RAND EUROPE

How frequent night-time bathroom visits can negatively impact sleep, wellbeing and productivity

Examining the associations between nocturia, wellbeing and economic outcomes in a working-age population

Marco Hafner, Jack Pollard,
Wendy M. Troxel, Erez Yerushalmi, Clement Fays,
Michael Whitmore and Chris van Stolk

For more information on this publication, visit www.rand.org/t/RR3043

Published by the RAND Corporation, Santa Monica, Calif., and Cambridge, UK

© Copyright 2019 RAND Corporation

RAND® is a registered trademark.

RAND Europe is a not-for-profit research organisation that helps to improve policy and decision making through research and analysis. RAND's publications do not necessarily reflect the opinions of its research clients and sponsors.

This study is partially based on data collected by Vitality UK, part of the Discovery Group, and AIA.

Limited Print and Electronic Distribution Rights
This document and trademark(s) contained herein are protected by law. This representation of RAND intellectual property is provided for noncommercial use only. Unauthorized posting of this publication online is prohibited. Permission is given to duplicate this document for personal use only, as long as it is unaltered and complete. Permission is required from RAND to reproduce, or reuse in another form, any of its research documents for commercial use. For information on reprint and linking permissions, please visit www.rand.org/pubs/permissions.

Support RAND
Make a tax-deductible charitable contribution at
www.rand.org/giving/contribute

www.rand.org

www.randeurope.org

Preface

This study examines the associations between nocturia (waking at night to urinate) and a set of factors and outcomes – including health, wellbeing and workplace productivity – in a working-age population. The report's findings directly contribute to the emerging scientific literature, which aims to better understand the condition and its ramifications. The study is partially based on international workplace survey data collected through two large, linked employer–employee datasets for Vitality UK and AIA, covering the UK, Australia, Malaysia, Hong Kong, Singapore, Thailand and Sri Lanka.

This research was prepared for Ferring Pharmaceuticals. During the entire research process RAND Europe had full editorial control and independence of the analyses performed and presented in this report. This work informs the public good and should not be taken as a commercial endorsement.

RAND Europe is a not-for-profit policy research organisation that helps to improve policy and decision making in the public interest through research and analysis. This report has been peer-reviewed in accordance with RAND's quality assurance standards. For more information about RAND Europe or this document, please contact Marco Hafner (mhafner@rand.org) at:

RAND Europe
Westbrook Centre, Milton Road
Cambridge CB4 1YG
United Kingdom
Tel. +44 1223 353 329

Executive summary

Why waking at night to visit the bathroom could have negative consequences for your sleep, health and productivity

Waking up at night to go to the bathroom interrupts sleep, and the more frequent the night-time voids, the more 'bothersome' it becomes for individuals. While there are several reasons why people have to get up at night to go to the bathroom (e.g. excessive fluid intake just before bedtime), frequent bathroom visits at night can be driven by a health condition referred to as nocturia. Nocturia is a lower urinary tract condition in which individuals wake up at night to void, where each void is preceded and followed by sleep (van Kerrebroeck et al., 2002). There are multiple types of nocturia, among the most common of which are nocturnal polyuria (NP) – when a large volume of urine is produced during the night – and reduced bladder capacity. Often nocturia is not acknowledged as a condition, with the result that some doctors and health practitioners overlook nocturia as a potential health problem associated with sleep loss, and patients do not report the condition until it becomes unbearable, substantially affecting individual quality of life (Marinkovic et al., 2004). Generally, those who experience less than two voids per night are not regarded as having clinically significant nocturia that warrants a diagnostic or clinical investigation or treatment. The reason behind this is that empirically, most individuals with less than two voids per night generally experience only minimal bother from the condition, whereas in contrast, the available evidence suggests that two or more night-time voids is likely to be associated with more severe consequences, such as an impaired sleep health and a lower quality of life (Bosch & Weiss, 2010). Hence, the occurrence of an average of two or more voids per night represents the threshold after which nocturia shifts from being perceived as a minor inconvenience to a more bothersome and clinically relevant condition. However, there may be some individuals who do experience distress even with one void per night.

Nocturia, defined as at least two night-time voids, is relatively common, affecting on average about 20 per cent of the overall population, with prevalence increasing with age (Bosch & Weiss, 2010). But even among younger individuals aged 18 to 30 years, nocturia is prevalent among about 9 per cent of women and 4 per cent of men. Not surprisingly, a key complaint of nocturia is disrupted sleep, but the consequences of nocturia extend to the daytime as well. For instance, nocturia is also associated with fatigue, cognitive impairment, increased risk of cardiovascular disease, depression and – in older individuals – a higher risk of injury through falls (Weidlich et al., 2017). However, the direction of the relationship between chronic health conditions, sleep problems and nocturia is not always well understood. Individuals with nocturia also report lower levels of subjective wellbeing, work engagement and workplace productivity, suggesting that the consequences of nocturia go beyond the individual, with potential wider societal consequences as well.

Objectives of the study

While the vast majority of existing empirical evidence on the effects of nocturia is based on analyses for older populations (e.g. aged 45 and older), this study aims to examine the factors associated with nocturia and related outcomes for a working-age population. The study contributes to the emerging evidence base examining nocturia as a serious condition with potentially negative health and economic consequences for those with the condition and the associated wider societal implications. Building on the existing scientific evidence and applying relevant quantitative research methods, this study seeks to:

1. **Identify the factors associated with nocturia in a working-age population.** Previous studies in mostly older adult populations have found that socio-demographic, lifestyle and health factors are associated with the prevalence of nocturia. These factors include, among others, age, gender, obesity and chronic health conditions such as depression and kidney disease. In this analysis, we examine the relative importance of these factors in explaining the prevalence of nocturia in a working-age population.
2. **Examine the associations between nocturia, sleep, subjective wellbeing and workplace engagement and productivity.** We examine the association between nocturia and self-reported sleep disturbance in more detail and also investigate the associations between nocturia and a variety of outcomes, including subjective wellbeing (e.g. measured as self-reported life satisfaction), as well as engagement and productivity in the workplace (e.g. measured as work impairment due to absenteeism or presenteeism).
3. **Quantify the economic implications associated with nocturia.** Drawing on parameters derived in the statistical analysis of this study, we conduct a cross-country analysis of the economic output lost associated with nocturia in terms of lower productivity and potential excess mortality risk. For this purpose, we apply a macroeconomic model to project how GDP for six countries would change if the prevalence of nocturia were to be reduced under different so-called 'what if' or counterfactual scenarios.

Key research findings

The study findings contribute to the existing evidence base and confirm previous research findings in four different areas: (1) nocturia is a debilitating condition that causes 'bother', the degree of which increases with the severity of the condition; (2) a number of demographic, lifestyle and health factors are associated with the prevalence of nocturia; (3) nocturia is associated with lower levels of subjective wellbeing, work engagement and workplace productivity; and (4) nocturia is associated with negative economic implications for national economies.

1. Nocturia is a common and 'bothersome' condition, with two voids per night a critical threshold

Estimates on the prevalence of nocturia suggest that, even though its prevalence is increasing with age, it is a condition that also affects approximately up to one in ten individuals aged 45 or younger. Using recent international workplace survey data covering the years 2017 and 2018, the findings of this study suggest that nocturia is a 'bothersome' condition

and that the proportion of individuals reporting significant 'bother' from the condition increases with the number of reported voids per night, independent of the age or gender of the respondent.

2. A variety of demographic, lifestyle and health factors – which differ by age and gender – are associated with nocturia

The research findings confirm previous research based on older study populations that some of the examined demographic factors associated with nocturia are also relevant for the working-age population, including age, gender or ethnicity. For instance, all else equal, we find that women tend to have a higher probability to report two or more voids per night, as well as black individuals. The probability of reporting more than two night-time voids also increases with age. Furthermore, we find that chronic health conditions – such as kidney disease, diabetes, cardiovascular disease, cancer and hypertension – are associated with more frequent night time voids.

3. Nocturia is associated with higher levels of sleep disturbance and daytime fatigue

Due to the importance of the link between sleep and nocturia the study examines in more detail the associations between different measures of sleep quality: (1) an overall sleep disturbance score (with a higher score representing higher levels of disturbance); (2) the self-reported first unit of uninterrupted sleep; and (3) a daytime fatigue score (with a higher score representing higher levels of fatigue). Across all three measures we find that the prevalence of nocturia is associated with self-reported poor sleep quality, higher levels of sleep interruption and higher levels of daytime fatigue, independent of age and gender of the respondent. The magnitude of these associations also increases with the number of reported night-time voids, suggesting that the negative association between nocturia and sleep quality is also a function of nocturia symptom-severity.

4. Nocturia is significantly associated with lower life satisfaction, work engagement and productivity

The empirical analysis presented in this study suggests that nocturia is associated with lower life satisfaction, work engagement and productivity in the working-age population, even after adjusting for many other factors that could determine these outcome variables, including sleep quality and duration.

For instance, an individual suffering nocturia reports on average, a 2 per cent lower life satisfaction compared to an individual not suffering from nocturia. When comparing the magnitude of this association with other factors, we find that this reduction in life satisfaction is of a similar magnitude as suffering from other negative health conditions such as hypertension, cardiovascular disease or asthma.

Furthermore, our empirical findings suggest that individuals with nocturia report on average, a 1.3 per cent lower engagement at work (measured using the Utrecht engagement scale) compared to individuals not suffering from the condition.

