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Vahé Nafilyan
London School of Hygiene & Tropical Medicine

Mauricio Avendano Pabon
King's College London and Harvard School of Public Health

Augustin de Coulon
King's College London, IZA and LSE

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IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

The Causal Impact of Depression on Cognitive Functioning: Evidence from Europe*

Cognitive skills are important determinants of employment and productivity in older adults. Although cognitive decline is often linked to changes in mental health, the causal nature of the association between mental illness and cognitive performance is not established. In this paper, we analyse the effect of depressive symptoms on cognitive function. Based on longitudinal data for older adults of working age, we use an instrumental variable approach to show that worsening depressive symptoms lead to a decline in cognitive skills. The economic consequences of impaired cognition caused by depressive symptoms may be a large component of mental illness's social costs.

JEL Classification: J24, I10

Keywords: cognitive skills, mental health, longitudinal data

Corresponding author:
Augustin de Coulon
King's College London
London WC2R 2LS
United Kingdom
E-mail: augustin.decoulon@kcl.ac.uk

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1 Introduction

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

Like physical illness, mental health problems impair human capital formation in early life (Currie & Stabile 2006, Johnston et al. 2014, Busch et al. 2014) and reduce labour market participation (Chatterji et al. 2007, Frijters et al. 2014, Banerjee et al. 2017). However, far less is known about the effect of mental health problems on the productivity of older adults. Mental illness, in particular depression, may reduce the productivity of older adults by impairing cognitive decision making (Gotlib & Joormann 2010). The association between depression and impaired cognitive abilities is well established (Bora et al. 2013). Some studies also document that mental health problems are associated with increased absenteeism and reduced self-reported productivity (Stewart et al. 2003, Burton et al. 2008, Banerjee et al. 2017, Bubonya et al. 2017). Yet, establishing whether this association is causal is challenging for several reasons. First, declines in cognitive function and onset of depression are known to share common underlying biological causes. Second, several life-time factors are strongly associated with both depression and cognitive function, such as socio-economic background (Lynch et al. 1997), educational attainment (Glymour et al. 2008, Banks & Mazzonna 2012, Courtin et al. 2019), and physical health (Lindeboom et al. 2002, Dantzer et al. 2008). These confounding factors would generate correlations between mental illness and cognitive impairment even in the absence of a causal link. Third, reverse causality could drive the association, as a decline in cognitive abilities may trigger depression (Newman 1999).

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

In this paper, we estimate the causal effect of suffering from depressive symptoms on cognitive functions amongst older adults of working age. The most rigorous evidence on the effect of suffering from depression on cognitive function is indirect and comes from randomised clinical trials of antidepressants. Some studies suggest that antidepressants improve cognitive function (Keefe et al. 2014, Rosenblat et al. 2015) and productivity at the workplace (Berndt et al. 1998). However, other studies find no evidence of such effect (Shilyansky et al. 2016). A limitation of clinical trials is that they only focus on individuals suffering from major depressive disorders, and in most cases, on selected subgroups of the depressed population, such as those with specific comorbidities. Therefore, these findings may not be generalised to the general population (Keefe et al. 2014), particularly to those suffering from milder forms of mental disorders, which are highly prevalent in the population of older adults. Prior evidence suggests that induced happiness improves performance at numeracy tasks (Oswald et al. 2015); Therefore, mild mental health disorders may also affect cognitive functions.

Using 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, we investigate the links between depressive symptoms and cognitive performance amongst older adults of working age. First, we estimate whether depressive symptoms are associated with cognitive performance once we account for time-invariant heterogeneity and observed time-varying confounders. Using an individual fixed-effect estimator, we find that depressive symptoms are associated with reduced cognitive performance, even after accounting for time-constant unobserved factors and some important time-varying factors, such as changes in marital status and income as well as health shocks. We also estimate the association between cognitive abilities and different depressive symptoms. We find that the association between depressive symptoms and cognitive performance is driven by reduced concentration and motivation but not by emotional symptoms, such as sadness and tearfulness.

To overcome the endogeneity of changes in depressive symptoms, we use an instrumental variable approach that exploits the timing of maternal death as an exogenous shock.

Our identifying assumption is that the timing of maternal death is uncorrelated with other time-varying covariates. We show some evidence that supports the assumption that maternal death is unanticipated and uncorrelated with other changes. Then, we show that recent maternal death has a strong short-term effect on depressive symptoms, and we conduct a set of tests to show that maternal bereavement is unlikely to affect cognition through channels other than mental health. Our Fixed-Effect Instrumental Variable (FEIV) estimates suggest that one standard deviation increase in depressive symptoms due to maternal bereavement reduces cognition by about 0.3 of a standard deviation.

Our paper makes three key contributions to the existing literature. First, we document a robust association between depressive symptoms and reduced cognitive performance using longitudinal data representative of the population of older adults in 18 European countries. Second, we shed light on the possible mechanisms explaining the links between depressive symptoms and cognition by showing that, in our individual fixed-effect models, cognitive performance is associated with reduced concentration and motivation, but not with emotional symptoms. Third, to the best of our knowledge, our study is the first to provide causal evidence that depressive symptoms reduce cognitive performance.

Our results have several important implications. First, as more tasks in the workplace rely on cognitive skills (Autor et al. 2003), the impairment in cognitive performance caused by depressive symptoms is likely to result in lower productivity at the workplace. Second, cognitive impairment may help explain the well-documented effect of depression on key decisions for financial well-being in later life. For example, cognitive effects may explain why older people suffering from depression are more likely to leave the labour market early and acquire risky financial assets, such as stocks and shares (Smith et al. 2010, Agarwal & Mazumder 2013, Bogan & Fertig 2013). Finally, cognitive abilities are also crucial for other important aspects of everyday life, such as social relationships (Aartsen et al. 2004), and represent an important cause of functional disability in later life (McGuire et al. 2006), which increase the demand for health and social care in later life.

2 Mental health and cognitive skills

Most of the literature on the relationship between mental health and cognition focuses on the early years of life. This literature suggests that mental health problems in childhood impair human capital formation in childhood and youth. Following Kessler et al. (1995), several studies have highlighted the association between mental illness and educational attainment using nationally representative data. For instance, 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 and lower college enrollment (Fletcher 2008) in sibling fixed-effect studies (Fletcher 2009). Loss of confidence, anxiety and depression and social dysfunction at a young age are also associated with poorer educational outcomes and the risk of being not in education, employment or training (Cornaglia et al. 2015). A few studies have tried 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 may be 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 and academic outcomes. While these studies suggest that mental health may be causally linked to educational outcomes, they do not explicitly provide direct evidence of a causal link between depression and cognitive performance. Importantly, these studies focus on children and younger adults, but less is known about the consequences of depression for older adults.

The association between depression and cognitive impairment among older adults is well documented in the medical literature (Burt et al. 1995, Lichtenberg et al. 1995, Bora et al.

