably at least as influential as individual income, both because of its importance for individual consumption and because it is a key determinant of the joint household consumption from which all members may benefit. For the psychosocial pathway, on the other hand, empirical evidence suggests that individual income may be just as relevant as, or even more relevant than, household income (see, e.g., Geyer 2011). We think this would be particularly likely for comparisons with past years, which are most relevant for our discussion.

When calculating household income one should somehow adjust for household composition (i.e., by use of consumer equivalents). Given our focus on income changes, using such an adjusted measure will introduce new problems. For example, a pronounced reduction in adjusted household income may be entirely due to the birth of a child while both parents manage to maintain their incomes. Such household changes may themselves have, or be associated with, conditions that have consequences for health and health behaviour quite different from those we are concerned with here.

In conclusion, it is not obvious whether individual income or household income is the most relevant. Since there are specific advantages and disadvantages associated with both, one should ideally use individual income and household income alternately in complementary analyses.

Table 1 The three main causal pathways and expected signs of effects of income falls and/or rises, given the average income

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Income fall</th>
<th>Income rise</th>
<th>Income fall and rise (variability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeling of uncertainty because of earlier changes, leading to precautionary saving and psychosocial stress, with long-term effects</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Concave effect of income at any given time on health and health behaviour at that time—through material channel or psychosocial stress—with long-term effects</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Psychosocial response to current income relative to income in the past, with long-term effects</td>
<td>+</td>
<td>(−)</td>
<td>(+)</td>
</tr>
</tbody>
</table>
Confounding by closely associated factors. Because few researchers have had access to data that allow the effects of income and those of work to be separated, the effects of observed changes in income usually also reflect effects of changes in work activity. Most importantly, many episodes of substantial income reductions are caused by unemployment (the unemployment benefit replacement rate in Norway is about two-thirds; see OECD 2006, table 3.2). Unemployment can also affect mortality through other mechanisms (see, e.g., Voss et al. 2004; Massakowski 2008; Eliason and Storrie 2009). Not being at work may induce a feeling of shame and thus increase the psychosocial stress (Theodossiou 1998; McKee-Ryan et al. 2005; Cohen et al. 2007; Janicki-Deverts et al. 2008; Hintikka et al. 2009), and there may be disadvantages associated with a less structured daily life and less contact with colleagues. Several investigations have documented stress responses to unemployment. Other individuals may earn a lower income because they have voluntarily reduced their working hours to have more leisure time, which is not likely to have similar adverse health effects.

When it comes to income rises, the story may be quite different. In particular, a person who earns a temporarily high income may be working extraordinary hours because of good opportunities. Overtime work is associated with excess mortality, at least in the short term, according to some studies (Nylén et al. 2001), though other studies are less clear in their conclusions about this association (Lallukka et al. 2008). There are of course many factors that may affect both a person’s work activity and income and mortality as well (through other channels). We elaborate on this selection problem below.

Part 2: An empirical analysis based on Norwegian register data

Data

The data covered the period up to and including 2002, and were extracted from three different sources. One source was the Norwegian population register, which includes everyone who has ever lived in Norway since 1964. There is information about time of death and migrations into and out of the country. The data from the population register were matched with histories of annual pre-tax labour incomes from 1968 to 2002 (from the Taxation Directorate through Statistics Norway), and annual data on highest educational attainment (from Statistics Norway’s education database). We analysed mortality from 1990 to 2002 and its relationship with income history over the preceding 22 years (1990 – 1968 = 22). As further explained below, we counted changes within a 15-year period, requiring five additional years (seven when making sensitivity checks) to measure changes in the first of these 15 years.

The pre-tax labour income was given in 1,000 Norwegian kroner (NOK) at 1998 prices, adjusted by the consumer price index. At the exchange rates of 1998, the value of 1,000 NOK was about 133 US dollars. Labour income included unemployment benefits and temporary sickness benefits, but neither pensions nor permanent disability benefits. With a measure of pre-tax labour income, we did not take into account income from savings and other assets. More detailed information about different income components and unemployment spells exists in registers, but only after 1992, and we did not have access to these data. It should also be noted that since taxation of labour income is heavy and quite progressive in Norway, the changes in after-tax incomes are smaller than those in pre-tax incomes. For example, a 15 per cent decrease, which we took as our limit for defining an income fall (see below), resulted in a smaller decrease in post-tax income.