With regard to workplace productivity (measured using the WPAI-GH scale), the findings suggest that an individual suffering nocturia loses on average more than seven working days per year more

due to absenteeism and presenteeism than an individual not suffering from nocturia. This is of the same magnitude of lost productivity as observed among individuals with asthma, kidney disease or hypertension.

5. Nocturia is associated with up to $79 billion of lost economic output per year across six countries

To provide estimates of the economic costs associated with nocturia for six countries, including the United Kingdom, the United States, Germany, Spain, Japan and Australia, we use a macroeconomic model that simulates the various agents – and their interactions – in an economy, including individuals, firms and the government. In our analytical approach, the effect of nocturia is translated into the supply of effective labour units that individuals provide in the economy. In essence, nocturia affects the labour supply through two mechanisms: (1) lower productivity; and (2) excess mortality risk. First, as our empirical findings suggest, individuals with nocturia are more likely to be absent from work due to sickness, or remain at work with reduced performance, leading to an efficiency loss for each unit of labour supplied in the economy. Secondly, the empirical evidence suggests that nocturia is associated with an elevated mortality risk, which potentially can reduce the size of the working population. In a first step, the economic model simulates the current economic situation of each of the six countries under consideration in the status quo (or baseline) scenario – the current proportions of people with nocturia. In a second step, under different 'what if' scenarios (compared to the status quo), the model predicts how economic output would be affected if the proportion of people suffering from nocturia were to be reduced. The two main scenarios included in the analysis examine either (1) only the productivity loss associated with nocturia, or (2) both the productivity loss and excess mortality associated with nocturia.

Overall, it is estimated that across the six countries analysed, more than 90 million people could have nocturia, which corresponds to between 13 and 17 per cent of the whole population across all age groups (see Table ES.1 for a breakdown by country).

Table ES.1: Number of individuals with nocturia (two or more voids per night) by country

	Total population		Working-age population	
Country	**Million**	**Share**	**Million**	**Share**
Japan	21.8	17.0%	12.5	13.8%
UK	9.1	14.2%	5.7	12.8%
Spain	6.9	14.7%	4.2	12.5%
Germany	12.9	16.0%	7.6	13.1%
USA	40.0	12.9%	27.5	12.5%
Australia	2.9	13.0%	2.0	12.3%

Notes: calculated using age-gender specific nocturia prevalence population data provided by the UN Population Database for each of the six countries. 'Working-age population' covers individuals aged 20 to 69.

Table ES.2 reports the estimated annual economic costs associated with nocturia by country. Our economic predictions indicate that in terms of annual GDP losses due to nocturia-associated absenteeism and presenteeism, Australia loses about $3 billion, Japan about $13.7 billion, the USA about $44.4 billion, Germany about $8.4 billion, Spain about $3.1 billion and the United Kingdom about $6 billion. Table ES.2 summarises the cost associated with nocturia and provides a breakdown of the annual GDP losses associated with lower productivity (Scenario 1), and both lower productivity and reduced labour supply (Scenario 2).

Table ES.2: Estimated annual economic cost associated with nocturia in GDP terms

	Scenario 1: Real GDP – productivity			Scenario 2: Real GDP – productivity & reduction labour supply		
$ billion (2018 Dollars)						
Country	Estimate	*Low*	*High*	Estimate	*Low*	*High*
Australia	3.0	*1.6*	*4.3*	3.2	*1.6*	*4.8*
Japan	13.7	*7.2*	*19.7*	14.6	*7.2*	*22.2*
USA	44.4	*24.2*	*63.3*	47.9	*24.2*	*73.1*
Germany	8.4	*4.5*	*12.1*	9.1	*4.5*	*13.8*
Spain	3.1	*1.7*	*4.5*	3.3	*1.7*	*5.0*
United Kingdom	5.9	*3.2*	*8.4*	6.3	*3.2*	*9.6*
% total GDP						
Country	Estimate	*Low*	*High*	Estimate	*Low*	*High*
Australia	0.21%	*0.11%*	*0.30%*	0.22%	*0.11%*	*0.33%*
Japan	0.21%	*0.11%*	*0.31%*	0.23%	*0.11%*	*0.35%*
USA	0.26%	*0.14%*	*0.37%*	0.28%	*0.14%*	*0.43%*
Germany	0.22%	*0.12%*	*0.32%*	0.24%	*0.12%*	*0.37%*
Spain	0.20%	*0.11%*	*0.29%*	0.22%	*0.11%*	*0.33%*
United Kingdom	0.23%	*0.12%*	*0.33%*	0.25%	*0.12%*	*0.37%*

Notes: All values are reported in 2018 US Dollars. 'Low' and 'High' represent the results from sensitivity analyses using the lower and upper bounds of the 95% confidence intervals for the main input parameters (percent work impairment due to absenteeism and presenteeism and mortality risk). The contribution of the reduction in labour supply can be calculated using the difference in real GDP between Scenario 2 and Scenario 1, however, the estimations including reduced labour supply due to excess mortality associated with nocturia should be used with caution as the evidence on the association between the condition and mortality risk is associated with some robustness issues.

Conclusions

The key insights and contribution from this study are as follows. Firstly, nocturia not only affects older age cohorts but is also prevalent in younger populations. Furthermore, the condition seems to be 'bothersome' for individuals and the level of 'bother' increases with the number of night-time voids reported. Secondly, nocturia is associated with a considerable number of lifestyle risks and co-morbidities. However, nocturia as a condition is still poorly understood and more research is needed to better understand the mechanisms of whether these lifestyle and health factors are caused by nocturia or whether nocturia is an underlying clinical indicator for these factors. Thirdly, given its potential sleep impairing association, the impact of nocturia goes beyond the individual's health or quality of life, potentially negatively affecting their productivity and engagement at work, with negative economic ramifications. This study highlights some of these associated economic costs. Fourthly, even after adjusting for a variety of different covariates, including sleep quality and duration, the statistical analysis of this study suggests that nocturia is associated with profound levels of work impairment due to absenteeism and presenteeism. Finally, this study shows clearly strong associations and overlaps between nocturia and sleep quality. These findings suggest that the consequences of nocturia are partially explained by poor sleep, but there remains an independent effect of nocturia on individual health and economic outcomes. This study cannot fully tease apart the directionality of the relationship between nocturia and sleep, which is an important area for future research. However, these findings highlight that both nocturia and poor sleep quality offer important opportunities for intervention. Given the substantial economic implications of untreated nocturia, this should be a 'wake-up' call to diverse stakeholders – including patients, health-care providers and employers – of the importance of identifying and treating nocturia.

Table of contents

Preface **i**

Executive summary **iii**
Why waking at night to visit the bathroom could have negative consequences for your sleep, health and productivity *iii*
Objectives of the study *iv*
Key research findings *iv*
Conclusions *viii*

Table of contents **ix**

List of figures **xi**

List of tables **xii**

Abbreviations **xiv**

Acknowledgements **xv**

1. Introduction **1**
1.1. Nocturia – a common but often-neglected condition *1*
1.2. Objectives of this study *2*
1.3. Research methodologies *3*
1.4. Structure of this report *3*

2. The prevalence of nocturia, factors associated with the condition and possible consequences – a glance at the literature **5**
2.1. Nocturia – a common but often-neglected condition *5*

3. Quantifying factors associated with nocturia and corresponding outcomes – data and methods **11**
3.1. International workplace survey data *11*
3.2. Statistical approach: a multivariate regression analysis *12*
3.3. Variables used in the analysis *14*

4. Factors associated with nocturia in the working-age population – demographics, lifestyle, co-morbidities and sleep **29**
4.1. Co-morbidities, demographic and lifestyle factors *29*
4.2. Nocturia symptom-severity and sleep disturbance *36*

5. Nocturia and the associations with life satisfaction, work engagement and impairment 43
5.1. Nocturia and the association with life satisfaction 43
5.2. Nocturia and work engagement 48
5.3. Nocturia and work impairment 52

6. Quantifying the macroeconomic implications associated with nocturia 57
6.1. The macroeconomic model 57
6.2. The macroeconomic cost associated with nocturia: model results 63

7. Summary and conclusion 67
7.1. Summary 67
7.2. Conclusions 68

References 69

Appendix A: Factors associated with nocturia in the working-age population: demographics, lifestyle, co-morbidities and sleep – corresponding regression output tables 75

Appendix B: Nocturia and the associations with life satisfaction, workplace engagement and productivity – corresponding regression output tables 91

Appendix C: The BHW and AIA surveys 99

Appendix D: Description of the CGE model 101

List of figures

Figure 3.1: Nocturia symptom-severity and bother – share of individuals with perceived bother 18

Figure 4.1: Associations between nocturia and demographic, lifestyle factors and co-morbidities – marginal probabilities 30

Figure 4.2a: Associations between demographic and lifestyle factors, co-morbidities and nocturia, by age – marginal probabilities (female sample) 33

Figure 4.2b: Associations between demographic and lifestyle factors, co-morbidities and nocturia, by age – marginal probabilities (male sample) 34

Figure 4.3: Nocturia symptom-severity and self-reported sleep disturbance (compared to individuals reporting zero night-time voids) – by age and gender 37

Figure 4.4: Nocturia symptom-severity and self-reported FUSP (compared to individuals reporting zero night-time voids) – by age and gender 38

Figure 4.5: Nocturia symptom-severity and daytime fatigue (compared to individuals reporting zero night-time voids) – by age and gender 39

Figure 5.1: Nocturia symptom-severity and life satisfaction (compared to individuals reporting zero night-time voids) – by age and gender 47