2013, Keefe et al. 2014). Depression is not only associated with mood, but also with anxiety, difficulty with concentration, and feelings of worthlessness, all of which may affect 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). Poor mental health is also 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). The main limitation of these studies is that while they highlight a strong association between clinical depression and decline in cognitive functions, the extent to which this relationship is causal is not clear. Many factors are strongly associated with both mental health and cognition, such as socio-economic background (Lynch et al. 1997), educational attainment (Glymour et al. 2008, Banks & Mazzonna 2012, Courtin et al. 2019), employment and physical health (Lindeboom et al. 2002, Dantzer et al. 2008). Besides, there is evidence that a decline in cognitive abilities can trigger depression (Newman 1999). A strong identification strategy that addresses endogeneity is required to establish a causal effect.

Randomised clinical trials (RCT) of antidepressants provide the most reliable evidence on the cognitive effects of depression on cognitive function. The literature reviews from clinical trials suggest that antidepressant treatments may improve some cognitive outcomes of depressed patients (Keefe et al. 2014, Rosenblat et al. 2015) and productivity at the workplace (Berndt et al. 1998). However, not all studies report positive effects: results from a recent large-scale study found that typical antidepressants do not improve cognitive function of depressed patients (Shilyansky et al. 2016). These studies, based on an RCT desgin, are not without limitations. Most of them focus on small samples of individuals suffering from major depressive disorders, and in most cases, on selected subgroups of people with physical health comorbidities. It not well understood whether the findings from this literature can be generalised to the population (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 population. While depression and psychological well-being are distinct concepts, a strand of the literature suggests that psychological well-being is associated with cognitive function in the general population (Llewellyn et al. 2008). In addition, some experimental evidence suggests that happiness may influence productivity (Oswald et al. 2015).[2] Yet, whether mental health problems, such as depressive symptoms, affect cognitive performance and productivity remains an open question.

Although no study has examined the causal impact of mental health on cognition, several studies have tried to estimate the causal effect of suffering from mental health problem on labour market outcomes using an instrumental variable approach. Instruments used include a 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) and religiosity (Chatterji et al. 2007). These studies conclude that mental health problems reduce employment and labour force participation and increase absenteeism. However, these studies were cross-sectional and based on time-constant instruments. The validity of the exclusion restriction for the selected instruments is often difficult to defend. The most rigorous evidence comes fromFrijters et al. (2014), who exploit longitudinal data and 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. None of these studies considered cognitive function as a potential mechanism or focused particularly in older workers, where both depressive symptoms and cognitive decline are more likely to co-exist. In this paper, we investigate the effect of depressive symptoms on cognitive performance. Using longitudinal data from a representative sample of older adults (50-65 years) in 18 European countries, we use the death of the respondent's mother as a shock to test whether an increase in depressive symptoms has a causal impact on cognitive performance. Our paper is the first to provide evidence that suffering from depressive symptoms has a causal effect on cognitive performance. We also investigate which depressive symptoms are most strongly related to a worsening in cognitive performance, shedding light on the mechanisms that link depression and cognitive performance.

[2]Based on a series of experiments which manipulated the happiness of university student through short-term shocks, such as watching a short comedy film, or providing chocolate and other treats, (Oswald et al. 2015) conclude that happiness affects performance in a numeracy task designed to measure productivity.

3 Data

We use data from the Survey of Health, Ageing and Retirement in Europe (SHARE), a longitudinal study collecting a wealth of information about demographics, socioeconomic status and health of adult aged 50 and over. We use data from the Waves 4 to 7, which were collected biennially from 2011 to 2017.[3] The countries covered in our analysis are Austria, Germany, Sweden, Netherlands, Spain, Italy, France, Denmark, Greece, Switzerland, Belgium, Israel, Czech Republic, Poland, Luxembourg, Portugal, Slovenia and Estonia. We restrict the sample to older respondents of working age (50 and 65) who were interviewed at least twice and were asked the depression score questions (28,198 individuals) and have no missing values in any of the variables used in the main models (27,315 individuals). Individuals are observed on average 2.5 times, with about 31.0 per cent being observed in waves 4 to 6, 29.0 per cent in waves 5 and 6, 21.8 in waves 4 and 5 and 6.7 per cent in all four waves. The sample was boosted in recent years, so only a small fraction of respondents were observed in all years. All variables used in this analysis are summarised in Table 1.

Our primary outcome is an overall cognitive index score which combines the scores for episodic memory, working memory and verbal fluency.[4] 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 were asked to give the words from the list in any order. After completing another test, respondents were again asked to give 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 Figure 1. Working memory, or the short-term integration, processing, disposal and retrieval of information, is assessed by the serial sevens test. In this test, respondents were asked to count down from one hundred by sevens. This test is a component of several routinely used screening tools for cognitive impairment, such as the Mini Mental State Examination (Crum et al. 1993). Working memory

[3]We excluded data from Wave 1 because it included no information on whether respondents have dementia or Alzheimer. In addition, the test measuring working memory was not administered in Wave 1. Wave 3 collected life history information and was not comparable to other waves.

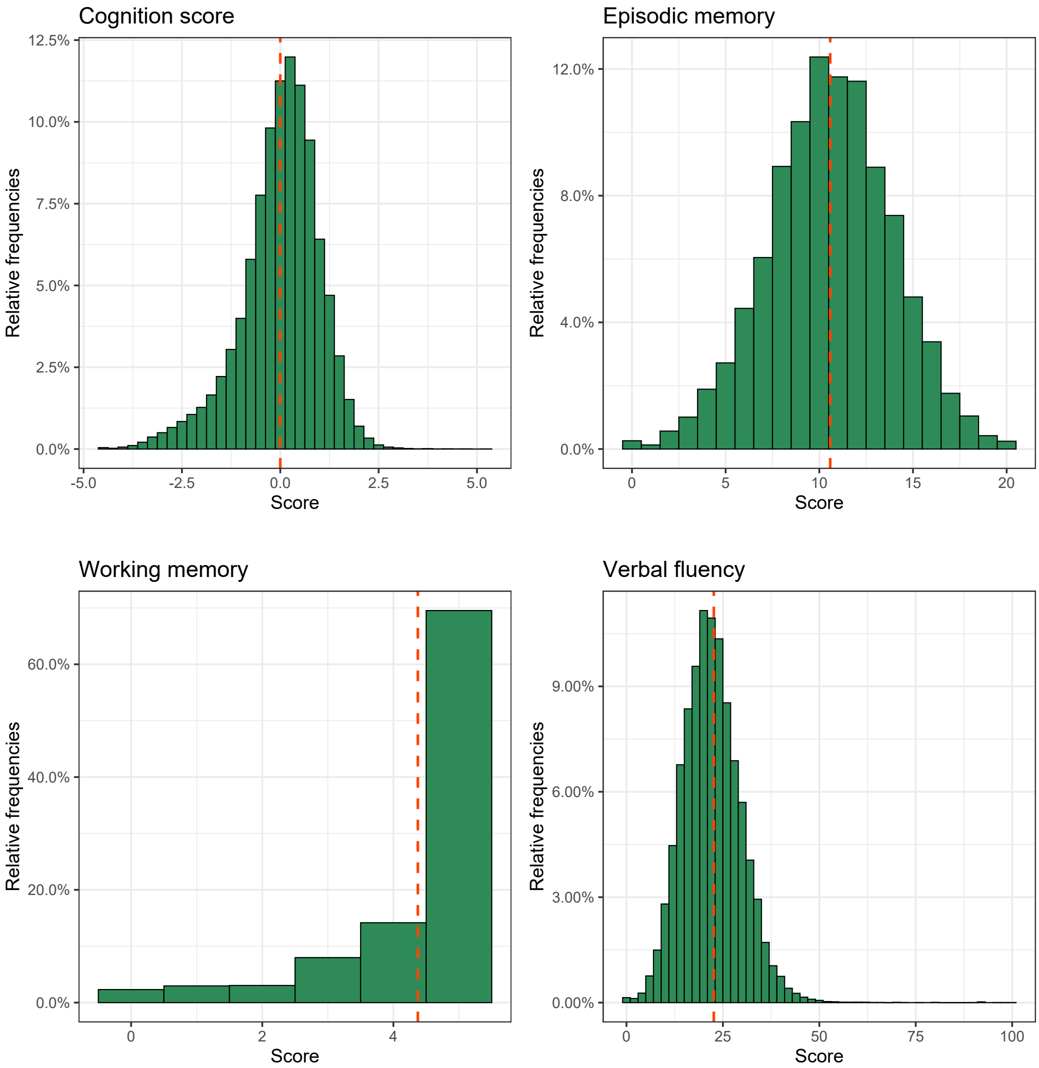
[4]We excluded numerical ability as part of this index because it would have resulted in a large drop in the number of observations.