Given that our income measure did not capture retirement pensions, we attempted to exclude the retired by restricting the analysis to those younger than 69 years of age. Retirement age varies, but the common age is 67 and almost all are retired by age 70. One may have an income from employment after retirement, but it is usually very low (partly because a retirement-earnings test reduces benefits if earnings exceed a specified sum; see, for example, Hernæs and Jia 2007). It was therefore reasonable to assume that those who did not have very low earnings had not retired. With this in mind, we restricted the analysis to those who earned a minimum of 200,000 NOK or more. Very similar estimates were obtained when the minimum income was set at 175,000 or 225,000 NOK (details not shown). In additional models, we also excluded the few men with incomes above 999,000 NOK. This had no impact on the estimates.

Age 50 was chosen as the starting age for the analysis, primarily because only about 3 per cent die at younger ages (Statistics Norway 2012). An additional argument was that, if we went 15 years back in time for those who were younger than 50, many income changes might have been due to the completion of education or re-enrolment, and the interpretation of the effects of the changes might therefore have had to be very different.
As argued earlier, we would have preferred to use both individual and household income in our analysis, but the data did not include the necessary information on cohabitation and with whom children lived after a disruption. This made proper calculations of household income impossible. As explained in the introduction, the analysis was restricted to men because individual income is more strongly correlated with household income for men than for women.

**Statistical model**

We estimated discrete-time hazard models. For each man, a series of 1-year observations was created, starting in January 1990 (if born 1920–39) or in January of the year in which the man turned 50 (if born 1940–52). Those born before 1920 or after 1952 did not contribute to the analysis. Follow-up continued until whichever of the following came first: the end of 2002, the end of the year in which the man turned 69 (similar results were found with a cut-off at age 64), or the date of death or last emigration. One-year observations starting when the man was abroad were omitted.

Mathematically, the model is

\[
\log(p_{ij}/(1-p_{ij})) = \beta_1 X_{1i} + \beta_2 I_{1i} + \beta_3 \log(I_{1i+2}) + \beta_4 \log(A_{i,t-15,j-3}) + \beta_5 V_{i,t-15,1-3}
\]

where \(p_{ij}\) is the probability that a given man (index \(i\)) who is alive at the beginning of year \(t\) dies within that year; \(X_{1i}\) is a vector of control variables referring to characteristics (age and education) of the man at the start of \(t\); \(I_{1i-2}\) is the income in the year \(t-2\) (as further explained below, this 2-year lag was introduced to reduce the health-selection problem); and \(A_{i,t-15,j-3}\) is the average income over the years between \(t-15\) and \(t-3\). We used the log of \(I_{1i-2}\) and \(A_{i,t-15,j-3}\) to reflect the expected concave relationship. \(V_{i,t-15,1-3}\) is a measure of income variation described further below. A linear time effect was included. The same results were obtained when 1-year dummies were included instead.

One reason for characterizing the income level by both the income shortly before the time of exposure and the average income over earlier years was the possibility of there being separate effects of recent and earlier income levels owing to the different types of mechanism involved (see theory). While the two income levels were strongly correlated, there was sufficient independent variation to separate their effects. However, our estimates of effects of income changes were only marginally different when we left out the recent income (details not shown).

We excluded 9 per cent of the observations either because there was at least one missing value for annual labour income during the foregoing 15 years, or because the person had lived abroad during some of that period (and the income for at least 1 year therefore may not have been known). The excluded observations were very similar to the others with respect to all other variables, which suggests that the exclusion was rather harmless. As just mentioned, we also left out those earning less than 200,000 NOK in the year \(t-2\). Within the remaining 2,125,394 person-years of observation, there were 10,317 deaths.

**Definition of income changes**

Because the individual income trajectories display a multitude of different patterns, selecting the empirical features that are most relevant in light of the theoretical considerations above is by no means easy. We will now present the operationalization we chose. It is, of course, important to keep in mind that all measures of income variation entered the regressions conditional on the average income over the study period.

