The Cognitive Effects of Depression: Evidence from an Instrumental Variable Approach

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Abstract

In this paper we analyse the effect of poor mental health on cognitive abilities. Whilst there is evidence that poor mental health reduces labour market participation, less attention has been paid to wider impacts on cognitive performance and productivity. Using longitudinal data about older adults from 18 countries, we show that worsening depressive symptoms move along a decline in cognitive abilities. We find that the association is driven by both reduced concentration and motivation. By contrast, mood-related symptoms have no independent effect on cognitive functions. To test whether the relationship is not driven by time-varying heterogeneity, we use recent maternal loss as an instrument for depressive symptoms. Our instrumental variable estimates indicate that poor mental health significantly reduces cognitive performance. These cognitive effects could be a significant element of the economic social cost of poor mental health, as impaired cognition may not only lead to reduced productivity in the workplace but also affect financial decisions and many other aspects of everyday life.

1 Introduction

Mental health conditions are among the leading contributors to the global burden of disease (Vos et al. 2015). In 2015, 17.9 percent of all adults had a mental illness in the United States and 14.2 percent had received mental health care in the past 12 months (Hedden et al. 2016). Because mental health problems typically have early onset in the lifespan and affect individuals during their most productive working years, the social and economic costs of mental ill health are likely to be substantial. In Europe, poor mental health is estimated to cost 3.5% of GDP in Europe, through health expenditure, transfers and lost productivity (OECD 2015)[1].

Measuring the true cost of poor mental health is challenging since mental health affect many aspects of our life. The economic literature has primarily focused on the effect of mental health on human capital formation and labour market outcomes. The existing literature shows that mental health problems in childhood impair human capital formation (Currie & Stabile

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[1]The estimate by the OECD study is based on the work of Gustavsson et al. (2011) on the cost of brain disorders.

2006, Johnston et al. 2014, Busch et al. 2014), reduce labour market participation (Chatterji et al. 2007, Frijters et al. 2014, Banerjee et al. 2017) but have no effect on wages (Chatterji et al. 2011, Peng et al. 2016).

Because most individuals with mental health problems are in work (OECD 2012), mental disorders may generate large economic costs if people are less productive when they have mental health issues. Poor mental health is linked with increased absenteeism and reduced self-reported productivity (Stewart et al. 2003, Burton et al. 2008, Banerjee et al. 2017, Bubonya et al. 2017). Further evidence of the potential effect of mental health problems on productivity comes from studies from the medical and epidemiology literature which have highlighted the association between poor mental health and impaired cognitive functions. Depression is associated with cognitive impairment, (Burt et al. 1995, Lichtenberg et al. 1995, Bora et al. 2013), age-related cognitive decline (Donovan et al. 2017) and the risk of dementia (Saczynski et al. 2010). If depression causes a cognitive impairment, then mental health problems may reduce productivity of those who are employed, since cognitive abilities are a key component of human capital[2].

Yet, whether suffering from depression has causal effect on cognitive functions and productivity at the workplace is not well understood. Whilst the association between depression and impaired cognitive abilities is well established, there is no direct evidence in the existing literature that depression causes a decline in cognitive abilities. Many factors are likely to be strongly associated with mental health and cognition, such as socio-economic background (Lynch et al. 2009) or physical health (Lindeboom et al. 2002, Dantzer et al. 2008). These could generate correlation between the two even in the absence of causal link. Besides, a decline in cognitive abilities could trigger depression (Newman 1999). Evidence from clinical trials indicate that antidepressant may have beneficial effects on cognitive function (Keefe et al. 2014, Rosenblat et al. 2015), but not all studies report such a result (Shilyansky et al. 2016). One study also reports that antidepressants improve productivity at the workplace (Berndt et al. 1998). However, clinical trials only focus on individuals suffering from major depressive disorders, and in most cases on selected subgroups of the depressed population such as the elderly or those with specific comorbidities. Therefore there are some doubts that these findings can be generalised to the population of depressed individuals (Keefe et al. 2014), in particular to those suffering from milder forms of mental disorders, which are highly prevalent in the general population.[3] Based on a series of experiments which manipulated happiness of university student through short-term shocks,[4] Oswald et al. (2015) conclude that happiness affects performance at a numeracy task designed to measure productivity. If happiness affects cognitive performance, then even mild mental health disorders may be expected to have a strong effect on cognitive tests.

In this paper, we estimate the causal effect of suffering from depressive symptoms on cognitive performance. We make three contributions to the existing literature. First, we use longitudinal data representative from the population of older adults in 18 European countries to show that depressive symptoms are associated with reduced cognitive performance even when controlling for time-invariant heterogeneity with a Fixed-Effect estimator. Second, we shed light on the mechanisms explaining the links between mental health and cognition. We

[2]There are substantial labour market returns to cognitive skills (Hanushek et al. 2015) and at the macro level differences in aggregate income can partially be attributed to differences in cognitive skills (Hanushek et al. 2017). In addition, cognitive effects of depression may generate wider social costs as cognitive abilities are crucial many other aspects of everyday life, such as financial decisions (Smith et al. 2010, Agarwal & Mazumder 2013).

[3]In 2015, 17.9 percent of all adults had a mental illness in the United States and 14.2 percent received mental health care in the past 12 months (Hedden et al. 2016)

[4]Such as watching a short comedy film, or providing chocolate and other treats

find that the association is driven by both reduced concentration and motivation but not by emotions such as sadness or tearfulness. Finally, our study is the first to provide direct evidence that mental health has a causal effect on cognitive performance. Combining panel data methods with a new time-varying instrument for depressive symptoms we show that depressive symptoms have a negative effect on performance at cognitive tests. We exploit the timing of maternal death, which can be deemed exogenous, to identify the effect of depressive symptoms on cognition. We show that maternal death has a strong short-term effect on mental health, and argue that it is unlikely to affect cognition through channels other than mental health. Our instrumental variable Fixed-Effect estimates suggest that one standard deviation increase in depressive symptoms reduce cognition by about 0.3 of a standard deviation.

Our results have several important implications. First, our results could partly explain the effect of depression on schooling performance: the cognitive effect of depression may explain why young people suffering from depression perform less well at tests and exams. Second, as an increasing number of tasks in the workplace rely on cognitive skills (Autor et al. 2003), the impairment in cognitive performance caused by mental health problems is likely to result in lower productivity at the workplace. Finally, because cognitive abilities are crucial for important aspects of everyday life, such as financial decisions (Smith et al. 2010, Agarwal & Mazumder 2013) or social relationships (Aartsen et al. 2004) , the social costs of depression may not be limited to health expenditure, transfers and lost productivity

2 Mental health and cognitive skills

Mental health problems in childhood impair human capital formation. Following the study by Kessler et al. (1995), several studies have highlighted the links between mental health disorders and educational attainment using nationally representative data. Attention Deficit Hyperactivity Disorder (ADHD) is associated with lower test scores and schooling attainment (Currie & Stabile 2006, Fletcher & Wolfe 2008). Adolescent depression is also linked to higher risks of dropping out of high school, lower college enrollment (Fletcher 2008) and the relationship is robust to the inclusion of sibling fixed-effects (Fletcher 2009). Loss of confidence, anxiety and depression and social dysfunction are associated with poorer educational outcomes the risk of being not in education, employment or training' at a young age (Cornaglia et al. 2015). A few studies try to establish whether the association between child mental health and educational attainment is causal. Using maternal education and mental health, family income and major adverse life events as exclusion restrictions, Johnston et al. (2014) find that child mental health has a large influence on educational progress. Some evidence indicates that antidepressant treatments may improve educational attainment, suggesting that the relationship between mental health and education performance is causal. Busch et al. (2014) show that warnings regarding the safety of antidepressants issued by the Food and Drug Administration in the US had a negative impact on the school performance of adolescents with probable depression. However, Currie et al. (2014) find that expanding insurance coverage for medication commonly prescribed for ADHD had little effect on emotional functioning or academic outcomes.