Figure 5.2: Nocturia symptom-severity and work engagement (compared to individuals reporting zero night-time voids) – by age and gender 51

Figure 5.3: Nocturia symptom-severity and work impairment (compared to individuals reporting zero night-time voids) – by age and gender 56

Figure 6.1: The interactions between nocturia and agents in the economy 59

List of tables

Table ES.1:	Number of individuals with nocturia (two or more voids per night) by country	vi
Table ES.2:	Estimated annual economic cost associated with nocturia in GDP terms	vii
Table 2.1:	Estimated annual economic burden of nocturia by country	10
Table 3.1:	Sample sizes by country and year	12
Table 3.2:	Distributions of the number of voids per night; by year and region	16
Table 3.3:	Percentage of sample population reporting two or more voids per night, by age and gender	17
Table 3.4:	Summary of lifestyle and health behaviour variables	21
Table 3.5:	Summary of sleep related variables	23
Table 3.6:	Summary of chronic health condition variables	25
Table 3.7:	Summary of life satisfaction, work engagement and impairment variables	27
Table 4.1:	Associations between nocturia and demographic, lifestyle factors and co-morbidities – marginal probabilities	31
Table 4.2:	Top three factors associated with nocturia, by age and gender	35
Table 4.3:	Summary of associations between nocturia symptom-severity and sleep disturbance, FUSP and daytime fatigue, by age and gender	41
Table 5.1:	Associations between nocturia and life satisfaction	44
Table 5.2:	Comparison between nocturia and other lifestyle factors and co-morbidities with regard to lower life satisfaction – full sample	46
Table 5.3:	Associations between nocturia and work engagement	49
Table 5.4:	Comparison between nocturia and other factors relating to lower work engagement – full sample	50
Table 5.5:	Associations between nocturia and work impairment	53
Table 5.6:	Comparison between nocturia and other factors with regard to annual working days lost – full sample	55

Table 6.1:	Population prevalence of nocturia (two or more voids per night) by age and gender	61
Table 6.2:	Number of individuals with nocturia (two or more voids per night) by country	61
Table 6.3:	Nocturia and percentage of working time lost due to absenteeism and presenteeism, by age and gender	62
Table 6.4:	Estimated annual economic cost associated with nocturia in GDP terms	63
Table A.1:	Associations between demographic and lifestyle factors, co-morbidities and nocturia – full sample	76
Table A.2:	Associations between demographic and lifestyle factors, co-morbidities and nocturia – UK sample	77
Table A.3:	Associations between demographic and lifestyle factors, co-morbidities and nocturia – Asia sample	78
Table A.4:	Associations between demographic and lifestyle factors, co-morbidities and nocturia – Australia sample	79
Table A.5:	Associations between demographic and lifestyle factors, co-morbidities and nocturia – female sample (Age: 18–30)	80
Table A.6:	Associations between demographic and lifestyle factors, co-morbidities and nocturia – female sample (Age: 31–50)	81
Table A.7:	Associations between demographic and lifestyle factors, co-morbidities and nocturia – female sample (Age: 51+)	82
Table A.8:	Associations between demographic and lifestyle factors, co-morbidities and nocturia – male sample (Age: 18–30)	83
Table A.9:	Associations between demographic and lifestyle factors, co-morbidities and nocturia – male sample (Age: 31–50)	84
Table A.10:	Associations between demographic and lifestyle factors, co-morbidities and nocturia – male sample (Age: 51+)	85
Table A.11:	Nocturia symptom-severity and sleep disturbance, by age and gender	86
Table A.12:	Nocturia symptom-severity and FUSP (hours), by age and gender	87
Table A.13:	Nocturia symptom-severity and fatigue score, by age and gender	88
Table A.14:	Average FUSP and sleep length by age and gender	89
Table B.1:	Associations between nocturia and life satisfaction – full sample	92
Table B.2:	Nocturia symptom-severity and life satisfaction – by age and gender	93
Table B.3:	Associations between nocturia and work engagement – full sample	94
Table B.4:	Nocturia symptom-severity and work engagement – by age and gender	95
Table B.5:	Associations between nocturia and work impairment – full sample	96
Table B.6:	Nocturia symptom-severity and work impairment – by age and gender	97

Abbreviations

BMI	Body Mass Index
BHW	Britain's Healthiest Workplace
CGE	Computational General Equilibrium
COI	Cost of Illness
HRQol	Health Related Quality of Life
FUSP	First Uninterrupted Sleep Period
GH	General Health
GTAP	Global Trade Analysis Project
ICS	International Continence Society
ILO	International Labour Organisation
LPM	Linear Probability Model
NP	Nocturnal Polyuria
OLS	Ordinary Least Squares
RCT	Randomised Control Trial
SAM	Social Accounting Matrix
SOE	Small-Open Economy
SWB	Subjective Wellbeing
UWES	Utrecht Work Engagement Scale
WHO	World Health Organisation
WPAI	Work Productivity and Activity Impairment

Acknowledgements

The authors would like to thank the quality-assurance reviewers Charlene Rohr (RAND Europe) and Sarah Ball (RAND Europe). In addition, we would also like to thank Professor Fredrik Andersson (Ferring International PharmaScience Center, Denmark) and Dr. Teodor Burtea (Ferring International Center S.A., Switzerland) for providing comments and suggestions during the research process. The authors are also grateful to Vitality UK and AIA for the permission to use Vitality and AIA workplace survey data in this study.

All views expressed in this report are the authors' and remaining errors are also our own.

1 Introduction

1.1. Nocturia – a common but often-neglected condition

Nocturia is a lower urinary tract condition in which complainants wake up one or more times to void at night, and each void is preceded and followed by sleep (van Kerrebroeck et al., 2002). There are different types of nocturia caused by different factors, among the most common of which are a large urine volume produced during the night or a reduced bladder capacity.

Generally, those who experience less than two voids per night are not regarded as having clinically significant nocturia that warrants a diagnostic or clinical investigation or treatment. This is because empirically, most individuals who experience less than two voids per night generally report only minimal bother from the condition, whereas in contrast, the available evidence suggests that two or more experienced voids is likely to be associated with more severe consequences, such as impaired sleep health and a lower quality of life (Bosch & Weiss, 2010). Hence, the occurrence of an average of two or more voids per night represents the threshold after which nocturia shifts from being perceived as a minor inconvenience to a more bothersome and clinically meaningful condition.

Nocturia, defined as at least two night-time voids, is relatively common, affecting on average about 20 per cent of the overall population, with prevalence increasing with older age (Bosch & Weiss, 2010). It is experienced as a troublesome condition with negative implications for individuals' sleep as well as consequences for daytime functioning and overall health, including increased risk of fatigue, cognitive impairment, cardiovascular disease, depression and – in older individuals – a higher risk of injury through falls (Weidlich et al., 2017). However, quite often nocturia is not acknowledged as a condition, with doctors and health practitioners often overlooking nocturia as a potential health problem associated with sleep loss, as well as patients not reporting the condition until it becomes unbearable, substantially affecting individual quality of life (Marinkovic et al., 2004).

Given the relatively higher prevalence-rates of nocturia in older individuals, the emerging evidence base regarding nocturia and its potential negative consequences is mostly derived from populations aged 45 years and older, and less is known about the negative implications of nocturia in populations of working-age individuals. However, given the condition's negative consequences on sleep and daytime functioning, understanding the consequences of nocturia in working-age individuals is important from a wider societal point of view, as it not only negatively affects individuals' quality of life but potentially also has economic consequences for employers.

1.2. Objectives of this study

This study aims to examine the associations between nocturia and a range of factors and outcomes, with the overarching objective to comprehensively analyse the potential ramifications of nocturia in a working-age population. Using large-scale, linked employer–employee data across different regions (United Kingdom, Australia and Asia) we examine the associations of nocturia with individual health, lifestyle, subjective wellbeing and workplace behaviour, such as engagement or productivity. Building on existing scientific evidence and applying relevant quantitative research methods, this study seeks to:

1. **Identify the factors associated with nocturia in a working-age population: Previous** studies in mostly older adult populations have found that individual socio-demographic, lifestyle and health factors are associated with the prevalence of nocturia. These factors include, among others, age, gender, obesity and chronic health conditions such as depression and kidney disease. In this analysis we examine the relative importance of these factors in explaining the prevalence of nocturia in a working-age population.
2. **Examine the associations between nocturia and sleep, subjective wellbeing and workplace engagement and productivity:** We examine the association between nocturia and sleep quality in more detail and also investigate the associations between nocturia and a variety of outcomes, including subjective wellbeing (e.g. measured as self-reported life satisfaction), as well as engagement and productivity in the workplace. We further divide the sample into different age and gender sub-samples to test whether any of the associations between nocturia and outcome variables also hold for different age and gender groups, especially the younger population – where specific knowledge on nocturia is still scarce. Furthermore, we examine the relative importance of nocturia in explaining these outcomes, by comparing the magnitude of the associations with those of other health and lifestyle behaviours (e.g. sleep health and BMI) and chronic conditions including cancer, cardiovascular disease or depression, among others.
3. **Quantify the economic burden associated with nocturia:** A small number of previous studies have aimed to assess the economic burden associated with nocturia, relying on cost-of-illness methods that use a bottom-up approach to calculate the healthcare costs and associated productivity losses (e.g. due to absenteeism at work). In this study we aim to quantify the economic costs associated with nocturia in a working-age population across six different countries, including the United Kingdom, Germany, Spain, Australia, Japan and the United States. For this purpose we apply a macroeconomic or so called 'lost economic output' model (Bloom et al., 2011) to estimate the potential economic loss associated with nocturia.[1] An advantage of using a more detailed economic model is that any changes in the supply of labour can have potential spillover effects to other agents in an economy (e.g. for the government through higher tax income), which are captured in this modelling framework.