There is a general upward drift in incomes as a result of an economy-wide growth in real wages and individual wage increases based on seniority. The average annual income increase in our sample was 1.3 per cent, with levels being on average 252,000 and 302,000 NOK at either end of the 15-year period (the corresponding standard deviation increased from 95,000 to 307,000). The upward movement is largely rather predictable and typically involves relatively small increases, so it is unlikely to have a great impact on mortality through the material channel. In addition, for effects related to psycho-social stress it probably matters a lot more if changes are rapid and unexpected than if they are more gradual. For these reasons, we decided that the most reasonable option was to consider only changes from a smooth underlying pattern (trend) that were not too small. The underlying trend might have been captured with a moving average, but it seemed more reasonable to use a measure that only reflected income in earlier years (recall our discussion of unpredicted changes, signals of increased uncertainty, and comparisons with a reference level based on recent experience). It is common in econometric studies of consumption to use more sophisticated methods to separate predictable and unpredictable components of the income path (see, for example,
Jappelli and Pistaferri (2010), but we thought this distinction would be less relevant in our context, and that such efforts were therefore not warranted.

More precisely, we defined an income fall as a decline to a value 15 per cent below the average income over the five preceding years, and classified individuals according to whether, over the 15-year period, they had experienced none, one, or two or more such falls. Because of the general upward drift in income, we set a higher limit for income rises, counting only increases of at least 30 per cent relative to the average over the preceding 5 years. Again, we classified individuals in groups having none, one, or two or more such rises. The exact limits defining a fall and a rise were clearly somewhat arbitrary, but represented interesting cases. The asymmetric limits led to fairly symmetric frequencies of falls and rises, as can be seen from Table 2(c). Almost the same mortality effects were estimated when we tried a 3- or 7-year reference period instead of a 5-year period.

It is worth emphasizing two important and attractive properties of our operationalization and how it treats various types of fall and rise. Firstly, if income in a certain year is, say, 10 per cent above the 5-year average, while it is 10 per cent below in the following year, this change will not count as a fall even if it is larger than 15 per cent. The prominent feature in such cases is that of moderate fluctuations around the average, rather than the substantial income falls we want to capture. Secondly, for an income peak, we usually count the rise, but a subsequent decline (reversion to trend) that is either gradual or happens shortly after the rise will not count as an income fall. Only if income stays at the new high level long enough for the 5-year average also to increase sufficiently will such a reversion count as a fall. As a somewhat undesirable property of our operationalization, it should be noted that sustained, steady increases can be counted as more than one rise provided they are large enough (and similarly for falls).

While we were primarily interested in the effects of moderate to large income falls and rises as defined above, we also estimated a model that, instead, included an indicator of variation around the trend more generally. It was defined as the square root of the average of the squared differences from the average over the five preceding years, that is, the standard deviation from trend. A traditional estimate of standard deviation (as employed by Prause et al. 2009 and Sullivan and von Wachter 2009) seemed ill-suited because it also gives high scores in situations with a steady decline or increase, which is an altogether different type of change.

Selection and causality

As in all studies of the relationship between income and health, our results should be interpreted cautiously with respect to causality. There are many determinants of a person’s work activity and his or her hourly wage that may also influence health through channels other than income change. In particular, some persons are probably more prone to take risks than others. This can result in a more volatile income, and might also be accompanied by a lifestyle with detrimental health effects. A volatile income can also be a necessary consequence of certain occupations, and these specific occupations can have their own implications for health. Even more importantly, poor health may affect work activity and wages, in addition to having obvious implications for later mortality. Some would refer to this as ‘reverse causality’. For example, a person may have a chronic health condition that increases mortality directly, and that also leads to recurrent episodes of reduced ability to work and associated income variation. In addition, a change in individual income for one household member may reflect characteristics or behaviours of other household members, which may have independent effects on mortality. As mentioned earlier, a man may for example work extra hours to compensate when the wife experiences an income fall owing to illness or for other reasons. On the other hand, he may also work less to be better able to care for a sick wife. These factors may themselves affect or be associated with mortality.

It is, of course, very difficult to control adequately for all the individual, household, and community characteristics that may affect job availability and wages as well as mortality. In this analysis, based on administrative registers, we included only education, age, and period as control variables. To reduce the most obvious effects of selection for health, we used income 2 years earlier rather than a measure of even more recent income.