It is well established that mental health problems are linked to lower labour market participation (Hamilton et al. 1997) and lower earnings (Kessler et al. 2008). These studies typically control for a range of individual characteristics but establishing whether the relationship is causal is challenging, because of unobserved heterogeneity and reverse causality. Mental health can be affected by individual traits[5] and shocks, such as job loss, also affecting labour market participation. Using panel data methods to rule out unobserved time-invariant heterogeneity, Peng et al. (2016) find that worsening in mental health is associated with lower labour market participation and higher absenteeism but has no effect on hourly wages. Several studies try to estimate the causal effect of suffering from mental health problem on labour market outcomes using an instrumental variable approach. The instruments which have been used in the economic literature with cross-sectional data, include parental history of mental health problems (Ettner et al. 1997, Chatterji et al. 2011), the frequency of physical activity and stressful life events (Hamilton et al. 1997), number of childhood psychiatric disorders (Ettner et al. 1997, Chatterji et al. 2007, Banerjee et al. 2017) religiosity (Chatterji et al. 2007). These studies typically find that mental health problems reduce employment and labour force participation and increase absenteeism. However, because these instruments are time-invariant, the validity of the exclusion restriction is difficult to defend. All these factors may have a direct impact on cognition. Exploiting longitudinal data, Frijters et al. (2014) use the death of a close friend as an instrument for mental health, and find that worsening in mental health has a strong negative effect on labour market participation.

Because most individuals with mental health problems are in work (OECD 2012), mental disorders may generate large economic costs if people are less productive when they have mental health issues. Poor mental health is linked with increased absenteeism and reduced self-reported productivity (Stewart et al. 2003, Burton et al. 2008, Banerjee et al. 2017, Bubonya et al. 2017). Further evidence of the potential effect of mental health problems on productivity comes from studies from the medical and epidemiology literature which have highlighted the association between poor mental health and impaired cognitive functions. There are substantial labour market returns to cognitive skills (Hanushek et al. 2015) and at the macro level differences in aggregate income can partially be attributed to differences in cognitive skills (Hanushek et al. 2017), which suggests that cognitive abilities are a key component of human capital and closely linked to productivity. The association between depression and cognitive impairment is well documented in the medical literature (Burt et al. 1995, Lichtenberg et al. 1995, Bora et al. 2013, Keefe et al. 2014). Depression affects does not only affect mood but causes anxiety, difficulty with concentration, and feelings of worthlessness, all of which may impair cognitive abilities. There is also evidence that suffering from depression may increase age-related cognitive decline (Donovan et al. 2017) and the risk of dementia (Saczynski et al. 2010). The main limitation of these studies is that while they highlight a strong association between clinical depression and decline in cognitive functions, it is not well understood the extend to which this relationship is causal. The observed relationship between depression and cognitive functions could be driven by unobserved factors or reverse causality, since a decline in cognitive abilities could trigger depression (Newman 1999).

Literature reviews from clinical trials suggest that antidepressant treatments may have beneficial effects on some cognitive outcomes of depressed patients (Keefe et al. 2014, Rosenblat et al. 2015). There is also some experimental evidence that providing antidepressants workers improve productivity at the workplace (Berndt et al. 1998). By contrast, a recent large-scale study found that typical antidepressants do not improve cognitive function of depressed patients (Shilyansky et al. 2016). Whilst there is some indication that antidepressants may improve cognition of depressed individuals, these studies do not evidence the magnitude of the cognitive impairment caused by depression. In addition, an important limitation of this literature is that studies only focus on small samples of individuals suffering from major de-

[5]Traits such as self-esteem, motivation, and personality may influence both the risk of suffering from mental health problems and labour market outcomes (Ettner et al. 1997)

pressive disorders, and in most cases on selected subgroups of the depressed population such as the elderly or those with specific comorbidities. It not well understood whether the findings from this literature can be generalised to the population of depressed individuals (Keefe et al. 2014). In particular, these results may not be generalised to those suffering from milder forms of mental health problems, which are highly prevalent in the general population[6] and may account for a large proportion of the social cost of mental ill health. Psychological well-being is associated with cognitive function in the general population (Llewellyn et al. 2008) and there is some evidence which supports the idea that happiness influences productivity. Based on a series of experiments which manipulated the happiness of university student through short-term shocks[7], Oswald et al. (2015) conclude that happiness affects performance at a numeracy task designed to measure productivity. If happiness affect cognitive performance, mild mental health disorders are likely to affect performance at cognitive tests.

Overall, there is a lack of studies which use data representative from the general population to examine the links between mental health and cognition and address the causality issue. In this paper, we examine the links between mental health and cognition using large longitudinal data, representative of older adults in 18 European countries. Our main contribution is to use a new instrument for depressive symptoms to test whether worsening in mental health has a causal impact on performance at cognitive tests. To the best of our knowledge, our paper is the first to provide evidence that suffering from depressive symptoms has a causal effects on cognitive performance. In addition, we investigate which depressive symptoms are most strongly related to a worsening in cognitive performance, shedding light on the mechanisms behind the effect.

3 Empirical Approach

Identifying the causal effect of mental health on cognitive performance is challenging as a wide range of factors are likely to influence both mental health and cognitive function. To account for time-invariant heterogeneity, we estimate an individual Fixed-Effect model, which can be written as:

$$cog_{i,t} = \beta EURO\text{-}D_{i,t} + \mathbf{x}_{i,t}\gamma + c_i + u_{i,t} \tag{1}$$

Where $cog_{i,t}$ is a measure of cognitive function for individual i at time t; $EURO\text{-}D_{i,t}$ is a measure of depressive symptoms; c_i is an individual time-constant effect. Because this individual effect is likely to be correlated with both mental health and cognitive abilities, we use the Fixed-Effect (FE) estimator, which allows for unobserved time-invariant heterogeneity.[8] To control for time-varying heterogeneity we include a vector $\mathbf{x}_{i,t}$ of time-varying characteristics which are likely to affect both mental health and cognition. We control flexibly for age by including age dummies in our model. Important life events, such as job loss, divorce, or retirement could affect both mental health and cognition (Lindeboom et al. 2002). Therefore, we condition for labour market and marital status. Income change may also affect mental health and there is growing evidence that poverty and concerns with money may reduce the amount of cognitive resources that individuals can allocate to other tasks, resulting in poorer

[6]In 2015, 17.9 percent of all adults had a mental illness in the United States and 14.2 percent received mental health care in the past 12 months (Hedden et al. 2016)

[7]Such as watching a short comedy film, or providing chocolate and other treats

[8]We also estimate the model with a Random Effect (RE) estimator to check whether the individual time-constant effects are correlated with the independent variables of interest.

cognitive performance (Mani et al. 2013, Mullainathan & Shafir 2013). To account for this, we control for household income and dummies indicating if the household has difficulties in making ends meet. Health and disability are also expected to affect both mental health and cognition. For instance, cancer is known to trigger depression (Mitchell et al. 2011) and there is some evidence that cancer treatment reduces cognitive abilities (Minisini et al. 2004). The onset of dementia or Alzheimer's disease not only impairs cognitive abilities but can also trigger depression Newman (1999). Controlling for the onset of these conditions is crucial to obtain unbiased estimates of β. We include dummies indicating if the respondent suffers from at least one limitation of activities of daily living (ADL)[9], instrumental ADL[10], is physically active, and dummies for serious health conditions, such as heart attack, stroke, diabetes, high blood pressure, cancer, dementia and Alzheimer disease.

However, there may be other unobserved factors that affect both mental health and cognitive functions, resulting in an omitted variable bias. Unobserved shocks that increase depressive symptoms and reduce cognitive abilities at the same time would bias FE estimates of the coefficient β towards overstating the effect of depression on cognitive symptoms. In addition, even if there were no unobserved time-varying factors affecting both mental health and cognition, the observed association could be due to reverse causation. For instance, a decline in cognitive abilities could trigger depression (Newman 1999), generating a strong association between depressive symptoms and cognitive performance. We control for dementia and Alzheimer's disease but some individuals may experience symptoms of dementia without having yet been diagnosed. On the other hand, the FE coefficients may be biased towards zero because of measurement error in depressive symptoms. Measurement error in independent variables may lead to large attenuation bias in Fixed Effect models, which rely only on the variation within individuals over time.

We follow an instrumental variable (IV) approach to identify the causal effect of depressive symptoms on cognitive abilities. We use a time-varying instrument, the recent death of the respondent's mother, to predict depressive symptoms. Our approach is similar to that of Frijters et al. (2014) who exploit the death of a close friend to identify the effect of mental health on labour force participation. In a first step, we estimate the effect of recent maternal loss on the the depression score using the following estimation equation:

$$EURO\text{-}D_{i,t} = \theta Motherdeath_{i,t} + \mathbf{x}_{i,t}\gamma + c_i + v_{i,t} \tag{2}$$

Where $Motherdeath_{i,t}$ is binary variable indicating whether the respondent lost their mother between the current and previous wave. $\mathbf{x}_{i,t}$ is a vector of relevant time-varying characteristics and we discuss in more detail below the time-varying variables we condition on. We then use the predicted values of $EURO\text{-}D_{i,t}$ in to retrieve the causal effect of depressive symptoms on cognitive performance.