1 The applied model is similar in nature to the WHO's Economic Cost of Ill-Health (EPIC) model, but more comprehensive and detailed in the representation of the model economy.

1.3. Research methodologies

In order to address the research objectives formulated above, our research incorporates three methodological strands:

1. **Non-systematic literature review:** we review the existing literature to collate currently available evidence about the definition, prevalence and associated factors of nocturia (Chapter 2).
2. **Multivariate regression analysis:** we use statistical multivariate regression methods to examine the associations between nocturia and socio-demographic and lifestyle factors, as well as co-morbidities, sleep disturbances and daytime fatigue (Chapter 4); and life satisfaction and workplace productivity and engagement (Chapter 5). The statistical analyses are based on large workplace surveys conducted across different countries for the years 2017 and 2018.
3. **Macroeconomic modelling:** we use a computational general equilibrium (CGE) economic model to calculate the overall economic cost associated with nocturia in a working-age population with regard to workplace productivity and potential elevated mortality risk (Chapter 6).

1.4. Structure of this report

Chapter 2 provides a summary of the existing literature. Chapter 3 describes in more detail the research approach taken and the data used in the statistical analysis. Chapter 4 presents the findings of the empirical analysis regarding co-morbidities and demographic and lifestyle factors associated with nocturia, as well as the associations between nocturia and sleep disturbances and daytime fatigue. Chapter 5 reports the empirical findings for the associations between nocturia and life satisfaction, workplace engagement and productivity. Chapter 6 reports the analysis regarding the economic costs associated with nocturia, and Chapter 7 synthesises and summarises the findings.

2 The prevalence of nocturia, factors associated with the condition and possible consequences – a glance at the literature

This chapter provides an overview to nocturia, and describes why the condition could have a negative impact on individuals and the wider society. It starts by discussing the clinical and practical definitions, prevalence and consequences for health, wellbeing and productivity, based on what is known from the available literature. Also discussed are the associations between nocturia and sleep, and the existing evidence on the estimated economic burden associated with nocturia.[2]

2.1. Nocturia – a common but often-neglected condition

Nocturia is defined by the International Continence Society (ICS) as *'the complaint that the individual has to wake at night one or more times to void'* where *'each void is preceded and followed by sleep'* (van Kerrebroeck et al., 2002). However, as noted by Coyne et al. (2003), this broad definition does not indicate the threshold of when nocturia becomes 'bothersome' to individuals. In general, those who experience less than two voids per night are not regarded as having clinically significant nocturia that warrants a diagnostic or clinical investigation or treatment. The reason behind this is that empirically, most individuals with less than two voids per night generally experience only minimal bother from the condition (assuming they return to sleep satisfactorily), whereas in contrast, the available evidence suggests that two or more experienced voids is likely to be associated with more severe consequences, such as impaired sleep health and a lower quality of life (Bosch & Weiss, 2010; Tikkinen et al., 2010). Hence, the occurrence of an average of two or more voids per night represents the threshold after which nocturia shifts from being perceived as a minor inconvenience to a more bothersome and clinically meaningful condition.

A recent review summarised the clinical recommendations of the ICS standards on nocturia and lower urinary tract function, and the 2018 ICS consultation on nocturia terminology (Hashim & Drake 2018). A conclusion from the review is that from a clinical diagnosis perspective, nocturia is waking at night to pass urine and the number of times an individual passes urine during their main sleep period is relevant for the diagnosis.

2 Note that the evidence discussed in this chapter has been gathered through a targeted but non-systematic literature review.

2.1.1. Types and prevalence of nocturia

The prevalent types of nocturia generally fall into three categories (Appell & Sand, 2008):

1. diurnal polyuria (excessive production of urine over a 24 hour period);
2. nocturnal polyuria (excessive production of urine at night, with the overall 24 hour output deemed normal);
3. low bladder capacity.

Among the three types, nocturnal polyuria (NP) is the most commonly reported type of nocturia. NP involves passing large volumes of urine at night due to excessive production of urine during the individual's main sleep period.[3] For instance, in a clinical study, data from a cohort of more than 1,700 subjects demonstrated that NP was present in between 66 to 83 per cent of nocturia patients younger than 65 years old, and in 90 to 93 per cent of those aged 65 years or older (Weiss et al., 2011).

In the overall population, nocturia, defined as at least two night-time voids, is relatively common, affecting on average about 20 per cent of the overall population (Weidlich et al., 2017). Epidemiologic data demonstrate that the prevalence of nocturia increases with age (Coyne et al., 2003; Bosch & Weiss 2010), with up to 59 per cent of men and 62 per cent of women awakening at least twice per night by the age of 70. However, even among younger men and women aged 20 to 40, prevalence estimates for nocturia, depending on the number of night time voids, range from 11 to 44 per cent. Beyond age, several studies have investigated gender differences in the prevalence of nocturia. For instance, in a random sample of the population in Finland, Tikkinen et al. (2006) find that in younger age groups from 18 to 49 years, women are more likely to suffer from nocturia than men. Interestingly, an equal share of men and women aged between 50 and 59 years report having nocturia, whereas in those aged 60 years and above nocturia tends to be more common in men.

In summary, nocturia is a condition that affects a significant proportion of the working-age population, with approximately up to one in ten individuals aged 45 or younger regularly waking to void twice or more in the night.

2.1.2. Factors associated with nocturia

Beyond age and gender, there are numerous other risk factors associated with the condition. For instance, the evidence suggests that nocturia is comorbid with other health conditions such as cardiovascular diseases, diabetes, lower urinary tract obstruction, pulmonary diseases, sleep disorders and anxiety (Jennum, 2002; Weiss & Blaivas 2000). Additionally, Häkkinen et al. (2008) find that depressive symptoms are associated with approximately a three times greater risk of having nocturia among middle-aged to older males in Tampere, Finland.

Furthermore, a small number of studies examine the association between nocturia and socio-demographic factors and socio-economic status. Examining data from a random sample of individuals from Boston, Fitzgerald et al. (2007) find that individuals from ethnic minority groups

3 Nocturnal polyuria – passing large volumes of urine at night – is a sign of the excessive production of urine during the individual's main sleep period. These should be quantified using a 3-day bladder diary, thereby facilitating identification of 24-polyuria, nocturnal polyuria, lower urinary tract dysfunction or sleep disorder.

are significantly more likely to suffer from nocturia than white respondents. In a comprehensive review of the nocturia epidemiological literature, Yoshimura (2012) find that different ethnicities were associated with different nocturia prevalence. For example, non-white ethnicities have a higher prevalence in the U.S. than their white counterparts, while indigenous residents are more likely to have nocturia in eastern Taiwan. Kim et al. (2017) investigate the association between socio-economic status and nocturia among Korean adult males. They find that individuals with lower income levels exhibit a symptom-severity dependent relationship with nocturia, such that those with lower education levels have significantly higher prevalence of nocturia, as compared to those with more education. Finally, the type of occupation is also significantly associated with nocturia. Students, the unemployed and blue-collar workers are more likely to suffer from nocturia. Collectively, these findings suggest that as with other health conditions, nocturia is socially patterned, disproportionately affecting certain racial/ethnic minorities and individuals from lower socio-economic classes.

With regards to the relationship between nocturia and sleep, Samuelsson et al. (1997) examine the impact of nocturia, defined as two or more voids per night, on the self-reported sleep of a sample of working age women in Sweden. Those with nocturia have significantly lower sleep-quality scores. Likewise, Kim et al. (2011) draw the same conclusion when studying the impact of nocturia on sleep among Korean men, albeit in a slightly older age group (40 to 79 years). In a community sample in the US, Coyne et al. (2003) find that the presence of nocturia is significantly and negatively associated with sleep. Further, they found that self-reported sleep quality grew worse with every additional reported night-time void. However, given the cross-sectional nature of the data, the direction of the relationship between nocturia and sleep was not established.

Previous research has shown that voiding is cited as one of the main reasons for waking at night, and sleep disturbance mediates the effect of nocturia on quality of life (Bing et al., 2006). Nocturia is negatively associated with direct measures of sleep efficiency and sleep quality (Yoshimura et al. 2009; Asplund, 2005. Another important factor debated in the literature is whether individuals with nocturia are awakened because of the urge to void, or whether they are awakened for some other reason and then sense the need to void (Pressman et al., 1996). To date, there is no clear data on this, and the cause-and-effect associations between nocturia and insomnia are not always obvious. Some studies support the relationship between nocturia and insomnia. For instance, Ayoub et al. (2014) identify nocturia as one of the independent correlates of insomnia amongst 380 older adults aged over 60 years, along with other factors such as a variety of chronic diseases, being female, anxiety, watching television in bed before sleeping, depression and daily sunlight exposure. However, secondary analyses performed on data from a study of behavioural treatment for insomnia in 79 older adults found that therapy was more efficacious in participants with no nocturia (Tyagi et al., 2014). This would indicate that nocturia and insomnia are to some extent independent of each other.

In conclusion, when discussing the relationship between sleep disturbance and nocturia, it is difficult to clarify which is the cause and which is the result. Nevertheless, it is clear that nocturia and sleep disruption go hand-in-hand.