is essential in complex cognitive tasks such as learning, reasoning, and comprehension. The main shortcoming with the measure of working memory in SHARE is that it does not have much variability: the score ranges from zero to five, but nearly two-third of respondents score the maximum value (see Figure 1). In addition, this test was only administered in waves 4 to 7. 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 were 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 zero and a standard deviation of one, and the distribution is more or less normal, albeit a bit left-skewed.

Our primary variable of interest is depressive symptoms assessed by the EURO-D scale, a 12-point scale explicitly designed to measure depressive symptoms among older people whilst ensuring comparability across countries (Prince et al. 1999). The EURO-D score is the sum of 12 binary indicators assessing different symptoms of depression. Respondents were asked to report whether in 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, enjoy 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 23.8 per cent of the respondents have a score of four or more, which is used as an indication for probable depression. Panel A of Figure 2 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. We use the EURO-D scale as our main measure of depressive symptoms, rather than a binary variable indicating if the respondent have a EURO-D score higher than four, because variation in depressive symptoms is more informative about the mental health of the respondent than a binary variable.[5] Panel B displays the proportion of respondents

[5]However, we show that our results are robust to using a binary variable for depression for values higher than four.

Figure 1: Distribution of cognitive scores



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

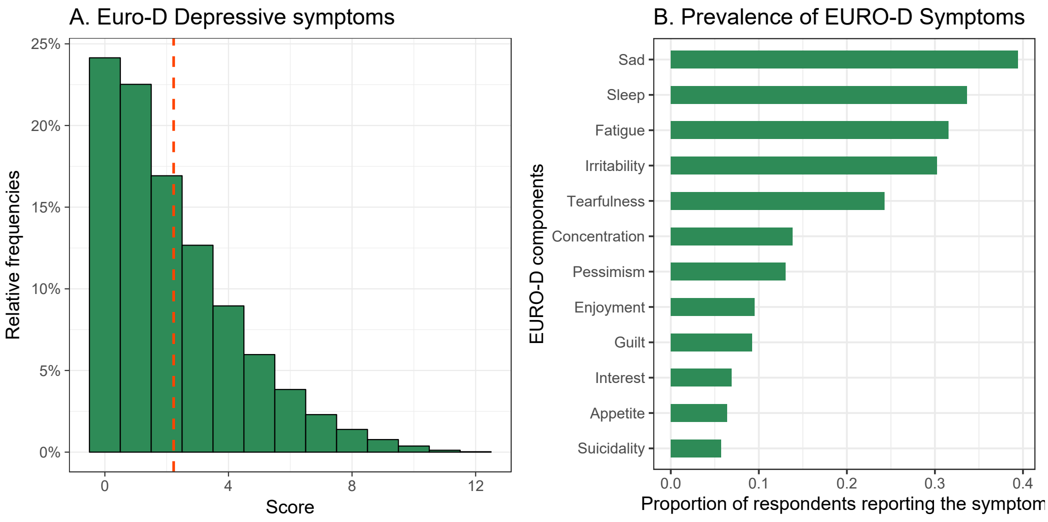
Table 1: Description of variables used in the analysis

Variable	Description
	Outcomes
Total word recall score	Immediate and delayed word recall tasks
Working memory score	Serial 7 subtraction test
Verbal fluency score	Animal names test
Overall cognitive score	Standardise sum the standardised scores working memory and fluency scores
	Exposure
Depression scale EURO-D	number of depressive symptoms (0 to 12)
EURO-D caseness	Depression scale EURO-D of 3 or more
	Covariates
Female	Binary variable for females
Age	Age in years
Marital status	Single/Widowed, Married, Divorced
Employment status	Employed, retired, other
Total household income	Log of monthly household income
Household able to make ends meet	No difficulty, some difficulty, great difficulty
1+ ADL limitations	Limitation with at least one activity of daily living (ADL)
1+ IADL limitations	limitation with at least one instrumental activity of daily living
Physical inactivity	Low level of physical activity
Health conditions	Binary variables for heart attack, high blood pressure, high blood cholesterol, stroke diabetes, chronic lung disease, cancer, digestive disorders, Parkinson disease, hip or femoral fracture, Alzheimer's disease or dementia.
	Instrument and relevant controls
Mother's death	Dummy for mother's death between previous and current wave
Father alive	Dummy for father being alive in current wave
Informal care for mother	Yes, No
Informal care for father	Yes, No
Health of mother	Poor, Fair, Good
Health of father	Poor, Fair, Good

reporting the symptoms that make up the EURO-D scale. Over one-third of the respondents reported having experienced sadness and difficulty sleeping in the past month, whilst just over 5 per cent reported having suicidal thoughts and a loss of appetite.

In our model, we control for many time-varying characteristics, which may simultaneously influence mental health and cognition, including age, labour market status, marital situation, and health (listed in Table 1. Summary statistics for the covariates we include in our models are displayed in Table A.1 in Appendix. Over half (56.4 per cent) of the respondents are female, and the mean age is 60.5. In our sample, 6.5 percent have limitation with at least one activity of daily living, such as bathing, dressing or personal hygiene; 9.8 per cent have limitation with at least one instrumental activity of daily living, such as cleaning and

Figure 2: Distribution of EURO-D score and prevalence of symptoms



maintaining the house, preparing meals, or managing money. Over a third (34.3 per cent) have high blood pressure or hypertension and 22.4 per cent cholesterol. Only 0.3 per cent of our respondents report having Alzheimer's disease or dementia. Although self-reports are likely inaccurate, this is consistent with evidence that before age 65, Alzheimer's disease and dementia have very low (van der Flier & Scheltens 2005) .