To be valid, the instrument must satisfy four conditions. First, it must have a strong effect on mental health. Maternal loss is a shock that can be expected to strongly affects the mental health of the respondents. Previous research suggests that parental deaths has an adverse effect on mental health (Kravdal & Grundy 2016) and subjective well-being, at least in the short-run (Leopold & Lechner 2015). We show that in our sample only maternal death but not paternal death has a statistically significant effect on depressive symptoms.

[9]Activities of daily living include daily self care activities such as bathing, self-feeding, dressing, or grooming.

[10]Instrumental ADL include tasks that are not necessary for fundamental functioning but allow people to live independently; they include activities such as cleaning and maintaining the house, preparing meals, or managing money.

Second, the effect of the instrument on mental health must be monotonic. In other words, while the instrument may have no affect everyone, it must affect everybody who are affected in the same way. One reason why maternal death could result in improved mental health may be that some respondents were providing informal care to their mother before her death and could see their mental health improve as they no longer have caring duties. Existing evidence suggests that care giving has detrimental effect on mental health (Coe & Van Houtven 2009, Heger 2017). To mitigate this issue we condition for whether their father is still alive, and if they provide care for them.

Finally, the instruments must be uncorrelated with the error term ($Cov(\mathbf{z}_{i,t}, u_{i,t}) = 0$). As pointed out by Angrist & Pischke (2009), there are two parts in this assumption. First, the instruments must be as good as randomly assigned. Individuals who have lost their mother may differ in terms of socio-demographic characteristics from those whose mother is still alive. However, we use a Fixed-Effect estimator and rely on the within-individual variation to identify the effect of depression on cognitive performance. Therefore, we only need the exact timing of maternal death to be as good as random, which can reasonably be assumed since maternal death is largely outside of the control of the respondents.

This independence assumption is sufficient to establish that our instruments have a causal effect on cognition, but does not necessarily imply that the causality runs only through the mental health channel. The instruments must further satisfy the exclusion restriction, which, in our context, implies that maternal loss affects the respondent's cognition only though their effect on mental health. Maternal loss is unlikely to have a direct effect on cognitive functions. However, one could argue that the death of their mother could change the propensity to provide informal care. Individuals who used to provide informal care to their mother would no longer have to do so, but on the other hand may have to give further care to their father if still alive. If care giving has a negative effect on cognition, then the FEIV estimates would overstate the effect of depressive symptoms on cognition. If it improves cognition, then our estimates would understate the true effect. While it is well documented in the literature that providing informal care has a strong negative effect on mental health (Coe & Van Houtven 2009, Heger 2017), its effect on cognitive functions is unclear (Bertrand et al. 2012). To mitigate the potential confounding effect of care giving we control for whether the health of the respondent's model and for whether and how often they provide informal care to their mother. We also show that our results are robust to controlling for whether the respondent's father is still alive, and whether they provide informal care for him.

Another potential threat to our identification strategy could be that maternal loss results in reduced social interactions, which could affect cognition directly. To assess whether this is likely to affect our results, we test whether excluding respondents who cohabit with their mother at any point during the study. In another specification, we also exclude respondents who had daily contacts with their mother when alive. In addition, respondents could inherit as a result of maternal death, and this could trigger changes in employment status and income which could affect cognition. To show that this is unlikely to be the case in the short-run, we estimate the reduced-form impact of maternal loss on employment status and income. As an additional robustness check, we also estimate the effect of maternal loss on other outcomes that could affect cognition, such as physical health and types of leisure activities.

Because we have longitudinal data with more than two time periods, the exogeneity of the instruments can be tested empirically by estimating the following augmented model by FEIV (Wooldridge 2010):

$$cog_{i,t} = \beta Euro\text{-}D_{i,t} + \mathbf{z}_{i,t+1}\delta + \mathbf{x}_{i,t}\gamma + c_i + u_{i,t} \tag{3}$$

If we fail to reject the null hypothesis that $\delta = 0$, then we can conclude that the instruments are likely to be strictly exogenous with respect to $u_{i,t}$.

4 Data

We use data from the Survey of Health, Aging and Retirement in Europe (SHARE), a longitudinal study collecting a wealth of information about demographics, socioeconomic status and health of adult aged 50 or over. We use data from the Waves 2, 4, 5 and 6, which were collected between 2006 and 2015 [11]. We restrict the sample to respondents aged between 50 and 70 who were interviewed at least twice and have no missing values in any of the covariates used in the main model. In our analytical sample, we have 41,660 individuals who are observed on average 2.6 times The country covered in our analysis include Austria, Germany, Sweden, Netherlands, Spain, Italy, France, Denmark, Greece, Switzerland, Belgium, Israel, Czech Republic, Poland, Luxembourg, Portugal, Slovenia and Estonia. .

Depressive symptoms are assessed by the EURO-D scale, a 12-point scale developed to ensure comparability across countries (Prince et al. 1999). EURO-D is the sum of 12 binary indicators assessing different symptoms of depression. Respondents were asked to report whether during the past month they experienced any of the following symptoms: depressed mood, pessimism, suicide thoughts, feelings of guilt, lessening of interest in things, irritability, appetite, fatigue, ability to concentrate, enjoyable things and tearfulness. As shown in Table A.1, which reports summary statistics, the average EURO-D score in our sample is 2.2 and 23.7 per cent of the respondents have a score of four or more, which is typically used as an indication that the respondents suffers from depression. Panel A of Figure 1 shows that about a quarter of the respondents have a score of zero, and fewer than five per cent have a core of seven or more. In this paper we use the EURO-D scale as our main measure of depressive disorders, rather than a binary variable indicating if the respondent have a EURO-D score higher than three, because variation in depressive symptoms is more informative about the mental health of the respondent than a binary variable[12]. Panel B displays the proportion of respondents reporting the symptoms that make up the EURO-D scale. Over one third of the respondents report having experienced sadness and difficulty with sleeping over the past month.

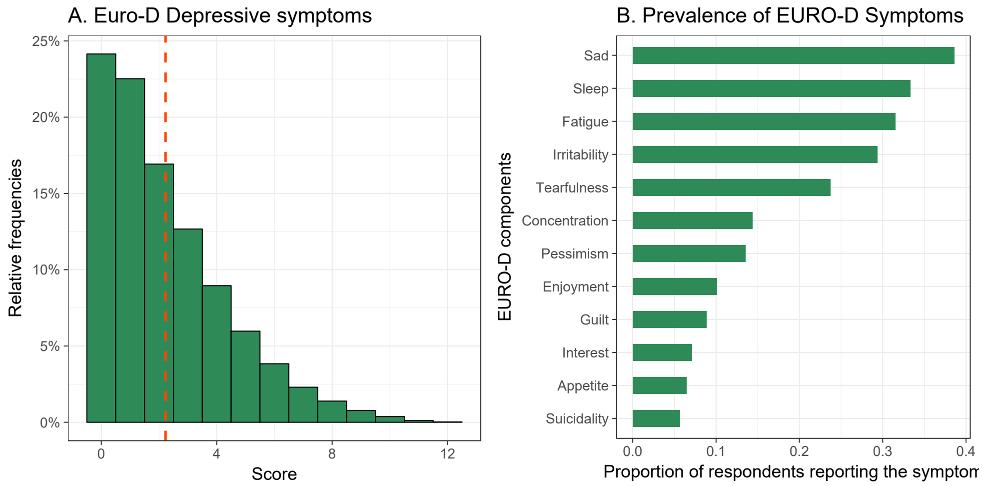
We primarily focus on an overall cognitive score which combines the scores for episodic memory, working memory and verbal fluency.[13] Episodic memory, the memory tied to a specific event, is measured by the immediate and delayed word recall tasks. Immediately after a computer has read a list of 10 words, respondents are asked to give the words from the list in any order. After completing another test was taken, respondents are again asked to remember the words from the list. The combined score of immediate and delayed word recall is normally distributed with a mean of 10.2, as shown in Figrue 2. Working memory, or the short-term integration, processing, disposal and retrieval of information, is assessed by the serial 7 subtraction test. This test is a component of a number of routinely used screening tools for cognitive impairment, such as the Mini Mental State Examination (Crum et al. 1993) Working memory is important in complex cognitive tasks such as learning, reasoning, and comprehension. The main shortcoming with the measure of working memory in SHARE is

[11] We excluded data from Wave 1 because in this wave there is no information on whether the respondent suffers from dementia or Alzheimer. In addition, the test measuring working memory was not administered in Wave 1.