2.1.3. Nocturia and health, social and work outcomes

As described above, nocturia has been found to be associated with decreased quality and length of sleep amongst those who suffer from the condition. Beyond its direct impact on sleep, nocturia is associated with a range of other negative health outcomes. Andersson et al. (2016) analyse physician-recorded data from patients across the UK, France, Germany, Spain and the US in an attempt to determine the impact of nocturia on health-related quality of life (HRQoL). HRQoL is indeed significantly lower among nocturia patients, where nocturia is defined as having two or more voids per night. Additionally, HRQoL decreases significantly with each additional night-time void. Tikkinen et al. (2010) also find that nocturia, again defined as at least two or more voids per night, is associated with impaired HRQoL in their study of a random sample of the population in Finland. Such findings are supported by previous work of a similar nature in the US (Coyne et al., 2003; FitzGerald et al., 2007) and Austria (Schatzl et al. 2000).

Specifically for older populations, nocturia is also associated with a higher risk of falling (Vaughan et al., 2012; Stewart et al., 1992). A study by Kim et al. (2017) shows that nocturia is associated with increased risk of falls in older people, but even among a subsample of younger men aged 19 to 30, the study found an association between high severity of nocturia (i.e. four or five night-time voids) and falling.

As well as its association with specific health outcomes, some studies show that nocturia is a strong predictor of (all-cause) mortality. In the US, Kupelian et al. (2011) analysed results from the *Third National Health and Nutrition Examination Survey* and found a statistically significant association between greater numbers of voiding episodes per night and mortality, even after controlling for relevant covariates such as sleep, socio-demographic status and other morbidities. Additionally, nocturia (defined as two or more voids per night) was found to be a stronger predictor of mortality among younger individuals than the elderly. In another US study of older men (mean age 74), those who voided three or more times per night had a 21 per cent greater risk of mortality than those with zero to one voids, also after controlling for important covariates (Endeshaw et al., 2016). In Finland, Akerla et al. (2018) analysed longitudinal survey data of middle-aged and elderly men and, controlling for important covariates, found that those with nocturia had a 38 per cent greater risk of mortality than those without, where nocturia was defined as two or more voids per night. Nakagawa et al., (2010) analysed the association between nocturia and mortality in a community-based sample of older Japanese individuals (aged 70 years or above), also using longitudinal survey data. Individuals in this sample of very old individuals with nocturia (defined as two or more voids per night) had a 98 per cent higher chance of mortality, even after controlling for smoking status and other comorbidities.

A significant drawback of the mortality literature summarised thus far is its focus on a few countries and specific populations. However, in a systematic review alongside a meta-analysis, Pesonen et al. (2016) found an increased mortality rate for individuals with nocturia equivalent to 28 per cent excess risk per year among the nine studies they identified. As Fan et al. (2015) highlight, the underlying mechanisms of how nocturia contributes to a higher mortality risk needs further research. Nocturia may represent a clinical indicator for a variety of diseases, including diabetes, cardiovascular disease, as well as falls and fractures and sleep disruption. Studies that cannot adjust for these diseases or sleep disorders may overestimate the mortality risk. Fran et al. (2015) provide several estimates for the relationship between nocturia and all-cause mortality and show

that in studies that measure nocturia as two or more voids per night, relative risk is 1.06 (95% CI: 0.97–1.17), suggesting that individuals reporting two or more voids per night have on average a 6 per cent higher probability to die than individuals with less than two voids.

A small strand of the literature looks beyond the impact of nocturia on sleep, health and mortality to consider the effect the condition has on workplace productivity. For instance, Kobelt et al. (2003) examine the impact of nocturia on the productivity of professionally active individuals in Sweden with the condition, compared to a matched control group of those without it. Productivity is captured using the Work Productivity and Activity Impairment (WPAI) measure, an externally validated questionnaire instrument that captures both absenteeism and presenteeism (Tang et al., 2011).[4] Work impairment is significantly higher among those with nocturia, with this difference being driven by presenteeism rather than absenteeism. Further, as the severity of nocturia increases (i.e. the higher the number of voids per night), so too does the level of work impairment. Overall, Kobelt et al. (2003) conclude that individuals with nocturia report 9.2 per cent lower workplace productivity than those without the condition.

In more recent work, Miller et al. (2016) compare the impact that nocturia has on workplace productivity with 12 other common chronic conditions, from asthma to arthritis. Undertaking a systematic review of the literature, the authors identify research that utilises the WPAI measure. Drawing on data from three nocturia-related studies (Andersson et al., 2013; Biliotti et al., 2014; Kobelt et al., 2003), Miller et al. (2016) find that nocturia increases overall work impairment from anywhere between 10 and 39 per cent, reporting a large range of work-impairment estimates varying, in part, based on which relevant covariates were included. When compared to the magnitude of work impairment of other conditions, nocturia has a similar impact on productivity as overactive bladder (11–41%), gastroesophageal reflux disease (6–42%), asthma/allergies (6–40%), chronic obstructive pulmonary disease (19–42%), sleep problems (12–37%), depression (15–43%) and gout (20–37%). Such findings demonstrate that nocturia might be just as detrimental to productivity as numerous other common chronic conditions, despite being significantly less researched. However, it is important to stress that the available studies examining the association between work impairment and nocturia are still scarce and are based on small samples and a limited number of covariates that have been adjusted for in the regression analysis.[5]

2.1.4. The economic burden of nocturia

Beyond intangible cost (e.g. lower levels of quality of life), there is emerging evidence that nocturia is potentially associated with a substantial economic burden in relation to health care costs and loss of workplace productivity of those with the condition (see Table 2.1 for a summary). For instance, Holm-Larsen (2014) estimates the wider economic impact of nocturia, defined as two or more voids per night, in the US and across the EU-15 countries (i.e. Austria, Belgium, Denmark, Finland,

4 Absenteeism is when employees do not show up at work, for instance due to sickness absence, and presenteeism is when people show up at work but do not function to the best of their ability and hence have a lower workplace productivity.

5 For instance Kobelt et al. (2003) found that work impairment for the nocturia group is more than 10 per cent larger than for the control group, but this estimate is only adjusted for age and gender and hence likely upward biased because many other factors that could impact workplace productivity and nocturia simultaneously have been omitted in the analysis. A similar percentage of work impairment has been found by Dmochowski et al. (2019), adjusted for age and gender and overactive bladder, and benign prostatic hypertrophy in a sample of about 1,000 US nocturia patients.

France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the UK) using a cost-of-illness approach.

Table 2.1: Estimated annual economic burden of nocturia by country

Study	Country	Direct cost (billion)	Indirect cost (billion)
Holm-Larsen (2014)	USA	$1.5	$61
	EU-15	$1.0	$29
Weidlich (2017)	Germany	€2.3	€20.8
	Sweden	€0.5	€2.0
	UK	€1.8	€5.6

Notes: annual direct costs include healthcare utilisation cost associated with nocturia, and annual indirect costs include cost related to lower workplace productivity in the form of higher levels of absenteeism or presenteeism.

Utilising data gathered through a search of the relevant literature, the author estimates: 1) the annual direct cost of nocturia, i.e. those related to the increased risk of falling; 2) the annual indirect cost of nocturia, i.e. those related to the loss of productivity; and 3) the intangible costs, such as behavioural modifications and poor mood. Firstly, the annual direct cost is found to be $1.5 billion in the US and €1 billion in the EU-15, based on the increased risk of falls and their associated hospitalisation costs. However, these estimates are based on data from patients of retirement age. Perhaps most significantly, Holm-Larsen (2014) estimates that nocturia costs the US $61 billion and the EU-15 €29 billion annually in lost productivity. These figures are calculated by using data on the prevalence of nocturia, the impact it has on productivity and the average income in each country. Weidlich et al. (2017) also estimate the annual direct and indirect cost attributable to nocturia in Germany, Sweden and the UK using a cost-of-illness approach. They find that the annual direct cost of healthcare resources to manage nocturia is about €2.3 billion in Germany, €0.54 billion in Sweden and €1.77 billion in the UK, with falls and fractures among the main cost drivers, as well as clinician visits. Furthermore, the study estimates the annual indirect cost associated with lower workplace productivity to be €20.76 billion in Germany and €2 billion in Sweden, whereas the annual cost related to absenteeism in the UK was estimated to be €5.64 billion.

In summary, the evidence base on the consequences of nocturia is an emerging field, with much of the current evidence consisting of small studies often undertaken in specific contexts, often among older, non-working adults. As a result, it is challenging to draw definitive conclusions about the prevalence, causes, risk factors and consequences of nocturia. Although there is evidence that nocturia negatively affects individuals, empirical results from working-age populations are limited. This is where this study aims to contribute to the existing knowledge gap.

3 Quantifying factors associated with nocturia and corresponding outcomes – data and methods

This chapter provides an overview of the international linked employer and employee data used in the statistical analysis to examine the factors associated with nocturia and its outcomes in a working-age population. It describes the statistical approach used to analyse the data and how the variables used in the analysis have been constructed, as well as providing corresponding descriptive statistics. Finally, the limitations to the statistical analysis are discussed.

3.1. International workplace survey data

We use data collected from employers and employees in the United Kingdom, Australia, Malaysia, Hong Kong, Thailand, Singapore and Sri Lanka. The data stems from data collected by RAND Europe as part of *Vitality UK's Britain's Healthiest Workplace Survey*, as well as *AIA's Asian Healthiest Workplace Survey*. Two annual survey waves are included, for the years 2017 and 2018.