We use recent maternal death as an instrument for depressive symptoms. Out of the 41,660 individuals in our sample, 15,747 still had a living mother in their first interview. Our instrument affects a substantial share of respondents in our sample, as nearly 30 per cent (4,661) lost their mother whilst participating in the survey. Just over 10 per cent of person-wave observations report having lost their mother between the previous and current wave.

4 Empirical Approach

Identifying the causal effect of depressive symptoms on cognitive performance is challenging because many factors are likely to influence mental health and cognitive function simultaneously. Exploiting the longitudinal dimension of our data, we model cognitive performance as a function of depressive symptoms, some time-varying factors and an individual effect:

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

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 a Fixed-Effect (FE) estimator, which allows for unobserved time-invariant heterogeneity. 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. To control for time-varying heterogeneity, we include a vector $\mathbf{x}_{i,t}$ of time-varying characteristics which are likely to affect both depressive symptoms 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 adjust for the individual's labour market and marital status. Income change may also affect mental health. There is growing evidence that poverty and worry about money may reduce the amount of cognitive resources that can be allocated to other tasks, resulting in poorer cognitive performance (Mani et al. 2013). To account for this, we adjust for household income and having difficulties in making ends meet.

Physical health shocks are also expected to affect both mental health and cognition. For instance, the onset of cancer is known to trigger depression (Mitchell et al. 2011) and there is some evidence that cancer treatment may reduce 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), instrumental ADL, is physically active, and dummies for self-reports of a doctor diagnosis of serious health conditions, such as heart attack, stroke, diabetes, high blood pressure, cancer, dementia and

Alzheimer's disease.[6] Yet, these FE estimates are likely to be biased, for three reasons. First, unobserved shocks may 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 depressive symptoms on cognitive symptoms. Second, even if no unobserved time-varying factors affected both mental health and cognition, the observed association could be generated by reverse causation. For instance, a decline in cognitive abilities could trigger depression (Newman 1999), generating a strong association between depressive symptoms and cognitive performance, even after accounting for time-invariant heterogeneity. Whilst we control for self-reports of dementia and Alzheimer's disease, most individuals may experience symptoms of dementia without having yet been diagnosed. Third, the FE estimates may be biased because of measurement error in the depressive symptoms variable. Measurement error would lead the FE estimates to be biased towards zero. This attenuation bias may be large in FE models, which rely only on variation within individuals over time.

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 depressive symptoms using the following estimation equation:

$$EURO\text{-}D_{i,t} = \theta Motherdeath_{i,t} + \mathbf{x}_{i,t}\delta + c_i + v_{i,t} \qquad (2)$$

Where $Motherdeath_{i,t}$ is binary variable indicating whether the respondent lost their mother between the current (t) and previous ($t-1$) wave of the survey. $\mathbf{x}_{i,t}$ is a vector of relevant time-varying characteristics, which we discuss in more detail below. We combine

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

equations 1 and 2 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 depressive symptoms. Maternal loss is a shock that can be expected to affect the mental health of the respondents strongly. Previous research suggests that parental death has an adverse effect on mental health (Kravdal & Grundy 2016) and subjective well-being, at least in the short-run (Leopold & Lechner 2015). In our sample, maternal death has a statistically significant effect on depressive symptoms. However, paternal death does not affect depressive symptoms.

Second, the effect of the instrument on depressive symptoms must be monotonic. While the instrument may not affect everybody's depressive symptoms, the direction of the effect must be the same for all those who are affected. Maternal death may improve mental health for people who provided informal care to their mother before her death. Their mother's death may improve their mental health if the care provision strongly affects their mental health. Existing evidence suggests that caregiving has a detrimental effect on mental health (Coe & Van Houtven 2009, Heger 2017). We discuss in detail below how we mitigate the potential confounding effect of caregiving.

Third, the assignment of the instrument must be as good as random. 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 FE estimator and hence rely on the within-individual variation to identify the effect of depressive symptoms 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 respondents' control. We test the exogeneity of maternal death ($Motherdeath_{i,t+1}$) by including the first order leading term of our instrument in the equation (Wooldridge 2010). Under the null hypothesis of strict exogeneity, the coefficient should be equal to zero.

This independence assumption is sufficient to establish that our instrument has a causal effect on cognition. Yet, it does not necessarily imply that the causality runs only through the depressive symptoms channel. The instruments must further satisfy the exclusion restriction, which, in our context, implies that maternal loss affects the respondent's cognition only though its effect on depressive symptoms. Maternal loss is unlikely to have a direct effect on cognitive functions. However, the death of their mother could change the propensity to provide informal care in two ways. First, those who used to provide informal care to their mother would no longer have to do so. Second, some people may have to give extra care to their surviving father. If caregiving harms cognition, then the Fixed-Effects Instrumental Variable (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 caregiving, we control the respondent's mother's health and 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 is that maternal loss may reduce social interactions, which could affect cognition. As a sensitivity analysis, we test whether our results are robust to excluding respondents cohabiting 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. Furthermore, respondents could inherit after the death of their mother. An increase in wealth could trigger changes in employment status, 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. 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.

5 Results

5.1 FE estimates

Table 2 shows Random-Effects (RE) and individual Fixed-Effects (FE) estimates of the association between depressive symptoms measured by the EURO-D scale and the overall cognitive score. Both variables are standardised with a mean of zero and a standard deviation of one.

For each model, we report results from three specifications. In the first set of columns, we show results adjusted for age and survey wave. RE models are also adjusted for gender, country and highest level of education. In the second set of columns, the models further include employment status, marital situation, household income and dummies indicating if the household has difficulties making ends meet. In the third set of columns, we adjust for disability and health, by 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 severe health conditions such as heart attack, stroke, diabetes, high blood pressure, cancer, dementia and Alzheimer disease.

Both RE and FE estimates show that higher depressive symptoms are strongly associated with reduced cognitive performance. The estimated coefficients from the FE estimators are smaller than estimates from the RE estimators. This suggests that there are time-constant unobserved factors that influence both depressive symptoms and cognitive performance. Many unmeasured characteristics are likely to be strongly associated with mental health and cognition, such as socio-economic background (Lynch et al. 1997). The Wu-Hausman statistics confirm the presence of time-constant unobserved heterogeneity. As a result, the FE estimator should be preferred to the RE estimator.

Controlling for the labour market and marital status has little effect on the FE estimates. However, adjusting for health and disability decreases the estimated coefficients slightly, which indicates that changes in physical health are correlated with changes in both depressive symptoms and cognitive performance. In our preferred specification (column 6), we estimate that one standard deviation (SD) increase in the EURO-D scale is associated with a 0.069 SD decrease in the overall cognitive score. In terms of magnitude, this is equivalent to the cognitive decline occurring for each year above 60.