[12] We show that our results are robust to using a binary variable for depression for values higher than three.

[13] We did not include numerical ability as part of this index because it would have resulted in a large drop in the number of observations

Figure 1: Distribution of EURO-D score and prevalence of symptoms

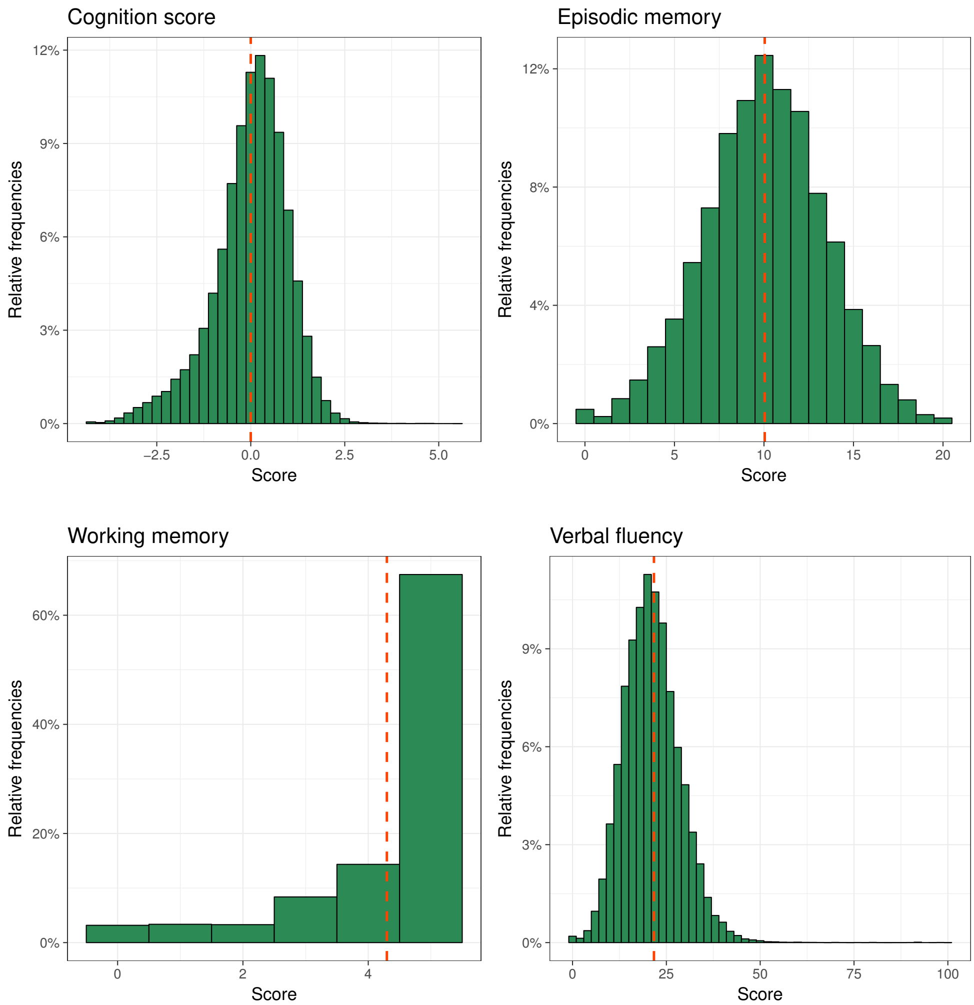


that is does not have much variability: the score ranges from 0 to 5 and nearly two third of respondents score the maximum value (see Figure 2). This test was only administered in waves 4 to 6. Verbal fluency is a test of semantic fluency but also measures some aspects of executive function, since respondents must think of words in the category, avoid duplicates and responses outside of the category, under time pressure. Respondents are asked to name as many animals as possible within one minute. In our sample, the average number of animals given by respondents is 21.9 and the distribution is approximately normal. To construct the overall cognitive score, we standardise the sum the standardised scores, as in Llewellyn et al. (2008). By construction this index has a mean 0 and a standard deviation of one, and the distribution is more or less normal , albeit a bit left-skewed.

In our model we control for a number of time-varying characteristics which may influence both mental health and cognition simultaneously, such as age, labour market status, marital situation and health. Summary statistics for the covariates we include in our models are displayed in Table A.1. Over half (56.4 per cent) of the respondents are female and the average age is 60.53. In our sample, 6.5 percent have limitation with at least one activity of daily living, such as bathing, dressing or personal hygiene, and 9.8 per cent have limitation with at least one instrumental activity of daily living, such as cleaning and maintaining the house, preparing meals, or managing money. 34.3 percent have high blood pressure or hypertension, 22.4 percent have cholesterol

We use recent maternal death as an instrument for depressive symptoms. We can see that 42.8 percent of respondents still had not lost their mother when they joined the study. Just over 10 percent of them lost their mother during the course of the study, which means that our instrument affect a substantial share of our sample.

Figure 2: Distribution of cognitive scores



Note: Sample restricted to those aged 50 or over who have been interviewed at least twice

5 Results

5.1 FE estimates

Table 1 shows Random-Effects (RE) and individual Fixed-Effects (FE) estimates of the effect of depression symptoms measured by the EURO-D scale on the overall cognitive score. Both variables are standardised with a mean of zero and a standard deviation of one. Whereas the RE estimator relies on the assumption that unobserved heterogeneity is not correlated with the independent variables, the FE estimator allows for correlation between independent variables and time-constant unobserved heterogeneity and relies on the assumption that there is no time-varying unobserved heterogeneity.

For each model, we report results from three specifications. In the first set of columns, we show results from models controlling only for age and survey wave, as well as gender, country and highest level of education for RE models. In the second set of columns, the models further include employment status, marital situation, household income and dummies indicating if the household has difficulties in making ends meet as covariates. In the third set of columns, we add information about disability and health to the models, including dummies indicating if the respondent suffers from at least one limitation of activities of daily living (ADL), instrumental ADL, is physically inactive, or suffers from serious health conditions such as heart attack, stroke, diabetes, high blood pressure, cancer, dementia and Alzheimer disease.

Results from both RE and FE estimators suggest that higher depressive symptoms are strongly associated with reduced cognitive performance. The estimated coefficients from FE estimator are smaller than estimates from RE estimators. This suggests that there are time-constant unobserved factors that influence both depression and cognitive performance. A wide range of characteristics that we do not observe are indeed likely to be strongly associated with mental health and cognition, such as socio-economic background (Lynch et al. 2009). The presence of time-constant unobserved heterogeneity is confirmed by the value of the Wu-Hausman statistics. As a result, the FE estimator should be preferred to the RE estimator.

Controlling for labour market and marital status has little effect on the FE estimates. However, including health and disability time-varying variables decreases the estimates slightly, which suggest that changes in physical health are correlated with both depressive symptoms and cognitive performance. The FE estimates with a full set of time-varying covariates, our preferred specification (column 3), indicates that a one standard deviation (SD) increase in the EURO-D scale decreases overall cognitive score by 0.062 of a standard deviation. In term of magnitude, a one SD increase in the EURO-D scale is equivalent to the cognitive decline occurring for each year above 60.

Table 1: RE and FE estimates of the effect of depression on overall cognitive score

	RE			FE		
	(1)	(2)	(3)	(1)	(2)	(3)
Standardised EURO-D	-0.1203***	-0.1061***	-0.0896***	-0.0673***	-0.0667***	-0.0621***
	(0.0032)	(0.0032)	(0.0032)	(0.0041)	(0.0042)	(0.0041)
R-Squared	0.314	0.331	0.341	0.036	0.047	0.067
Observations	93,088	93,088	93,088	93,088	93,088	93,088
Individuals	41561	41561	41561	41561	41561	41561
Hausman test	501.1	1016.6	1046.5			
Individual fixed effects	No	No	No	Yes	Yes	Yes
Labour market and marital status	No	Yes	Yes	No	Yes	Yes
Financial situation	No	Yes	Yes	No	Yes	Yes
Disability and Health	No	No	Yes	No	No	Yes

Note: Sample restricted to those aged 50-70 who have been interviewed at least twice. All models also include age (in year) and wave dummies. Cognitive score and EURO-D scale are standardised with mean 0 and standard deviation 1. RE models also include country, gender and level of highest qualification dummies. Labour market and marital status include dummies indicating if the respondent is employed, retired, married, divorced. Financial situation refers to household income and dummies indicating if the household is able to make ends meet. Disability and Health covariates include dummies indicating if respondent suffer from at least one limitation of activities of daily living (ADL), instrumental ADL, has regular physical activity as well as dummies for serious illnesses, including Alzheimer, dementia and senility. Standard errors clustered at individual level.
*** p<0.01, ** p<0.05, * p<0.1

Table 2 shows RE and FE estimates of the effect of depressive symptoms on episodic memory, working memory and verbal fluency. The models include the same time-varying covariates as in column 3 of Table 1. As for the overall cognitive score, both RE and FE estimates show a negative association between depressive symptoms and the three cognitive functions. The Wu-Hausman test suggests that time-constant unobserved heterogeneity is correlated with the independent variables and therefore the FE estimator should be preferred to the RE estimator. Results from the FE estimator indicate that a one SD increase in the EURO-D scale decreases episodic memory by 0.056 SD, working memory by 0.061 SD, and verbal fluency by 0.032 SD.