Both surveys are large working-age population surveys among the workforces of the UK, Australia, Malaysia, Thailand, Sri Lanka, Singapore and Hong Kong, with the goal to collect information about all aspects of health and wellbeing and corresponding health-promotion interventions in the workplace. In both BHW and AIA surveys, employers are surveyed about their provision of health and wellbeing interventions, while the employee survey covers more than 100 questions related to demographic factors (e.g. age, gender, education, income), lifestyle and health behaviour (e.g. nutrition, smoking habits, physical activity, sleep behaviour), health factors (e.g. mental and physical health indicators, chronic and musculoskeletal conditions), as well as measures including workplace productivity and job and life satisfaction.[6] Both surveys include a question on the number of times an individual reports waking at night to visit the bathroom.[7] We discuss in more detail the variables applied in the empirical analysis in the next section. Table 3.1 below reports the sample sizes for each country included in the two surveys, by year.

6 A more detailed description of the survey data and an explanation about the representativeness of the data is provided in Appendix C.

7 The exact wording of the question is as follows: *'How often do you usually get up during the night to go to the bathroom?'*

Table 3.1: Sample sizes by country and year

Country	Year		Survey
	2017	2018	
UK	31,893	26,407	BHW
Australia	2,446	2,906	AIA
Malaysia	5,369	11,551	AIA
Hong Kong	1,162	2,177	AIA
Singapore	1,162	-	AIA
Thailand	-	7,513	AIA
Sri Lanka	-	1,133	AIA
Total	**42,032**	**51,687**	

Source: RAND Europe, based on Vitality BHW survey and AIA survey

Overall, the pooled UK sample includes 58,300 individuals across the years 2017 and 2018. Across the six countries involved in the AIA survey, the sample includes 35,419 across the two years.[8]

For the purpose of the main analysis we pool the available data across the seven countries and two survey waves.[9]

3.2. Statistical approach: a multivariate regression analysis

For the purpose of this analysis, we use multivariate regression models to investigate the associations between nocturia and a set of outcome measures, including workplace productivity, quality of life and a set of sleep measures. Depending on the analysis, nocturia (e.g. measured as a dichotomous variable taking the value one if a respondent reports two or more voids per night and zero otherwise) may be the independent or dependent variable. We primarily apply ordinary least squares (OLS) regression analysis to explore associations between nocturia and a number of different variables. In non-technical terms, a linear regression model is used to describe the relation between two or more variables in a set of data points with a line. Hence, OLS is a statistical approach to fitting a model to the observed data by finding the function that most closely approximates (or best fits) the data (Wooldridge, 2015). In technical terms, the OLS method is used to fit a straight

8 Note that while the same individual could participate in both 2017 and 2018, it is not possible to directly observe the repeating participants over time. Hence, those who participate twice feed into the analysis as two separate individuals. For instance, in case the nocturia severity is fluctuating (e.g. from three voids per night to one void or vice versa), the same individual would be in the nocturia group in one year and not in the other. It is known that roughly 5 per cent of the overall samples participate in both years.

9 Where relevant we also report the findings on a more granular regional level for the UK, the Asian countries and Australia separately. However, note that all regression analyses presented in this study are adjusted for ethnicity and region, and hence only take into account within ethnicity and within region variation in nocturia when estimating the associations with different outcomes.

line through a set of data-points so that the sum of the squared vertical distances (called residuals) from the actual data-points is minimised. Therefore, the best fit can be represented by the line that minimises the total distance between the actual data-points and the predicted values. As described in Section 3.3 many of the explanatory variables included in the regression analysis are binary indicator variables related to health or lifestyle factors.[10]

Note that the analysis also includes outcome variables that are binary indicators (e.g. two or more reported voids per night), and using OLS leads automatically to the linear probability model (LPM).[11] One issue that may arise with LPM is that it might predict values for the probability of being in the nocturia population that lie outside the probability interval between 0 and 1. A Probit or Logit response estimator takes this into account but makes (strong) assumptions about the error terms using maximum-likelihood techniques. However, as long as the relative proportion of LPM predicted values that fall outside the unit interval is small, the LPM estimator is expected to be unbiased (Angrist and Pischke, 2010). That is, the LPM is our preferred estimator, as for interpretational practicality the LPM directly delivers the marginal effects of our variables of interest without the need for conversion of odds ratios into meaningful metrics.[12] Because we only have cross-sectional data, we cannot infer causal relationships in the data. However, the dataset includes a large set of control variables that allows for the adjustment of many confounding factors, which allows us to examine the independent association between nocturia and a given variable. As the data is a linked-employer-employee dataset, in each regression we include company-fixed-effects that adjust for any company-specific factors in the response of individuals, and we cluster standard errors at the company level. All statistical analyses are conducted in STATA 15.[13] Results are reported at the 5 per cent significance level. That means for statistical significance we expect the p-value to be less than the significance level ($p<0.05$).[14]

10 In other words, for interpretation purposes the variables should be interpreted relative to an omitted base or reference category (e.g. for a variable female the omitted category would represent a male employee).

11 See Angrist and Pischke (2010) for a discussion about the advantages of using LPM instead of Logit and Probit binary response models.

12 For sensitivity analysis we also applied logistic regression models where the outcome variable is binary. The findings are identical to the models estimated with LPM.

13 https://www.stata.com/.

14 The concept of statistical significance is generally used to determine whether a null hypothesis is to be rejected or retained. For this analysis, the null hypothesis is the default statement that the true association between two variables is zero. P-values represent the probability of observing an effect given that the null hypothesis is true (there is no real association), whereas the null hypothesis is rejected if the p-value is less than the significance level. The significance level therefore represents the probability of rejecting the null hypothesis given that it is true (DeGroot & Schervish, 2002).

3.3. Variables used in the analysis

In the statistical analysis of this study we examine a set of factors associated with the prevalence of nocturia, as well as the associations between nocturia and a set of outcome variables of interest. In what follows we describe in more detail the variables used in the analysis, beginning with how nocturia is measured, followed by a description of some of the key covariates, as well as a description of the outcome variables. The variables used in the analysis can be divided into the following categories:

Socio-demographic;

Nocturia;

Lifestyle and health behaviour;

Sleep;

Chronic health conditions;

Subjective wellbeing, work engagement and productivity.

3.3.1. Socio-demographic variables

Like other surveys in the area of health and wellbeing, the BHW and AIA surveys include a number of socio-demographic indicators. We use these indicators as covariates in the analysis. They include:

Gender: the binary variable takes the value one if the respondent is female or zero otherwise.

Date of birth: for which we calculate current age in years. In addition to the continuous variable age in years we also create three age categories, including either (1) between age 18 and 30; (2) 31 and 50; or (3) 51 or older, respectively.

Education: is divided into five different categories according to the highest level of educational degree achieved: (1) primary education only; (2) lower secondary; (3) upper secondary but not university; (4) undergraduate university; (5) postgraduate.

Income: is measured in the surveys through a scale of ten different country-specific income categories.[15]

Marital status: is captured in the surveys through five different categories, including (1) married; (2) cohabitating; (3) separated/divorced; (4) never married; (5) widowed.

Occupation: information is collected in the surveys through various occupational categories, including, among others: manager, professional, technician, clerical support worker; service worker, sales worker, skilled agricultural and fishery worker, craft and related trades worker, plant and machine operator or assembler, elementary occupations, armed forces occupations.

Irregular hours: a binary variable taking the value one if an individual reports to work irregular or shift hours and zero otherwise.

Ethnicity: including four ethnicity related categories: (1) White; (2) Asian; (3) Black; and (4) other ethnic background.

3.3.2. Nocturia or the frequency of night-time bathroom visits

The BHW and AIA surveys include a question on the number of times an individual reports having to get up at night to go to the bathroom to void. In line with existing literature, we define nocturia as a dichotomous variable, consisting of those individuals reporting two or more voids per night versus individuals reporting less than two voids per night. Table 3.2 reports the frequency for the reported number of voids per night across respondents of three regions (UK, Asia and Australia) by year and total.

15 Income scales have been adapted to each country's income distribution in the local currency, which roughly correspond to deciles of the work-income distribution.

Table 3.2: Distributions of the number of voids per night; by year and region

Panel A: United Kingdom				
	Years		Total	
Number of voids:	2017	2018	individuals	per cent
0	16,411	12,539	28,950	49.7%
1	12,776	10,943	23,719	40.7%
2	2,003	2,060	4,063	7.0%
3	492	555	1,047	1.8%
4	119	126	245	0.4%
5+	92	184	276	0.5%
Total	**31,893**	**26,407**	**58,300**	**100.0%**
Panel B: Malaysia, Hong Kong, Singapore, Thailand, Sri Lanka				
	Years		Total	
Number of voids:	2017	2018	individuals	per cent
0	3,085	8,453	11,538	43.4%
1	2,671	9,399	12,070	45.4%
2	528	1,581	2,109	7.9%
3	146	441	587	2.2%
4	22	85	107	0.4%
5+	48	133	181	0.7%
Total	**6,500**	**20,092**	**26,592**	**100.0%**
Panel C: Australia				
	Years		Total	
Number of voids:	2017	2018	individuals	per cent
0	1,159	1,429	2,588	48.4%
1	1,040	1,183	2,223	41.6%
2	164	208	372	7.0%
3	52	59	111	2.1%
4	11	12	23	0.4%
5+	14	12	29	0.5%
Total	**2,443**	**2,903**	**5,346**	**100.0%**

Source: RAND Europe, based on Vitality BHW survey and AIA surveys 2017 and 2018.