Table 2: RE and FE estimates of the effect of depression on overall cognitive score

	RE			FE		
	(1)	(2)	(3)	(4)	(5)	(6)
Standardised EURO-D	-0.1136***	-0.0977***	-0.0838***	-0.0751***	-0.0741***	-0.0691***
	(0.0039)	(0.0039)	(0.0039)	(0.0049)	(0.0049)	(0.0049)
R-Squared	0.284	0.306	0.313	0.038	0.046	0.058
Observations	67,274	67,274	67,274	67,274	67,274	67,274
Individuals	27315	27315	27315	27315	27315	27315
Hausman test	429.1	897.1	930.2			
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 50-65 who were 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 3 shows RE and FE estimates of the association between depressive symptoms and three measures of cognitive functions - episodic memory, working memory and verbal fluency. The models are adjusted for the same time-varying covariates as in our preferred specification. For the overall cognitive score, both RE and FE estimates show a negative association between depressive symptoms and these three cognitive functions. The Wu-Hausman tests also suggest that time-constant unobserved heterogeneity is correlated with the independent variables; therefore, the FE estimator should be preferred to the RE estimator. We estimate that one SD increase in the EURO-D scale decreases episodic memory by 0.052 SD, working memory by 0.075 SD, and verbal fluency by 0.028 SD.

Some depressive symptoms may affect cognition more strongly than others. To test whether some depressive symptoms are more strongly associated with cognitive perfor-

Table 3: 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	-0.0652***	-0.0520***	-0.0848***	-0.0745***	-0.0408***	-0.0284***
	(0.0041)	(0.0054)	(0.0047)	(0.0063)	(0.0040)	(0.0053)
R-Squared	0.200	0.017	0.174	0.035	0.221	0.021
Observations	67,274	67,274	67,274	67,274	67,274	67,274
Individuals	27315	27315	27315	27315	27315	27315
Hausman test	533.7		337.8		915.6	

Note:Sample restricted to those aged 50-65 who were 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

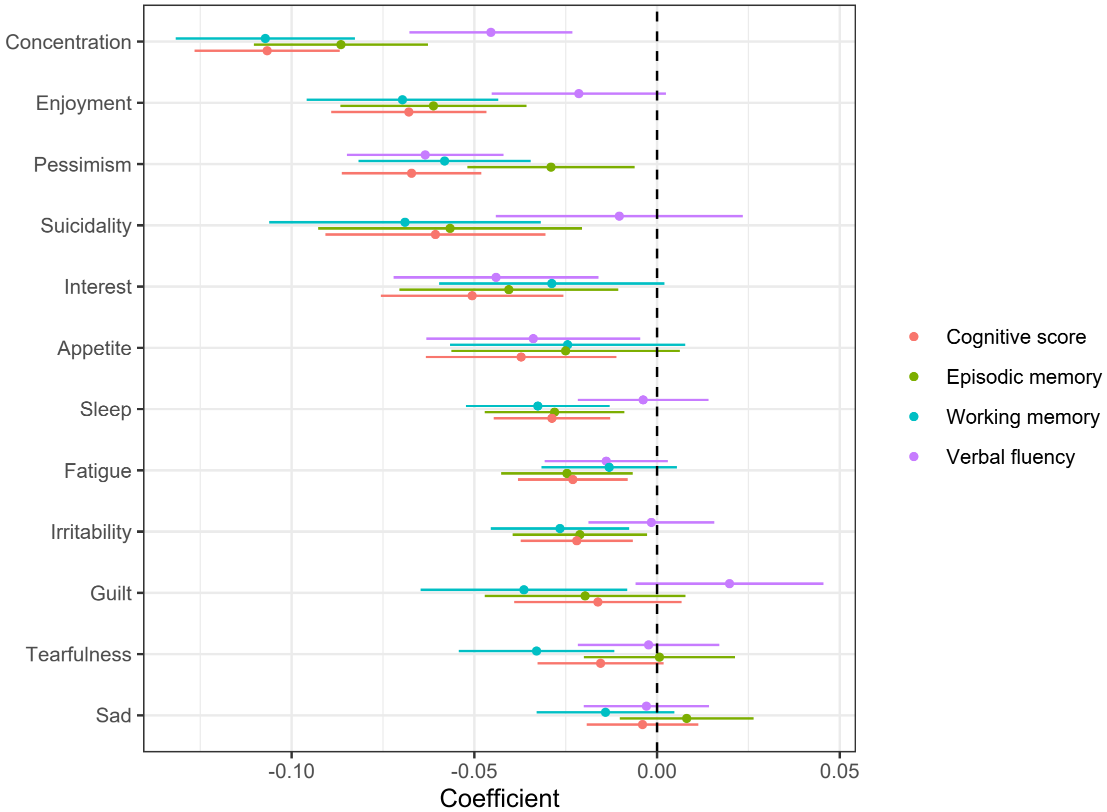
mance than others, we estimate a FE model with the 12 components of the Euro-D scale included as independent variables. All individual components are binary variables for reporting that particular symptom. Figure 3 reports the FE estimates of the association between each component of the Euro-D scale and the overall cognitive score. It also shows results for the three dimensions of cognition analysed in this paper. Difficulty to concentrate is the depressive symptom most strongly associated with the overall cognitive score.[7] Holding all other components constant, having difficulty to concentrate is associated with a decrease in cognitive performance of 0.107 of a standard deviation. Difficulty to concentrate is also associated with the three dimensions of cognition we analyse. The association is larger for episodic and working memory than on verbal fluency.

Symptoms that can result in low motivation are also strongly associated with cognitive performance. For instance, being pessimistic, measured by failing to mention any hopes when asked about hopes for the future, not enjoying anything in life, having suicidal thoughts and lacking interest are associated with a decrease in cognitive performance of more than 0.05 SD. Lacking interest in anything and loss of appetite are also associated with a reduction in cognitive performance. By contrast, emotional symptoms, such as being sad,

[7] "Diminished ability to concentrate" is considered a diagnostic symptom of depression in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5).

tearful, or irritable are only weakly, if at all, associated with cognition. The associations are smaller for verbal fluency than for working memory and episodic memory.

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



Note: Coefficients and 95% 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. Sample restricted to those aged 50-65 who were 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 suffers 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 the individual level.

5.2 FEIV estimates

As discussed in Section 4, the FE estimates are likely to be biased because of unobserved shocks that affect both depressive symptoms and cognition, potential reverse causality and measurement error. We use recent maternal loss as an instrument for depressive symptoms to address these potential sources of bias. Our instrument is a binary variable equal to one if the respondent lost their mother between the previous and the current wave. We restrict our sample to those whose mother was still alive in their first interview.