Some depressive symptoms may affect cognition more strongly than others. To test for this, we estimate a FE model with all 12 components of the Euro-D scale as independent variables. All individual components are binary variables equal to one if the respondent reports that particular symptom. Figure 3 show the FE estimates of the marginal effect of the different components of the Euro-D scale on the overall cognitive score and the three dimensions of cognition analysed in this paper. Difficulty to concentrate has the largest independent effect of all components on the overall cognitive score. Holding all other components constant, having difficulty to concentrate[14] is associated with cognitive performance by 0.097 of a standard deviation. Difficulty to concentrate also has a strong effect on the three dimensions of cognition we analyse, but the effect is larger on episodic and working memory than on verbal fluency.

Symptoms that can result in low motivation also have a strong effect on cognitive performance. Pessimism, measured by failing to mention any hopes when asked about hopes for the future, as well as not enjoying anything in life and having suicidal thoughts are associated with a decrease in cognitive performance of more than 0.05 SD. Other components that strongly af-

[14]Deficit in attention is associated with depression, and "diminished ability to concentrate" is considered a diagnostic symptom of depression in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5).

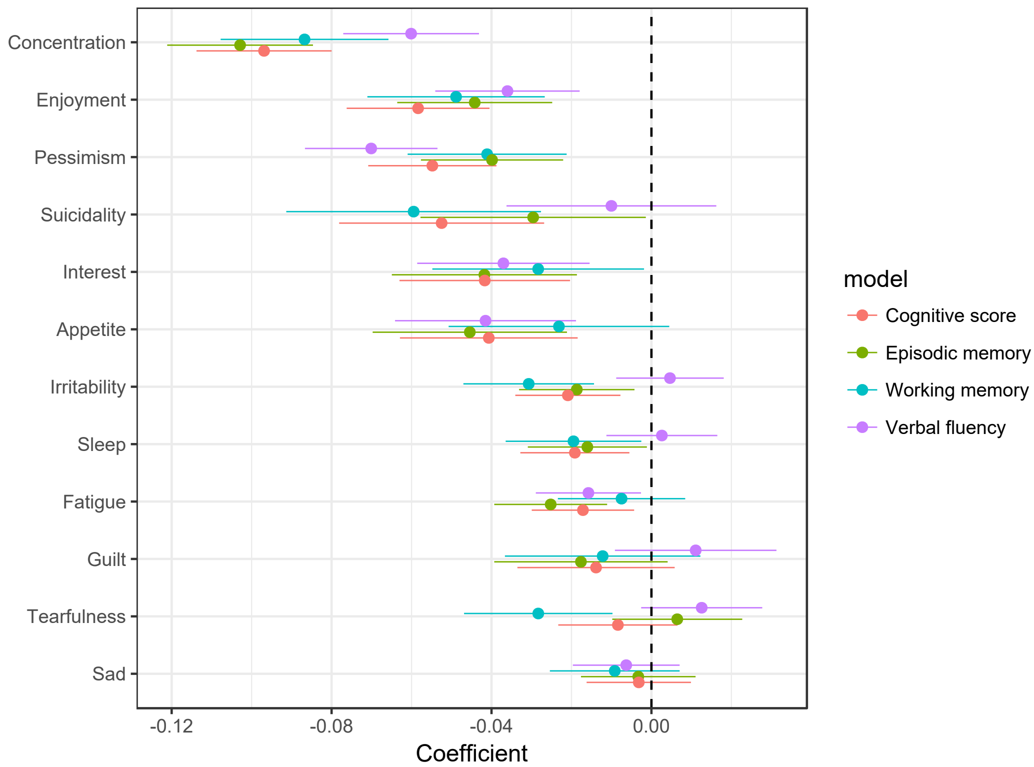
Table 2: RE and FE estimates of the effect of depression on congitive functions

	Memory		Working memory		Verbal fluency	
	RE	FE	RE	FE	RE	FE
Standardised EURO-D	-0.0728***	-0.0563***	-0.0857***	-0.0608***	-0.0494***	-0.0322***
	(0.0032)	(0.0041)	(0.0039)	(0.0053)	(0.0031)	(0.0039)
R-Squared	0.218	0.058	0.184	0.034	0.256	0.025
Observations	107,183	107,183	93,745	93,745	107,213	107,213
Individuals	41632	41632	41633	41633	41637	41637
Hausman test	682.3		525.0		655.8	

Note:Sample restricted to those aged 50-70 who have been interviewed at least twice. All models also include age (in years) wave dummies. Time-varying covariates include log household income, dummies indicating if the respondent is employed, retired, married, divorced, if the household is able to make ends meet, dummies indicating if respondent suffer from at least one limitation of activities of daily living (ADL), instrumental ADL, has regular physical activity as well as dummies for serious illnesses, including Alzheimer, dementia and senility. Standard errors clustered at individual level.
*** p<0.01, ** p<0.05, * p<0.1

fect cognitive performance are lacking interest in anything and appetite. All these symptoms may result in low level of motivation, which could explain the effect on performance at cognitive tests. By contrast, mood-related symptoms, such as being sad, tearful, or irritable have a much smaller, if any, impact on cognition. A similar pattern is observed for all three cognitive functions.

Figure 3: FE Estimate of independent effect of components of Euro-D scale on overall cognitive score



Note: Coefficients and confidence interval for components of the Euro-D scale. Results from a FE model regressing cognitive score on dummy variables for each Euro-D component.

Whilst we control for some time-varying factors likely to affect both mental health and cognition, other factors not included in our models may yet jointly affect mental health and cognitive functions, and generate a negative association between these two outcomes. In addition, even if there were no unobserved time-varying factors affecting both mental health and cognition, the observed association could be due to reverse causation. For instance, a decline in cognitive abilities could trigger depression (Newman 1999), generating a strong association between depressive symptoms. We control for dementia and Alzheimer's disease but some individuals may experience symptoms of dementia without having yet been diagnosed. On the other hand, the FE coefficients may be biased towards zero because of measurement error in the depressive symptoms variable. Measurement error in independent variables may lead to large bias in fixed Effect models, which rely only on the variation within individuals over time.

5.2 FEIV estimates

To address the potential endogeneity of and measurement error in depressive symptoms, we use recent maternal loss as an instrument for depressive symptoms. Our instrument is a binary variable equal to one if the respondent lost their mother between the previous and the current wave. We further restrict our sample to those whose mother was still alive in their first interview. Out of these 12,622 respondents, about a fifth (2,549) lost their mother whilst they were participating in the survey.

The first stage estimates of the FEIV models are reported in Panel A of Table 3. Results from all the model specifications suggest that maternal death has a strong, statistically significant short-term effect on depressive disorders. In column 1 we show results from a model that control only for age and survey wave. Our approach essentially consists of estimating the difference in depressive symptoms reported by respondents in wave following the death of their mother compared to other waves. The estimate of the mental health effects of maternal loss obtained from column 1 would be downward biased if the respondents experience events that may negatively affect their mental health in the years prior to the death of their mother. For instance, their mother may be in poor health and require a lot of informal care in the years before her death. Existing evidence suggests providing care for elderly parents has a negative effect on mental health (Coe & Van Houtven 2009, Heger 2017). In addition, there is some evidence that having parents in poor health may have adverse mental health outcomes, regardless of care provision (Wolf et al. 2015). Because of the relatively short time dimension of our panel, we cannot fully model this process. Instead, we control for the health of respondent's mother, by including dummies for being in fair or poor health, and we also control for how frequently the respondents provide care for their mother, if any at all. Results are reported in column 2 and show that controlling for maternal health and care provision increases the estimate of the effect of maternal loss on depressive symptoms. This is our preferred specification and suggests that recent maternal loss increases depressive symptoms as measured by the EURO-D depressive score by just about 0.127 of a standard deviation. The F-Statistics of our preferred specification is very large, which confirms that the maternal death is a strong predictor of depressive symptoms and can be used as an instrument.