Results

Summary statistics are presented in Table 2(a)–(c). Most interestingly, 42 per cent of the men had experienced at least one fall according to our definition (i.e., the income had fallen to a level
more than 15 per cent below the average over the 5 previous years), and 16 per cent had experienced this twice or more often. Forty per cent had experienced at least one increase (i.e., to a level more than 30 per cent above the average over the five previous years) and 14 per cent had experienced at least two increases.

Among those who had experienced at least one income fall, a little more than one-third had not also experienced an income increase, that is, the fall was the dominant change. Conversely, among those who had experienced an increase, a little more than one-third had not also experienced a fall. The remaining 27 per cent of the study population had experienced at least one fall and at least one increase. A subset of this group had experienced a fall at least once and an increase at least twice, or vice versa (the three groups in the lower right corner, adding up to 17 per cent of the study population).

Estimates of effects are shown in Table 3(a). As expected, higher age increases mortality, while higher education has the opposite effect. There is also a decline in mortality over time. More interestingly from our perspective, income 2 years earlier is inversely related to mortality, while there is no significant effect of the average income over the 13 previous years, though the point estimate suggests an effect in the same direction. A 16% higher mortality is estimated for the three groups that had most variation in income than for the reference group with least variation (i.e., no falls or increases according to our definition). The point estimates suggest a smaller excess mortality for the other groups with either falls or declines, but significance at the 5 per cent level is not attained.

In Table 3(b), we show the effects of the income change variable (presented in Table 3(a)) in a matrix format. Comparing opposite cells, we see a remarkable symmetry: excess mortality is similar regardless
Main patterns and possible explanations

We have shown that, given the income 2 years earlier (which has a negative effect) and the average income of whether the income variation is dominated by falls or increases.

When the indicator of income variation was excluded from the model, the effect of the average income was significant (0.884, CI 0.796–0.980; not shown in the tables) and was almost the same as the effect of income 2 years before the time of exposure. In other words, the low mortality seen among those with a high average income according to this simpler model seems to be explained by the lower amount of variation in this group.

<table>
<thead>
<tr>
<th>Table 3a</th>
<th>Effects of income changes and other variables (with 95 per cent CI) on odds of mortality among Norwegian men aged 50–69 in 1990–2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>1.098*** (1.093–1.102)</td>
</tr>
<tr>
<td>Calendar year</td>
<td>0.969*** (0.964–0.974)</td>
</tr>
<tr>
<td>Educational level</td>
<td>1</td>
</tr>
<tr>
<td>10 years</td>
<td>1</td>
</tr>
<tr>
<td>11–12 years</td>
<td>0.897*** (0.847–0.949)</td>
</tr>
<tr>
<td>13 years</td>
<td>0.855*** (0.803–0.910)</td>
</tr>
<tr>
<td>14–17 years</td>
<td>0.772*** (0.725–0.822)</td>
</tr>
<tr>
<td>18+ years</td>
<td>0.718*** (0.662–0.777)</td>
</tr>
<tr>
<td>Log(Income t−2, in 1,000 NOK)</td>
<td>0.815*** (0.732–0.906)</td>
</tr>
<tr>
<td>Log(Average income t−15 to t−3, in 1,000 NOK)</td>
<td>0.925 (0.833–1.026)</td>
</tr>
<tr>
<td>Number of income increases and decreases</td>
<td>1</td>
</tr>
<tr>
<td>0 increases, 0 decreases</td>
<td>1.047 (0.984–1.114)</td>
</tr>
<tr>
<td>0 increases, 1 decrease</td>
<td>1.077 (0.968–1.197)</td>
</tr>
<tr>
<td>1 increase, 0 decreases</td>
<td>1.070* (0.997–1.148)</td>
</tr>
<tr>
<td>1 increase, 1 decrease</td>
<td>1.034 (0.963–1.110)</td>
</tr>
<tr>
<td>1 increase, ≥2 decreases</td>
<td>1.188*** (1.095–1.289)</td>
</tr>
<tr>
<td>≥2 increases, 0 decreases</td>
<td>1.085 (0.934–1.260)</td>
</tr>
<tr>
<td>≥2 increases, 1 decrease</td>
<td>1.163*** (1.087–1.279)</td>
</tr>
<tr>
<td>≥2 increases, ≥2 decreases</td>
<td>1.188*** (1.096–1.288)</td>
</tr>
</tbody>
</table>

1Reference category.
2Count of increases of at least 30 per cent compared to the average over the previous 5 years and decreases of at least 15 per cent compared to the average over the previous years. Asymmetric limits are due to overall upward trend.