The first stage estimates of the FEIV models are reported in Panel A of Table 4. Results from all model specifications suggest that maternal death has a large and statistically significant short-term effect on depressive symptoms. In column 1, we show results from a model adjusted only for age and survey wave. Our approach essentially consists of estimating the difference in depressive symptoms reported by respondents in the wave following their mother's death compared to the average in other waves. The estimate of the effect 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 before losing their mother. For instance, their mother may be in poor health and require much informal care in the years before her death. Existing evidence suggests that providing care for older parents has a negative effect on mental health (Coe & Van Houtven 2009, Heger 2017). Besides, having parents in poor health may also have adverse mental health effects, regardless of care provision (Wolf et al. 2015). Because of the relatively short time dimension of our panel, we cannot fully model this dynamic process. Instead, we control for the health of respondent's mother, by including dummies for their mother's being in fair or poor health. We also adjust for the frequency of informal care provision to their mother. 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 measured by the EURO-D depressive score by 0.100 of a standard deviation. As indicated by the large F-statistics, recent maternal death is a strong predictor of depressive symptoms and can be used as an instrument.

In columns 3 to 6, we show that estimates of the effect of maternal loss on depressive symptoms are robust to including additional time-varying covariates. In columns 3, we add the same variables as in our preferred specification of our FE models. As expected, adding these exogenous control variables does not affect the estimate. In column 4, to account for the potential increase in care provision to their surviving father that may follow maternal loss, we add dummies indicating whether the respondent's father is alive and whether the respondent provides care for their father. Including these potentially endogenous variables does not affect our estimates. Therefore, a change in care provision is unlikely to explain the mental health effects of maternal loss. In column 5, we restrict the sample to respondents not living in the same household as their parents at any point during the survey. Maternal death may directly affect the cognition of those who lived in the same household as their mother, as they 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, equal to one if the respondent's mother died between wave $t-2$ and $t-1$. The coefficient of the lag variable is close to zero and not statistically significant, suggesting that maternal loss affects mental health only in the short-run. Because it does not predict the level of depressive symptoms, we do not use the lag as an excluded instrument in our preferred specification. The test for strict exogeneity of the instrument proposed by Wooldridge (2010) suggests that the instrument is exogenous (See Table A.4 in the Appendix).

Panel B of Table 4 reports the 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.3 in the Appendix. For every specification, the FEIV estimates of the effect of depressive symptoms on cognitive performance are negative and statistically significant. In our preferred specification (column 2), one standard deviation increase in Euro-D scale is estimated to reduce cognitive performance by 0.340 of a standard deviation. The estimates are larger than the FE estimates presented in Table 3 but are not significantly different from the FE estimates obtained on the same sample.[8] As is common with IV methods, the coefficients are imprecisely estimated.

The difference in magnitude may be due to measurement error which would bias the FE coefficients towards zero. More importantly, the difference between the FE and FEIV estimates may be due to the two approaches having different estimands. The FEIV estimates

[8]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.

Table 4: FEIV estimates of the effect of depression on overall cognitive score

	(1)	(2)	(3)	(4)	(5)	(6)
	A. First Stage: standardised EURO-D score					
$Mother\ death_t$	0.0684***	0.0966***	0.0929***	0.0990***	0.0956***	0.1093***
	(0.0174)	(0.0183)	(0.0181)	(0.0185)	(0.0186)	(0.0210)
$Mother\ death_{t-1}$						0.0354
	B. Second Stage: cognitive score					
Standardised EURO-D	-0.3879*	-0.3396**	-0.3487**	-0.3566**	-0.3197*	-0.2878*
	(0.2230)	(0.1661)	(0.1732)	(0.1687)	(0.1694)	(0.1587)
F- Stat. (excl. inst.)	15.512	27.750	26.474	28.637	26.327	14.578
Z-score (Diff. FE)	1.402	1.651	1.681	1.777	1.520	1.402
Observations	31,147	31,147	31,147	28,402	29,372	31,147
Individuals	12462	12462	12462	11752	11768	12462
Model	age, wave FE	+ mother's health, caring	+ labour, income & health	+ father alive, caring	(2), excl. resp. living with parents	(2)

Note: Sample restricted to those aged 50-65 whose mother was alive in first interview and who were interviewed at least twice. Cognitive score and EURO-D scale are standardised with mean 0 and standard deviation 1. Instruments: dummy for mother's death. Fixed-Effect models estimated via 2SLS. All models include wave and age dummies. 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. Z-scores indicate the difference with FE estimates obtained on the same sample.
*** p<0.01, ** p<0.05, * p<0.1

should be interpreted as Local Average Treatment Effects (LATE); they measure the cognitive effects of a change in depressive symptoms triggered by recent maternal loss. Maternal loss may affect depressive symptoms differently than other life events captured in the FE estimates. In Table A.5 in the Appendix, we report FE estimates of the effect of maternal death on each of the depressive symptoms contained in the EURO-D scale. Maternal loss has a statistically significant effect on sadness, tearfulness, sleep, lacking interest in anything and appetite. Results reported in Figure 3 indicate that whilst sadness and tearfulness are not strongly related to cognitive functions, sleep problems, lacking interest in anything and loss of appetite were strongly associated with cognitive performance. This could explain why the FEIV estimates are larger than the FE estimates. In addition, the EURO-D only measures the number of symptoms but not their intensity. If recent maternal death affects not only the prevalence but also 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.

Could maternal death affect the respondent's cognition through channels other than mental health? In Table A.6 in the 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, marital status, health, physical inactivity, and caring for a surviving father. Nonetheless, to test the sensitivity of our results to changes in caregiving patterns, we control for whether the respondent provides informal care to their father and if they do, the frequency. Estimates reported in column 4 of Table 4 are very similar to those of our preferred specification (column 2).

Maternal loss could also result in people having fewer social interactions. A reduction in interactions with others could directly affect 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 with their mother, for instance, if they live with 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 reported in column 5 show that the estimate is very similar to the estimate of our preferred specification. In Table A.7 in the 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 restrictions have little effect on our results.

Another threat to the exclusion restriction's validity is that maternal loss could affect the types of leisure activities the respondents engage in. As leisure activities are associated with cognitive functions (Fratiglioni et al. 2004), a change in leisure activities caused by maternal death could affect cognitive performance. Depressive symptoms would not necessarily cause these effects, thereby threatening the validity of the exclusion restriction. We show in Table A.8 that recent maternal loss does not affect the respondents' leisure activities. This rules out the hypothesis that maternal loss could impact cognition through a change in leisure activities.

Finally, the effect of maternal loss on depressive symptoms may depend on whether they provide informal care to their mother. Since providing informal care for parents has a negative effect on mental health (Coe & Van Houtven 2009, Heger 2017), carers who lost their mother may experience a sense of relief, which could improve their mental health. This would violate the monotonicity assumption, as maternal loss could positively or negatively affect different respondents. To test the sensitivity of our results, we exclude respondents who ever provided weekly or daily care to their mother. As shown in column 5 of Table A.7 in Appendix, the results do not substantially change, suggesting that the monotonicity assumption's potential violation is unlikely to alter our results. In Table A.7 we further show that the results are robust to using different measures of depressive symptoms (columns 6 and 7), estimating the model via Limited Information Maximum Likelihood instead of 2SLS (column 8) and clustering standard errors at the country instead of individual-level (column 9).