In columns 3 we add the same time-varying variables as in our preferred specification of our FE models. As expected, adding these exogenous control variables has no effect on the estimate. In column 4 we add dummies indicating whether the respondent's father is alive and whether the respondent provides care for their father, in order to account for the fact that maternal death may lead the respondent to provide more care to their father. The estimates are not affected by including these potentially endogenous variables, which suggest that a change in care provision is unlikely to explain the mental health effects of maternal loss. In column 5 we restrict our sample to respondents who were not living in the same household as their parents at any point during the survey. We do so because if they live in the same household the death of their mother may have a direct impact on the respondent cognition, as the respondent may have fewer opportunities to interact with other people. We find that restricting the sample has little effect on the magnitude of the estimates. Finally, in column 6 we include the lag of maternal death as an additional excluded instrument, which is equal to one if the respondent's mother died in between wave $t-2$ and $t-1$. The coefficient of the lag variable is very close to zero and not statistically significant, suggesting that maternal loss only affect mental health in the short-run. The lag should therefore not be used as an excluded instrument since it does not predict current mental health.

Panel B of Table 3 shows FEIV estimates of the effect of depressive symptoms on cognitive performance for the same six specifications as for the First-Stage results. The corresponding reduced form results are shown in Table A.2 in Appendix. For every specification, the FEIV estimates of the effect of depressive symptoms on cognitive performance are negative and statistically significant. Results from our preferred specification (column 2) show that one standard deviation increase in Euro-D scale reduces cognitive performance by 0.311 of a standard deviation. The estimates are larger than FE estimates presented in Table 2 but are not signifi-

Table 3: FEIV estimates of the effect of depression on overall cognitive score

	(1)	(2)	(3)	(4)	(5)	(6)
	A. First Stage: standardised EURO-D score					
Mother death$_t$	0.0849***	0.1265***	0.1244***	0.1286***	0.1190***	0.1246***
	(0.0199)	(0.0219)	(0.0216)	(0.0222)	(0.0224)	(0.0254)
Mother death$_{t-1}$						-0.0064
						(0.0422)
[1em]	B. Second Stage: cognitive score					
Standardised EURO-D	-0.4152**	-0.3105**	-0.3088**	-0.3543**	-0.3017*	-0.3056**
	(0.2064)	(0.1489)	(0.1513)	(0.1543)	(0.1612)	(0.1486)
F- Stat. (excl. inst.)	18.184	33.356	33.080	33.627	28.249	16.743
Z-score (Diff. FE)	1.697	1.644	1.650	1.914	1.534	1.615
Observations	30,632	30,632	30,632	27,764	28,653	30,632
Individuals	12616	12616	12616	11917	11815	12616
Model	age, wave FE	+ mother's health, caring freq.	+ labour, income & health	+ father alive, caring freq.	(2), excl. resp. living with parents	(2)

Note: Sample restricted to those aged 50-70 whose mother was alive in first interview and who have been interviewed at least twice. Cognitive score and EURO-D scale are standardised with mean 0 and standard deviation 1. Instruments: dummy mother's death. Fixed-Effect models estimated via 2SLS. All models include wave and age dummie. Labour and marital status include dummies indicating if the respondent is employed, retired, married and divorced. Income includes household income and dummies indicating if the household is able to make ends meet. Health covariates include dummies for suffering from at least one limitation of activities of daily living (ADL), instrumental ADL, has regular physical activity, as well as dummies for serious illnesses, including Alzheimer, dementia and senility. Standard errors cluster at individual level. Standard errors cluster at individual level.
*** p<0.01, ** p<0.05, * p<0.1

cantly different from the FE estimates obtained on the same sample. [15]. As is common with IV methods, the coefficients are rather imprecisely estimated. The difference in magnitude may be due to measurement error which results in FE coefficients being biased towards zero. More importantly, FE and FEIV estimates may not measure the same estimand. FEIV estimates should be interpreted as Local Average Treatment Effects (LATE), and reflect the cognitive effect of a change in depressive symptoms triggered by recent maternal loss. Maternal loss may affect depressive symptoms differently than other life events that we probably capture in our FE estimates. In Table A.3 we report FE estimates of the effect of maternal death on each of the depressive symptoms contained in the EURO-D scale. Maternal loss does not increase the prevalence of all these depressive symptoms. It has a statistically significant effect on sadness, tearfulness, sleep, lacking interest in anything and appetite. Results reported in Figure 3 indicate that whilst the first two symptoms are not strongly related to cognitive functions, the latter three were strongly associated with cognitive performance. This could explain why the FEIV estimates are larger than the FE estimates. In addition, EURO-D only measures the number of symptoms but not the intensity of the symptoms. If recent maternal death affects not only the prevalence but the intensity of the symptoms, then we would expect the FEIV estimates to be larger than the FE estimates even if these were not biased by endogeneity and measurement error.

[15]We estimate FE models on the same sample as used for the FEIV estimates (respondents whose mother was still alive in their first interview) and calculated significance of the difference between FE and FEIV estimates using Z-score.

Could maternal death affect the respondent's cognition through any channel other than mental health? In table A.4 in Appendix we estimate the effect of maternal death on several outcomes that could indirectly affect cognition. We find that maternal death has no effect on employment and household income. It also has no effect on limitations with activities of daily living or instrumental activities of daily living, nor on physical inactivity. However, there is some indication that losing their mother increases the probability that respondents provide informal care to their surviving father. Providing care for elderly parents has negative effect on mental health (Coe & Van Houtven 2009, Heger 2017) but the effects on cognition are unclear (Bertrand et al. 2012). To test the sensitivity of our results to this, we include a binary variable indicating whether the respondent provides informal care to their father. Estimates reported in column 4 of Table 3 are very similar to those of our preferred specification (column 2).

One could argue that maternal loss could also result in people having fewer social interactions, which could have a direct effect on cognition, as poor social relationships are associated with cognitive decline (Kuiper et al. 2016) . This hypothesis is more likely to hold for people whose main social relationship is their mother, for instance, those who live with their parents, or were very close to their mother. To test whether this hypothesis could be driving our results, we first exclude respondents who lived in the same household as their parents at any point during the survey period. Results are reported in column 5 and show that FEIV estimate is very similar to the estimate of our preferred specification. In Table A.5 in Appendix we also show results for models excluding respondents who used to have daily contacts with their mother (column 2) and who live alone (column 3), as the change in social interactions following maternal loss is likely to be larger for them than other individuals. These restriction have little effect on our results.

Another threat to our identification strategy could be that maternal loss could affect the types of leisure activities the respondents engage in. As leisure activities are associated with cognition (Fratiglioni et al. 2004), a change in leisure activities caused by maternal death could have cognitive effects. These effects would not necessarily be caused by depressive symptoms, thereby threatening the validity of the exclusion restriction. We show in Table A.6 that recent maternal loss has no effect on the leisure activities undertaken by the respondents, which rules out the hypothesis that maternal loss could impact cognition through a change in leisure activities.

In table 4, we show FEIV estimates of the effect of depressive symptoms on the three dimensions of cognitions we focus on in this paper. For each outcome, we present results from a baseline specification which only includes the age of the respondent and the spouse and wave dummies as time-varying covariates, and from our preferred specification which contains the same time-varying covariates as in column 2 of Table 3. The FEIV estimates of the effect of experiencing depressive symptoms on episodic memory are negative but imprecisely estimated and therefore not statistically significant. The FEIV estimates indicate that suffering from depressive symptoms has a strong effect on working memory and verbal fluency.