Panels A, B and C report the number of voids for the UK, Asian and Australia-specific sub-samples. Overall, we find a relatively similar prevalence of two or more voids per night across the three regions. For the UK, 9.7 per cent of respondents report two or more voids; in the Asian sample 11.2 per cent of respondents report two or more voids and in the Australian sample about 10 per cent of respondents report two or more voids per night. The three regional samples are also relatively similar with regards to the nocturia symptom-severity distribution. In the UK and Australia sub-sample, about 7 per cent of respondents report two voids per night, compared to 7.9 per cent in the Asian sub-sample. The proportion of three voids per night varies between 1.8 per cent (UK) and 2.2 per cent (Asia), whereas the proportion of four voids per night is identical across all three sub-samples, namely 0.4 per cent. Finally, the proportion of five or more reported voids per night is identical across the UK and Australian sub-samples (0.5 per cent), and slightly higher in the Asian sub-sample (0.7 per cent). Note that given the relatively low prevalence of more than three voids per night for the remainder of the analysis, we separately define and analyse the association with some factors for four sub-groups within the nocturia population: (1) zero voids; (2) one void; (3) two voids and (4) three or more voids.

Table 3.3 reports the share of individuals reporting two or more voids per night by gender-age sub-samples. Within the female sample population aged 18–30, out of 17,070 individuals 8.95 per cent report two or more voids per night. This increases to 10.19 per cent for the female sample population aged 31–50 (out of 26,203 individuals) and 18.11 per cent for the female sample population aged 51 or older (out of 6,633). Within the male sample population aged 18–30, out of 12,285 individuals, 6.34 per cent report two or more voids per night. This share increases to 8.56 per cent (out of 23,671 individuals) for the male sample population aged 31–50 and to 14.65 per cent for the male sub-population aged 51 or older (out of 7,497 individuals).

Table 3.3: Percentage of sample population reporting two or more voids per night, by age and gender

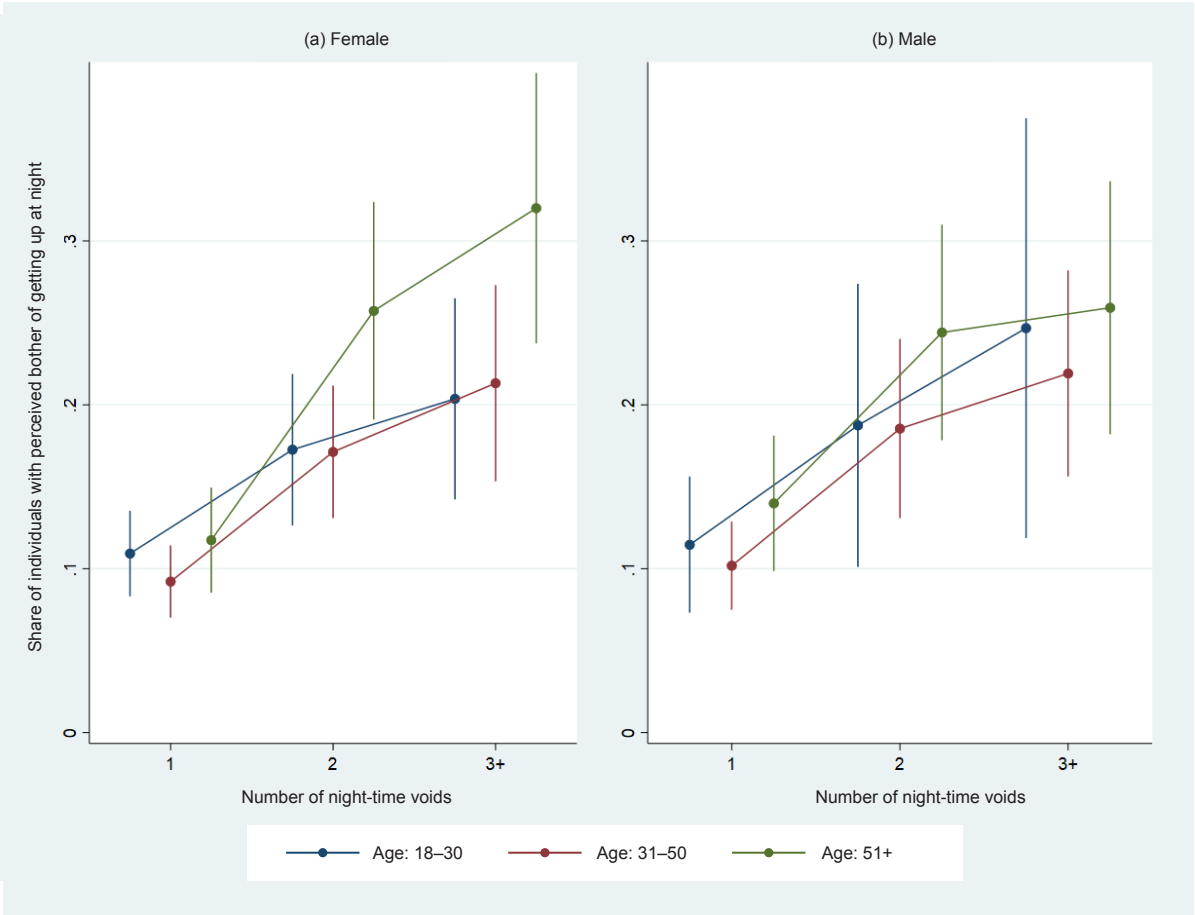
	Female		Male	
	%	N	%	N
Age: 18–30	8.95	17,070	6.34	12,285
Age: 31–50	10.19	26,203	8.56	23,671
Age: 51+	18.11	6,633	14.65	7,497

Notes: based on Vitality BHW survey and AIA surveys 2017 and 2018. Per cent represents the share of individuals within the gender-age sub-sample reporting two or more voids per night. N represents the total number of individuals within each gender-age sub-sample.

In addition to the experienced number of voids per night, UK respondents in the 2018 BHW survey rate how bothered they are with having to get up at night and go to the bathroom on a scale ranging from 1 ('not at all bothered') to 5 ('extremely bothered'). The item is dichotomised taking the value 0 if the respondent is not at all bothered and 1 if the respondent is bothered. Figure 3.1 reports the coefficients from a linear regression of bother (as the dependent variable) as a function of symptom severity, separately for age and gender.

Overall, we observe that nocturia is bothersome and that the level of bother increases with the number of reported voids per night, independent of age or gender. For instance, while about 10 per cent of individuals aged between 18 to 30 report that one void per night is bothersome, more than 20 per cent report being bothered if they have three or more voids per night. This rises to over 30 per cent for women aged 51 and older and more than 25 per cent for men aged 51 and older.[16]

Figure 3.1: Nocturia symptom-severity and bother – share of individuals with perceived bother



Source: Author's calculations, based on BHW survey 2018.

Interestingly, we observe that the marginal rate of being bothered declines somewhat with the number of voids, with a relative steep increase in reports of being bothered across all age and gender groups between one void and two voids per night. The findings confirm previous research that shows two voids per night represents a threshold at which individuals start to feel bothered by the condition. It also suggests that having to void once per night may not be problematic for most people, nor would it be considered a clinical condition.

16 Note that we also used the non-dichotomised bother scale as a dependent variable and found identical results, with the level of bother increasing as a function of nocturia symptom-severity.

3.3.3. Lifestyle and health behaviour variables

The BHW and AIA surveys also include a number of relevant variables with relation to individual lifestyle and health behaviour. We include the following variables in the analysis:

Body Mass Index (BMI): calculated using self-reported height and weight. In addition to the continuous BMI variable we generate four BMI categories: (1) underweight (BMI < 18); (2) normal weight (BMI 18–25); (3) overweight (BMI 25–30) and (4) obese (BMI > 30).

Smoking: a binary variable taking the value one if the respondent is currently smoking or zero otherwise.

Excessive alcohol consumption: measured as a binary variable taking the value one if the individual exceeds the weekly alcohol consumption that is regarded as within the healthy range of 14 units (8mg), and zero otherwise.

Physical inactivity: measured as a binary variable taking the value one if the individual does not perform at least 150 mins of physical exercise per week.[17]

Excessive salt intake: measured as a binary variable taking the value one if the individual adds more than a pinch of salt to every meal on a regular basis, and zero otherwise.[18]

High blood pressure: respondents are asked whether last time they (or somebody else) checked their blood pressure it was normal or high, where high is measured as a binary variable taking the value one if the respondent has a blood pressure above: 120/80 mmHg (UK, Malaysia, Singapore, Hong Kong, Sri Lanka; 140/90 mmHg (Australia); 135/85mmHg (Thailand); or zero otherwise.

17 This is in line with the WHO recommendations regarding physical activity of at least 150 mins per week. https://www.who.int/dietphysicalactivity/physical-activity-recommendations-18-64years.pdf

18 Note that the full response categories for this variable include (1) zero added salt; (2) a pinch of salt; (3) half a teaspoon; (4) a heaped teaspoon; (5) a level dessert spoon; and (6) a heaped dessert spoon of additional salt.

High cholesterol: respondents are asked whether last time they (or somebody else) checked their blood pressure it was normal or high, whereas high is measured, depending on the country, as binary variable taking the value one if the respondent has a cholesterol level above: 5 mmol/L (UK, Malaysia, Singapore); 4.0 mmol/L (Australia); 5.2 mmol/L (Hong Kong); 200 mg/dl (Thailand and Sri Lanka); or zero otherwise.