In Table 5, we show FEIV estimates of the effect of depressive symptoms on the three dimensions of cognition we focus on in this paper. For each outcome, we present results from a baseline specification that only includes the respondent's age 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 4. The FEIV estimates of the effect of experiencing depressive symptoms on episodic memory and verbal fluency 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.

Table 5: FEIV estimates of the effect of depression on congitive functions

	Memory		Working memory		Verbal fluency	
Standardised EURO-D	-0.2904	-0.2365	-0.4988*	-0.4129**	-0.0803	-0.1119
	(0.2520)	(0.1892)	(0.2754)	(0.2015)	(0.2341)	(0.1806)
F- Stat. (excl. inst.)	15.512	27.750	15.512	27.750	15.512	27.750
Z-score (Diff. FE)	0.930	1.019	1.523	1.644	0.202	0.503
Observations	31,147	31,147	31,147	31,147	31,147	31,147
Individuals	12462	12462	12462	12462	12462	12462
Time-varying covariates	No	Yes	No	Yes	No	Yes

Note:Sample restricted to those aged 50-65 who have been interviewed at least twice. All models include age and wave dummies, health and mother and caring frequency. 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 triggered by maternal loss has a negative effect on cognitive abilities amongst older adults of working age. Using longitudinal data representative from the population of older adults in 18 European countries, we find that depressive symptoms are associated with reduced cognitive performance even when controlling for time-invariant heterogeneity with a Fixed-Effect estimator and adjusting for a range of adverse life events. To test whether the relationship is causal, we use recent maternal loss as an instrument for depressive symptoms. Our analysis shows that maternal loss is an exogenous shock that increases depressive symptoms in the short-run and is unlikely to affect cognition directly. We find that depressive symptoms triggered by recent maternal loss have a substantial adverse effect on cognitive performance.

Our main contribution 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 improve the cognitive outcomes of depressed patients (Keefe et al. 2014, Rosenblat et al. 2015) and workplace productivity (Berndt et al. 1998). Whilst these studies focus on clinically depressed patients, we show that depressive symptoms, which are highly prevalent in the population, can also reduce 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 depressive symptoms and cognition by analysing each depressive symptom's independent effect. We find that reduced concentration, pessimism and motivation are strongly associated with cognitive performance, whereas emotional symptoms such as sadness or tearfulness are not.

Our study is not without limitations. Because we use recent maternal loss as an instrument, our results should primarily be interpreted as the cognitive effects of depressive symptoms caused by bereavement. Depressive symptoms caused by other life events may affect cognitive performance differently. Another limitation is that we do not observe workplace productivity directly but instead 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 important implications. Since many tasks in the knowledge-based economy rely on cognitive skills (Autor et al. 2003), the cognitive effects of depressive symptoms may reduce productivity at the workplace, even among those who are not clinically depressed but suffer from mild mental health disorders. Therefore, the economic cost of mental illness goes 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. The cognitive effects of depression may also generate wider social costs, since cognitive abilities are crucial for many aspects of everyday life, such as financial decisions (Smith et al. 2010, Agarwal & Mazumder 2013), and social relations (Aartsen et al. 2004), and are an important cause of functional disability in later life (McGuire et al. 2006), potentially increasing the demand for long-term care.

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A Appendix

Table A.1: Descriptive Statistics

	Mean	SD	*N*
Depression scale EURO-D	2.232	2.129	87,999
EURO-D caseness	0.238	0.426	87,999
Total word recall score	10.32	3.358	87,999
Working memory score	4.347	1.204	87,999
Verbal fluency score	22.32	7.499	87,999
Female	0.567	0.496	87,999
Age	60.74	5.320	87,999
Married	0.723	0.447	87,999
Divorced	0.111	0.315	87,999
Employed	0.394	0.489	87,999
Retired	0.434	0.496	87,999
Other	0.172	0.378	87,999
Total household income	39661.1	99778.2	87,999
1+ ADL limitations	0.0663	0.249	87,999
1+ IADL limitations	0.0958	0.294	87,999
Physical inactivity	0.0606	0.239	87,999
Heart attack	0.0759	0.265	87,999
High blood pressure or hypertension	0.348	0.476	87,999
High blood cholesterol	0.223	0.417	87,999
Stroke	0.0237	0.152	87,999
Diabetes or high blood sugar	0.109	0.311	87,999
Chronic lung disease	0.0535	0.225	87,999
Cancer	0.0401	0.196	87,999
Stomach or duodenal ulcer, peptic ulcer	0.0392	0.194	87,999
Parkinson disease	0.00341	0.0583	87,999
Cataracts	0.0406	0.197	87,999
Hip fracture or femoral fracture	0.0101	0.100	87,999
Alzheimer's disease, dementia, senility	0.00344	0.0586	87,999
Mother alive in 1st interview	0.462	0.499	74,616
Mother's death	0.105	0.306	34,350
Helped mother: No	0.815	0.388	34,483
Almost every day	0.0427	0.202	34,483
Almost every week	0.0717	0.258	34,483
Almost every month	0.0409	0.198	34,483
Less often	0.0298	0.170	34,483
Health of mother: fair	0.261	0.439	34,350
Health of mother: poor	0.157	0.364	34,350
Father alive	0.230	0.421	32,292
Helped Father	0.0378	0.191	34,483