Table 4: FEIV estimates of the effect of depression on congitive functions

	Memory		Working memory		Verbal fluency	
Standardised EURO-D	-0.4211	-0.2611	-0.6524**	-0.5166***	-0.5075*	-0.4159**
	(0.2611)	(0.1742)	(0.2662)	(0.1880)	(0.2652)	(0.1779)
F- Stat. (excl. inst.)	15.217	31.711	19.234	35.281	14.246	30.408
Z-score (Diff. FE)	1.406	1.185	2.165	2.340	1.811	2.181
Observations	39,588	39,588	30,969	30,969	39,578	39,578
Individuals	15059	15059	12748	12748	15054	15054
Time-varying covariates	No	Yes	No	Yes	No	Yes

Note:Sample restricted to those aged 50 or over who have been interviewed at least twice. All models include age, age-squared and wave dummies, dummies indicating if respondent suffer from at least one limitation of activities of daily living (ADL), instrumental ADL, at least two chronic diseases, is employed, has other activities. Standard errors cluster at individual level.
*** p<0.01, ** p<0.05, * p<0.1

6 Conclusion

In this paper, we provide robust evidence that suffering from depressive symptoms has a negative effect on cognitive abilities amongst older adults. We longitudinal data representative from the population of older adults in 18 European countries which contain a range of cognitive tests and a clinically validated measure of depressive symptoms, the EURO-D scale. First, we show that depressive symptoms are associated with reduced cognitive performance even when controlling for time-invariant heterogeneity with a Fixed-Effect estimator and for a range of time-varying factors that are expected to influence both depressive symptoms and cognition. Second, we analyse the independent effect of each symptom that makes up the EURO-D scale. Our results indicate that the association is driven by both reduced concentration, pessimism and motivation but not by mood-related symptoms, such as sadness or tearfulness. Finally, to test whether the relationship is not driven by time-varying heterogeneity we use recent maternal loss to instrument depressive symptoms. We present evidence that recent maternal loss is an exogenous shock that has a strong short-term effect on depressive symptoms and is unlikely to affect cognition directly. We find that depressive symptoms triggered by recent maternal loss have a strong adverse effect on cognitive performance.

Our main contribution to the literature is to provide direct evidence that depressive symptoms have a causal effect on cognitive performance. Our results complement the findings from clinical trials that antidepressant treatments may have beneficial effects on some cognitive outcomes of depressed patients (Keefe et al. 2014, Rosenblat et al. 2015) and may improve workplace productivity (Berndt et al. 1998), thereby implying that clinical depression may impact cognition. Whilst these studies focus on clinically depressed patients, we show that depressive symptoms in the general population can also affect cognitive performance. Our results suggest that the associations highlighted in the literature between poor mental health and cognitive impairment (Burt et al. 1995, Lichtenberg et al. 1995, Bora et al. 2013) and self-reported productivity (Stewart et al. 2003, Burton et al. 2008, Banerjee et al. 2017, Bubonya et al. 2017) are likely to reflect a causal relationship. Another important contribution to the literature is that we shed light on the mechanisms explaining the links between depression and cognition, by analysing the independent effect of each depressive symptom contained in the EURO-D scale. We find that reduced concentration, pessimism motivation have a strong effect on cognition, whereas emotional symptoms such as sadness or tearfulness have no effect on cognitive performance.

Our study is not without limitations. Because we use recent maternal loss as an instrument, our results should be interpreted as the cognitive effects of depressive symptoms caused by bereavement. Depressive symptoms caused by other life events may have different cognitive effects. Another limitation of our study is that we do not observe productivity at the workplace directly but rely on performance at cognitive tests as a proxy. Further work would be needed to establish beyond doubt that mental health problems affect productivity at the workplace.

These results have nonetheless important implications. Since many tasks in the knowledge-based economy rely on cognitive skills, the cognitive effects of depressive symptoms are likely to affect productivity at the workplace, even among those who are not clinically depressed. Even mild mental health disorders, which are highly prevalent in the population, may have strong effects on cognitive tests. Therefore the economic cost of depression is likely to go beyond its effects on labour market participation. Because most individuals with mental disorders are in work (OECD 2012), reduced workplace productivity may be the largest component of the economic cost of poor mental health. Prevention and treatment of mental health problems are likely to improve cognitive abilities and generate substantial productivity gains. However, further work would be needed to establish beyond doubt that mental health problems affect productivity at the workplace. In addition, the cognitive effects of depression may generate wider social costs as cognitive abilities are crucial for many aspects of everyday life, such as financial decisions (Smith et al. 2010, Agarwal & Mazumder 2013), social relations (Aartsen et al. 2004).

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A Appendix

Table A.1: Descriptive Statistics

	Mean	SD	N
Despression scale EURO-D	2.226	2.142	107,930
EURO-D caseness	0.237	0.426	107,930
Total word recall score	10.16	3.368	107,183
Working memory score	4.313	1.251	93,745
Verbal fluency score	21.93	7.541	107,213
Numeracy score	3.591	1.034	40,323
Orientation to date, month,year and day of week	3.900	0.353	71,341
Overall cognitive score	0.000	1.000	93,088
Female	0.564	0.496	107,930
Age	60.53	5.352	107,930
Married	0.733	0.442	107,930
Employed	0.397	0.489	107,930
Retired	0.420	0.493	107,930
Other	0.183	0.387	107,930
Total household income	38296.4	92406.5	107,930
1+ adl limitations	0.0654	0.247	107,930
1+ iadl limitations	0.0979	0.297	107,930
Physical inactivity	0.0626	0.242	107,930
Heart attack	0.0769	0.266	107,930
High blood pressure or hypertension	0.343	0.475	107,930
High blood cholesterol	0.224	0.417	107,930
Stroke	0.0233	0.151	107,930
Diabetes or high blood sugar	0.107	0.309	107,930
Chronic lung disease	0.0511	0.220	107,930
Cancer	0.0388	0.193	107,930
Stomach or duodenal ulcer, peptic ulcer	0.0397	0.195	107,930
Parkinson disease	0.00334	0.0577	107,930
Cataracts	0.0389	0.193	107,930
Hip fracture or femoral fracture	0.00997	0.0993	107,930
Alzheimer's disease, dementia, senility	0.00349	0.0590	107,930
wave 2	0.129	0.335	107,930
wave 4	0.262	0.440	107,930
wave 5	0.321	0.467	107,930
wave 6	0.288	0.453	107,930
Mother alive in 1st interview	0.428	0.495	93,797
Mother's death	0.102	0.302	40,005
Help mother: No	0.802	0.399	40,157
Almost every day	0.0440	0.205	40,157
Almost every week	0.0769	0.266	40,157
Almost every month	0.0441	0.205	40,157
Less often	0.0332	0.179	40,157
Health of mother: fair	0.277	0.448	40,005
Health of mother: poor	0.167	0.373	40,005
Father alive	0.240	0.427	37,862
Helped Father	0.0388	0.193	40,157

Note: Sample restricted to 50-70 interviewed at least twice

Figure A.1: Correlation of Euro-D components

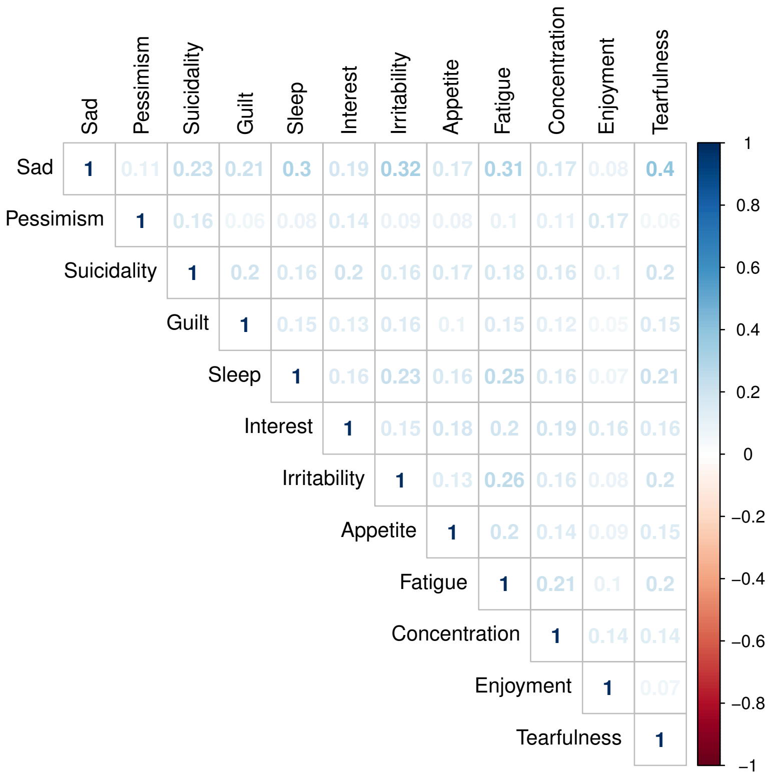

Table A.2: FE estimates of the effect of maternal loss on overall cognitive score