*p < 0.10; **p < 0.05; ***p < 0.01.
Source: As for Table 2(c).

<table>
<thead>
<tr>
<th>Number of decreases of at least 15 per cent compared to the average over the previous 5 years</th>
<th>0</th>
<th>1</th>
<th>≥2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of increases of at least 30 per cent compared to the average over the previous 5 years</td>
<td>0</td>
<td>1</td>
<td>1.070*</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1.047</td>
<td>1.034</td>
</tr>
<tr>
<td></td>
<td>≥2</td>
<td>1.077</td>
<td>1.188***</td>
</tr>
</tbody>
</table>

We also tried different limits in our classification of income falls and rises, counting reductions of 30 per cent and increases of 50 per cent (both still compared to the earlier 5 years). The pattern was quite similar, with 16 per cent excess mortality among those men (12 per cent) who had experienced at least one fall and at least one decline (not shown in tables). There was again symmetry with respect to falls and increases. The most striking difference was the clearer excess mortality among the very few who had experienced two declines and no rise, or vice versa.

In the next step, we included an alternative measure of income variability: the standard deviation from the trend, as measured by the average over the five preceding years (mean 46.8, standard deviation 134.43). With this specification, both the effect of recent income and the effect of average income are significant, and they are of the same size (Table 4). High variability raises mortality significantly, though it is not an effect that matters substantively. For example, a one-standard-deviation increase in variability is associated with only a 0.8 per cent increase in mortality.

When this alternative measure of income variation was included in addition to the other main measure of income variation, the effects of the main measure were essentially the same as those shown in Table 3(a), and the effect of the alternative measure was far from significant (p = 0.41). In other words, there does not seem to be an additional effect of small variation (which would be picked up by the alternative measure) around the larger falls and rises considered in the main measure, and the alternative measure is not able to capture much of the effect of these larger changes.

Summary and conclusion

Main patterns and possible explanations

We have shown that, given the income 2 years earlier (which has a negative effect) and the average income...
During the 13 preceding years (which has no additional significant effect), income variation during this period is associated with excess mortality, though it is a relatively moderate excess. For example, the 17 per cent of the men who had experienced at least two falls in income (of at least 15 per cent) and one increase (of at least 30 per cent), or vice versa, had approximately 17 per cent higher mortality than those with a rather stable income. For men who had experienced fewer upward or downward changes, there is also an indication of excess mortality, though it is not significant at usual levels. When we included our measure of income change we found no significant effect of average income. There is relatively more income variation among men with low average income, so if the effects of income variation are not taken into account, effects of average income may be biased. In other words, and to the extent that the results can be generalized, the effects of average income reported in earlier studies may actually be due to the large income variation among the relatively poor.

Such an adverse effect of income variation, given the average income, is consistent with our theoretical assumptions: (i) there is a concave relationship between the income level (absolute or relative to, for example, the country average) in any given year and what may, for simplicity, be described as health or health behaviour in that year; (ii) there is a reduced feeling of well-being when income declines from the level expected or to which one is accustomed, and a corresponding, but not necessarily equally strong, advantage from a relative improvement; and (iii) uncertainty leads to reduced consumption (owing to precautionary savings) and causes psychosocial stress.

Interestingly, mortality seems to increase by just as much regardless of whether the income variation is dominated by falls or increases. This does not accord equally well with all the above-mentioned ideas, and may suggest that the concavity argument or the uncertainty argument, which do not involve the direction of the changes to the same extent as the other arguments, is relatively important. On the other hand, one may consider the findings as lending little support to the argument about income relative to the past few years, which predicts higher mortality among those experiencing more falls than rises, than among those experiencing the opposite.