Note: Sample restricted to 50-65 interviewed at least twice

Figure A.1: Correlation of Euro-D components

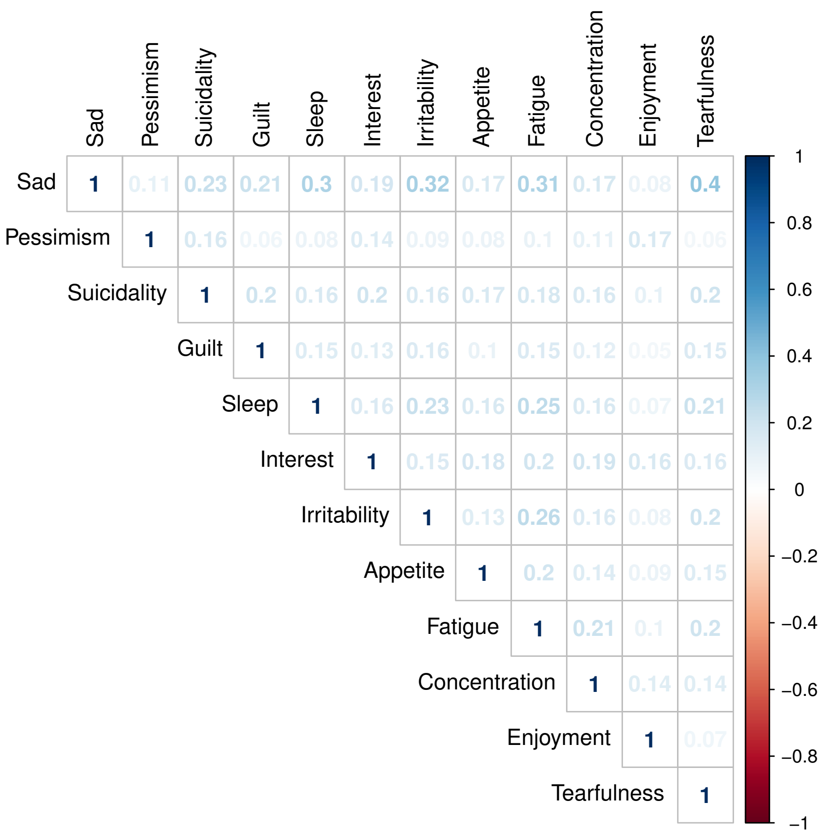

Table A.2: Testing strict exogeneity of the instruments

	Cognitive score					
	(1)	(2)	(3)	(4)	(5)	(6)
EURO-D	-0.7793	-0.8252	-0.8190	-0.8230	-0.9378	-0.9641
	(0.5911)	(0.6221)	(0.6117)	(0.6168)	(0.7378)	(0.7494)
Mother death $t+1$	0.0121	-0.0047	-0.0030	0.0037	-0.0186	-0.0199
	(0.0331)	(0.0416)	(0.0389)	(0.0410)	(0.0505)	(0.0513)
Observations	11,048	11,048	11,048	8,438	10,377	10,377
Individuals	5042	5042	5042	3752	4736	4736
Model	age, wave FE	+ mother's health, caring	+ labour, income & health	+ father alive, caring	(2), excl. resp. living with parents	(2) + lag as instrument

Note: Sample restricted to those aged 50-65 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 dummies. 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 the effect of maternal loss on overall cognitive score

	(1)	(2)	(3)	(4)	(5)	(6)
$Mother\ death_t$	-0.0265*	-0.0328**	-0.0324**	-0.0353**	-0.0306**	-0.0244
	(0.0143)	(0.0153)	(0.0153)	(0.0158)	(0.0156)	(0.0175)
$Mother\ death_{t-1}$						0.0234
						(0.0232)
R-Squared	0.003	0.001	0.017	0.004	0.001	0.001
Observations	31,172	31,172	31,172	29,135	29,397	31,172
Individuals	12462	12462	12462	11752	11768	12462
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 50-65 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.4: Testing strict exogeneity of the instruments

	Cognitive score					
	(1)	(2)	(3)	(4)	(5)	(6)
EURO-D	-0.7793	-0.8252	-0.8190	-0.8230	-0.9378	-0.9641
	(0.5911)	(0.6221)	(0.6117)	(0.6168)	(0.7378)	(0.7494)
Mother death $t+1$	0.0121	-0.0047	-0.0030	0.0037	-0.0186	-0.0199
	(0.0331)	(0.0416)	(0.0389)	(0.0410)	(0.0505)	(0.0513)
Observations	11,048	11,048	11,048	8,438	10,377	10,377
Individuals	5042	5042	5042	3752	4736	4736
Model	age, wave FE	+ mother's health, caring	+ labour, income & health	+ father alive, caring	(2), excl. resp. living with parents	(2) + lag as instrument

Note: Sample restricted to those aged 50-65 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 dummies. 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.5: 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
$Mother\ death_t$	0.0480***	-0.0160**	-0.0020	0.0011	0.0157*	0.0144**	0.0081	0.0191***	0.0248**	0.0068	0.0093	0.0771***
	(0.0101)	(0.0073)	(0.0047)	(0.0061)	(0.0093)	(0.0061)	(0.0095)	(0.0059)	(0.0098)	(0.0074)	(0.0069)	(0.0095)
R-Squared	0.004	0.000	0.000	0.002	0.001	0.001	0.002	0.001	0.000	0.000	0.000	0.004
Mean	0.392	0.119	0.055	0.091	0.331	0.064	0.310	0.059	0.306	0.135	0.090	0.239
Observations	31,039	31,039	31,039	31,039	31,039	31,039	31,039	31,039	31,039	31,039	31,039	31,039
Individuals	12426	12426	12426	12426	12426	12426	12426	12426	12426	12426	12426	12426

Note: Sample restricted to those aged 50-65 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.6: FE estimates of effect of maternal death on several outcomes

	Employed	Married	Financial distress	Any health condition	Number of conditions	Physical inactivity	Give care to father
Mother's death	0.0024	0.0042	-0.0047	0.0003	0.0136	0.0039	0.0058
	(0.0072)	(0.0028)	(0.0080)	(0.0085)	(0.0156)	(0.0050)	(0.0040)
R-Squared	0.016	0.000	0.004	0.006	0.017	0.002	0.053
Mean	0.595	0.732	0.316	0.480	0.747	0.047	0.043
Observations	31,039	31,039	31,039	31,039	31,039	31,039	31,039
Individuals	12426	12426	12426	12426	12426	12426	12426

Note: Sample restricted to those aged 50-65 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.7: Additional specifications - FEIV estimates of the effect of depression on cognition

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	A. First Stage: standardised EURO-D score								
Mother death$_t$	0.0942***	0.0856***	0.0896***	0.0972***	0.1006***	0.1006***	0.1006***	0.0972***	0.0972***
	(0.0232)	(0.0200)	(0.0212)	(0.0185)	(0.0192)	(0.0192)	(0.0192)	(0.0185)	(0.0147)
	B. Second Stage: cognitive score								
Standardised EURO-D	-0.4087*	-0.6026***	-0.4287**	-0.3388**	-0.3105*			-0.3388**	-0.3388*
	(0.2245)	(0.2296)	(0.2176)	(0.1652)	(0.1649)			(0.1652)	(0.1739)
EURO-D caseness						-0.7662**			
						(0.3813)			
EURO-D excl. concentration							-0.1650**		
							(0.0805)		
F- Stat. (excl. inst.)	16.543	18.359	17.873	27.594	27.388	24.472	29.010	27.594	43.953
Z-score (Diff. FE)									
Observations	15,967	21,944	22,531	31,017	26,149	31,017	31,017	31,017	31,017
Individuals	6516	8776	9069	12404	10522	12404	12404	12404	12404
Sample	Father dead	No daily contact with mother	Married/ cohabiting	Excluding Italy and Spain	Excluding weekly or daily carers	All	All	All	All
Estimation	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS	LIML	2SLS
Clustered SE	Ind.	Ind.	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.

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

Table A.8: 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's death	-0.0090	0.0014	-0.0023	-0.0110	-0.0100*	-0.0069	0.0119	-0.0143
	(0.0072)	(0.0078)	(0.0086)	(0.0136)	(0.0053)	(0.0081)	(0.0083)	(0.0089)
R-Squared	0.001	0.015	0.001	0.000	0.000	0.004	0.000	0.003
Mean	0.206	0.221	0.344	0.098	0.079	0.806	0.466	0.352
Observations	31,016	31,016	31,016	11,402	31,016	31,016	31,016	31,016
Individuals	12426	12426	12426	8908	12426	12426	12426	12426

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.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$