	(1)	(2)	(3)	(4)	(5)	(6)
$Mother\ death_t$	-0.0352**	-0.0393**	-0.0384**	-0.0456**	-0.0359*	-0.0518**
	(0.0163)	(0.0182)	(0.0182)	(0.0188)	(0.0186)	(0.0210)
$Mother\ death_{t-1}$						-0.0437
						(0.0345)
R-Squared	0.009	0.006	0.003	0.000	0.007	0.006
Observations	30,638	30,638	30,638	28,468	28,659	30,638
Individuals	12616	12616	12616	11917	11815	12616
Model	age, wave FE	+ mother in poor health, caring	+ labour, income & health	+ father alive, caring	(2) excl. resp. living with parents	(2)

Note: Sample restricted to those aged 50-70 whose mother was alive in first interview and who have been interviewed at least twice. Cognitive score and EURO-D scale are standardised with mean 0 and standard deviation 1. Labour and marital status include dummies indicating if the respondent is employed, retired, married and divorced. Income includes household income and dummies indicating if the household is able to make ends meet. Health covariates include dummies for suffering from at least one limitation of activities of daily living (ADL), instrumental ADL, has regular physical activity, as well as dummies for serious illnesses, including Alzheimer, dementia and senility. Standard errors cluster at individual level. Standard errors cluster at individual level.
*** p<0.01, ** p<0.05, * p<0.1

Table A.3: FE estimates of effect of maternal death on components of EURO-D

	(1) Depression	(2) Pessimism	(3) Suicidality	(4) Guilt	(5) Sleep	(6) Interest	(7) Irritability	(8) Appetite	(9) Fatigue	(10) Concentration	(11) Enjoyment	(12) Tearfulness
$Mother\ death_t$	0.0487***	-0.0066	0.0011	0.0097	0.0393***	0.0255***	0.0167	0.0222***	0.0197*	0.0012	0.0092	0.0804***
	(0.0121)	(0.0088)	(0.0058)	(0.0075)	(0.0111)	(0.0073)	(0.0114)	(0.0071)	(0.0116)	(0.0088)	(0.0083)	(0.0111)
R-Squared	0.003	0.000	0.000	0.001	0.003	0.002	0.002	0.001	0.000	0.000	0.000	0.003
Observations	31,630	31,630	31,630	31,630	31,630	31,630	31,630	31,630	31,630	31,630	31,630	31,630
Individuals	13614	13614	13614	13614	13614	13614	13614	13614	13614	13614	13614	13614

Note: Sample restricted to those aged 50-70 whose mother was alive in first interview and who have been interviewed at least twice. Time-varying covariates include: age (in years) and wave dummies, mother in poor health, care for mother. Standard errors cluster at individual level.
*** p<0.01, ** p<0.05, * p<0.1

Table A.4: FE estimates of effect of maternal death on several outcomes

	Employed	Log household income	Financial distress	2+ limitations with ADL	2+ limitations with IADL	Physical inactivity	Give care to father
Mother death	-0.0018	-0.0232	0.0086	0.0021	0.0093	-0.0007	0.0087*
	(0.0076)	(0.0375)	(0.0096)	(0.0056)	(0.0066)	(0.0062)	(0.0047)
R-Squared	0.037	0.000	0.006	0.000	0.000	0.002	0.055
Observations	31,630	31,630	31,630	31,630	31,630	31,630	31,630
Individuals	13614	13614	13614	13614	13614	13614	13614

Note: Sample restricted to those aged 50-70 whose mother was alive in first interview and who have been interviewed at least twice. Time-varying covariates include: age and wave dummies, mother's health (fair, poor), frequency care for mother. Standard errors cluster at individual level.
*** p<0.01, ** p<0.05, * p<0.1

Table A.5: Additional specifications - FEIV estimates of the effect of depression on cognition

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	A. First Stage: standardised EURO-D score							
Mother death$_t$	0.1169***	0.1104***	0.1317***	0.1265***	0.1265***	0.1265***	0.1265***	0.1265***
	(0.0269)	(0.0245)	(0.0255)	(0.0219)	(0.0219)	(0.0219)	(0.0219)	(0.0203)
	B. Second Stage: cognitive score							
Standardised EURO-D	-0.4511**	-0.5200**	-0.2778*	-0.3105**			-0.3105**	-0.3105**
	(0.2104)	(0.2075)	(0.1675)	(0.1489)			(0.1489)	(0.1488)
EURO-D caseness					-0.8242**			
					(0.4125)			
EURO-D excl concentration						-0.1477**		
						(0.0707)		
F- Stat. (excl. inst.)	18.911	20.373	26.681	33.356	20.598	37.119	33.356	38.653
Observations	16,759	21,419	22,013	30,632	30,632	30,632	30,632	30,632
Individuals	7095	8830	9130	12616	12616	12616	12616	12616
Sample	Father dead	No daily contact with mother	Married/ cohabiting	Excluding Italy and Spain	All	All	All	All
Estimation	2SLS	2SLS	2SLS	2SLS	2SLS	LIML	2SLS	
Clustered SE	Ind.	Ind.	Ind.	Ind.	Ind.	Ind.	Country	

Note: Sample restricted to those aged 50-70 whose mother was alive in first interview and who have been interviewed at least twice. Cognitive score and EURO-D scale are standardised with mean 0 and standard deviation 1. Instruments: dummy mother's death. Fixed-Effect models estimated via 2SLS. Labour and marital status include dummies indicating if the respondent is employed, retired, married and divorced. Income includes household income and dummies indicating if the household is able to make ends meet. Health covariates include dummies for suffering from at least one limitation of activities of daily living (ADL), instrumental ADL, has regular physical activity, as well as dummies for serious illnesses, including Alzheimer, dementia and senility. Standard errors cluster at individual level. Standard errors cluster at individual level.
*** p<0.01, ** p<0.05, * p<0.1

Table A.6: FE estimates of effect of maternal death on leisure activities

	Voluntary or charity work	Educational or training course	Gone to a sport or social club	Participated in religious organisation	Participated in political or community org.	Read books, magazines or newspaper	Did word or number games	Played cards or board games
Mother death	-0.0030	-0.0042	-0.0036	0.0030	-0.0101	0.0052	0.0127	-0.0181*
	(0.0087)	(0.0091)	(0.0102)	(0.0170)	(0.0063)	(0.0096)	(0.0098)	(0.0107)
R-Squared	0.001	0.022	0.002	0.000	0.000	0.002	0.000	0.003
Observations	31,607	31,607	31,607	12,431	31,607	31,607	31,607	31,607
Individuals	13612	13612	13612	9781	13612	13612	13612	13612

Note: Sample restricted to those aged 50-70 whose mother was alive in first interview and who have been interviewed at least twice. Time-varying covariates include: wave and age dummies, mother's health (fair, poor), frequency care for mother. Standard errors cluster at individual level.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A.7: Testing strict exogeneity of the instruments

	Cognitive score					
	(1)	(2)	(3)	(4)	(5)	(6)
EURO-D	-0.2537	-0.2027	-0.1933	-0.2549	-0.3455	-0.3455
	(0.4245)	(0.3293)	(0.3322)	(0.3425)	(0.3725)	(0.3725)
Mother death $t+1$	0.0371	0.0350	0.0344	0.0272	0.0178	0.0178
	(0.0241)	(0.0271)	(0.0261)	(0.0276)	(0.0308)	(0.0308)
Observations	10,800	10,800	10,800	7,860	10,046	10,046
Individuals	5400	5400	5400	3930	5023	5023
Model	age, wave FE	+ mother's health, caring freq.	+ labour, income & health	+ father alive, caring freq.	(2), excl. resp. living with parents	(2)

Note: Sample restricted to those aged 50-70 whose mother was alive in first interview and who have been interviewed at least twice. Cognitive score and EURO-D scale are standardised with mean 0 and standard deviation 1. Instruments: dummy mother's death. Fixed-Effect models estimated via 2SLS. All models include wave and age dummie. Labour and marital status include dummies indicating if the respondent is employed, retired, married and divorced. Income includes household income and dummies indicating if the household is able to make ends meet. Health covariates include dummies for suffering from at least one limitation of activities of daily living (ADL), instrumental ADL, has regular physical activity, as well as dummies for serious illnesses, including Alzheimer, dementia and senility. Standard errors cluster at individual level. Standard errors cluster at individual level.

*** p<0.01, ** p<0.05, * p<0.1