### Limitations

We believe the quality of the income histories was high, since they were based on tax registers rather than personal recollections. We were also able to exclude individuals with periods abroad when they may have had incomes not registered by Norwegian authorities. However, the study also had some limitations. One of them (and one that is certainly not unique to our investigation) is related to the fact that changes in labour income are due to any combination of changes in working hours and changes in hourly wages. The adverse effects of income change that we observe may to some extent reflect the negative consequences for health of the non-economic effects of unemployment or even of voluntary increases in working hours. The separation of such effects is generally difficult, and was not facilitated by the data available to us. Furthermore, we may not have fully excluded the retired, who have a much higher purchasing power than is indicated by their labour income, and we have not been able to take into account financial incomes from savings and other assets, wealth, taxes, and public transfers, all of which are important for people’s purchasing power.

It would also have been very valuable to complement our analysis with one using household income instead of individual income. As argued in the theoretical discussion, changes in individual income may be particularly important for some mechanisms, while changes in household income may be more important for other mechanisms, and the trajectory of the two income measures can be quite different. Given this complexity, it is impossible to predict how results from a model with household income would differ from those we report based on individual income.

There are four types of effect on health that would be interesting to explore: the effects for any combination of men and women of changes in either

### Table 4

<table>
<thead>
<tr>
<th>Source</th>
<th>Log(Income $t - 2$, in 1,000 NOK)</th>
<th>Log(Average income $t - 15$ to $t - 3$, in 1,000 NOK)</th>
<th>Standard deviation from trend$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(Income $t - 2$, in 1,000 NOK)</td>
<td>0.873*** (0.789–0.966)</td>
<td>0.876** (0.790–0.972)</td>
<td>1.000063*** (1.000010–1.000116)</td>
</tr>
</tbody>
</table>

$^1$Trend is measured as the average over the previous 5 years. Age, calendar year, and education were also included in the model.

*p <0.10; **p <0.05; ***p <0.01.

**Source:** As for Table 2(e).
individual income or household income. Our study deals with only one of the four. For two main reasons, we might have seen different patterns if we had considered women instead of men in our analysis based on individual income. Firstly, the relative importance of changes in individual income and changes in household income may be different for women. For example, the psychosocial effects of success relative to the past in terms of own income may generally be less prominent for women. Secondly, the relationship between changes in individual income and changes in household income is probably also different, because on average women contribute less to household income.

Furthermore, it was a limitation of our study that we controlled only for age, period, and education, given that several other factors may affect mortality and working hours and wages. It should be noted, however, that we also experimented with including marital status and crude measures of occupation in some models, but did not find this to alter the results in any important way.

**Broader implications**

Some recent studies have shown pro-cyclical mortality at the aggregate level, although there is no agreement about whether this is because working-age adults themselves have a different lifestyle when incomes are higher and they perhaps work more, or whether everyone is adversely influenced by the generally higher income levels and economic activity (e.g., Tapia Granados 2005; Ruhm 2007; Miller et al. 2009). It is not obvious what our study adds to this discussion. We show that an increase in income raises mortality, but this estimate is from a model where the income level is controlled for. The overall effect of an income increase cannot be predicted from our results, because an income increase will also contribute positively to the income level, and therefore positively to health.

**The main message**

Our analysis suggests that earlier studies of the effects of income reductions have missed some of the story. A change that is considered to be a fall can actually be either the beginning of a trough or end of a peak, which substantively are two quite different phenomena. What are referred to as estimates of effects of income falls can therefore reflect a combination of rises and falls, both of which may have an adverse effect on mortality according to our theoretical arguments and empirical results. In fact, when a fall is observed, it is quite likely that there have been several falls and rises (i.e., a fall can primarily be an indication of a generally large variation). Therefore, one should consider income variation in more detail than has been done in previous studies. However, it is not obvious what kind of income changes could reasonably be considered falls and rises. How large should the change be, and compared to what? If income is compared with the income level in earlier years, how many years should be taken into account? Is the average the most relevant measure, or should the direction of trend within the period also be considered as an indication of what the individual might expect for the ensuing years? We chose a definition that we believe made good sense, but further refinements should be a topic for future research.

We hope that our findings and arguments will stimulate additional research on the association between income variation and mortality, preferably using data that include information on all types of income, for all household members. With such data, the analysis could easily be extended to women and to the retired. Studies that were able to control better for selection would also be welcome. If patterns similar to the ones we have identified are confirmed in these studies, the implications for public health would be that there is a rationale for avoiding large income variation, and that individuals who have highly varying incomes may deserve special attention.

**Notes**

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2 The authors greatly appreciate the advice received from reviewers.

**References**

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