High glucose: respondents are asked whether last time they (or somebody else) checked their glucose level it was normal or high, where high is measured as a binary variable taking the value one if the respondent has a random glucose level above: 7.8 mmol/L (United Kingdom, Australia, Singapore); 9.0mmol/L (Malaysia, Hong Kong); 200mg/dl (Thailand, Sri Lanka); or zero otherwise.

Psychological distress and anxiety: measured through the *Kessler Psychological Distress Scale.* The six-item scale is a simple measure of psychological distress, involving six questions (each with a five-level response scale) about emotional states. The measure can be used as a brief screen to identify levels of psychological distress, with a larger number suggesting a greater distress. In line with previous research, we generate a dichotomous variable taking the value one if the overall Kessler score is above 13, which is generally assumed the threshold of medium to severe psychological distress.

Table 3.4 reports a descriptive summary for each of the lifestyle and health behaviour variables, including a description and the sample means and corresponding standard deviations for individuals reporting less than two voids per night, and those reporting two or more voids per night.[19] For almost all of the factors presented, the sample population reporting two or more voids per night reports on average a higher level of the factor, except for excessive alcohol consumption, where the difference between the two groups is not statistically significantly different from zero (e.g. p-value from t-test at least smaller than 0.1).

19 Note that for binary variables sample means are equal to the average share of individuals that report a specific factor. For instance in Table 3.4, the mean value of 0.310 for individuals reporting less than two voids per night means that 31 per cent of individuals within this group report a BMI between 25 and 30.

Table 3.4: Summary of lifestyle and health behaviour variables

		< 2 voids		>= 2 voids		
Variable	**Description**	**Mean**	**SD**	**Mean**	**SD**	**p-value**
BMI: underweight	BMI < 18.5; (1 yes - 0 no)	0.036	(0.186)	0.029	(0.167)	0.001*
BMI: overweight	BMI > 25 to 30; (1 yes - 0 no)	0.310	(0.462)	0.327	(0.469)	0.001*
BMI: obese	BMI > 30; (1 yes - 0 no)	0.157	(0.364)	0.247	(0.431)	0.000**
Current smoker	Currently smoking cigarettes (1 yes - 0 no)	0.099	(0.298)	0.108	(0.310)	0.017*
Excessive alcohol consumption	Consumption > 14 units (8mg) per week (1 yes - 0 no)	0.198	(0.398)	0.196	(0.397)	0.765
Physical inactivity	Exercising less than 150 mins per week (1 yes - 0 no)	0.325	(0.468)	0.384	(0.486)	0.000**
Excessive salt intake	Salt addition to every meal regularly more than a pinch of salt (1 yes - 0 no)	0.093	(0.290)	0.113	(0.317)	0.000**
High blood pressure	BP last time measured > 120/80 mmHg (UK, Malaysia, Singapore, Hong Kong, Sri Lanka); 140/90 80 mmHg (Australia); 135/8580 mmHg (Thailand); (1 yes - 0 no)	0.224	(0.417)	0.296	(0.456)	0.000**
High cholesterol	Cholesterol last time measured > 5 mmol/L (UK, Malaysia, Singapore); 4.0 mmol/L (Australia); 5.2 mmol/L (Hong Kong); 200 mg/dl (Thailand and Sri Lanka); (1 yes - 0 no)	0.032	(0.177)	0.049	(0.216)	0.000**
High glucose	Glucose last time measured > 7.8 mmol/L (United Kingdom, Australia, Singapore); 9.0mmol/L (Malaysia, Hong Kong); 200mg/dl (Thailand, Sri Lanka); (1 yes - 0 no)	0.013	(0.112)	0.034	(0.182)	0.000**
Psychological distress	Kessler score above 13 on total score of 24; (1 yes - 0 no)	0.065	(0.247)	0.107	(0.309)	0.000**

Notes: *based on Vitality BHW survey and AIA surveys 2017 and 2018. Mean of binary variable represents the share of individuals within category and to convert shares into per cent entries need to be multiplied by 100. SD represents corresponding standard deviation. P-values from t-test reported (** p<0.01, * p<0.05).*

3.3.4. Sleep duration and quality

The BHW and AIA surveys also include a number of questions related to sleep health, **including self-reported sleep duration as well as quality. In addition to these two sleep measures, the surveys also ask respondents about their first unit of uninterrupted sleep and their level of daytime fatigue.**

In order to take into account short-sleep, we generate a binary variable taking the value one if the self-reported hours of sleep per night are less than six hours or zero otherwise.

In addition to sleep duration, the surveys also include questions related to sleep quality. For instance, individuals are asked to rate sleep quality experienced during the last seven days on a five-point scale (1: very poor – 5: very good). Included are also three further questions measured on a five-point scale (1: not at all – 5: very much) on whether, during the last seven days: (1) the sleep was refreshing; (2) the individual had a problem with sleep; or (3) had difficulties falling asleep. Each of these sleep-quality items have been recoded so that higher values represent a lower sleep quality, and dichotomised to take the value one if the item score was 4 or 5 and zero if the item score was less than 4. We also create a summary measure to capture overall sleep disturbance by summing up all the four binary sleep-quality items into a single disturbance composite-measure ranging from 0 to 4.

In addition to the four sleep-quality questions, survey participants are also asked about the self-reported **average length of the first period of uninterrupted sleep at night (FUSP).** As Bliwise et al. (2014) highlight, in the urology literature the prevalent proxy outcome used for sleep quality is the self-reported FUSP. Since the majority of essential slow-wave sleep (SWS) occurs during the first 3–4 hours of sleep, the larger the FUSP, the better the sleep, all else equal. Hence, in addition to the sleep-quality measures described above, our data allows the examination of the association between nocturia and this additional measure of sleep quality.

The BHW and AIA surveys further ask respondents whether they feel tired or fatigued during their waking time, measured on a five-point scale (1: rarely or never – 5: almost every day). We use this scale to determine the association between nocturia and daytime fatigue.

Table 3.5 reports a summary for each of the sleep-related variables, including a description and the sample mean with corresponding standard deviation for individuals reporting less than two voids per night and those reporting two or more voids per night. The sample means for both groups suggest that individuals reporting two or more voids are more likely to report sleeping less than six hours a night, and report on average a lower sleep quality than individuals reporting less than two voids per night. Interestingly, individuals with more than two voids per night also report an FUSP of more than one hour less than individuals reporting less than two voids per night. They also report on average a higher daytime fatigue score.

Note that, unfortunately, the data does not include a direct question on whether the individual suffers insomnia or other sleep disorders, such as sleep apnea. For the statistical analyses presented in Chapter 5 – where we look at the association between nocturia and life satisfaction, work engagement and work impairment – we include sleep quality and short-sleep variables in the regression models as proxies for insomnia or other sleep disorders. While we cannot solve the question on the direction of causality between sleep and nocturia, at least it allows us to examine the independent association between nocturia and the given outcome, even after adjusting for sleep problems.

Table 3.5: Summary of sleep related variables

		< 2 voids		>= 2 voids		
Variable	**Description**	**Mean**	**SD**	**Mean**	**SD**	**p-value**
Sleep duration: less than 6 hours	Self-reported sleep duration < 6 hours (night); (1 yes - 0 no)	0.203	(0.402)	0.270	(0.444)	0.000**
Sleep quality: low	In past seven days, overall sleep quality rated as 'Very poor' or 'Poor' on 5-item scale (5 'Very good'); (1 yes - 0 no)	0.144	(0.351)	0.257	(0.437)	0.000**
Sleep not refreshing	In past seven days, sleep rated as 'not at all' or 'a little bit' refreshing on 5-item scale (5 'very much'); (1 yes - 0 no)	0.157	(0.363)	0.292	(0.454)	0.000**
Sleep problems	In past seven days, problems with sleep 'Quite a bit' and 'Very much' on 5-item scale (1 'Not at all'); (1 yes - 0 no)	0.116	(0.320)	0.215	(0.411)	0.000**
Difficulties falling asleep	In past seven days, difficulties falling asleep 'Quite a bit' and 'Very much' on 5-item scale (1 'Not at all'); (1 yes - 0 no)	0.282	(0.450)	0.424	(0.494)	0.000**
Sleep Disturbance Score	Composite measure by adding binary variables Sleep quality (low); Sleep not refreshing; Sleep problems; Difficulties falling asleep together with range (0 to 4) with higher values meaning higher level of sleep disturbance	0.698	(1.102)	1.188	(1.360)	0.000**
FUSP	Self-reported first period of uninterrupted sleep in hours	4.411	(1.968)	3.371	(1.564)	0.000**
Daytime Fatigue Score	During wake time feeling tired or fatigued on 5-item scale (1 'Rarely or never' to 5 'Almost every day'	2.887	(1.120)	3.133	(1.163)	0.000**

*Notes: based on Vitality BHW survey and AIA surveys 2017 and 2018. Mean of binary variable represents the share of individuals within category and to convert shares into per cent entries need to be multiplied by 100. SD represents corresponding standard deviation. P-values from t-test reported (** p<0.01, * p<0.05).*

3.3.5. Diagnosed chronic health conditions

In both surveys, respondents are asked whether they have been diagnosed within the last 12 months with any of the following chronic health conditions:

Asthma or severe allergies;

Heart condition or disease;

Kidney condition or disease;

Cancer;

Diabetes;

Hypertension;[20]

Severe mental illness (e.g. schizophrenia, bipolar disorder, major-depressive disorder or post-traumatic stress disorder).

We include these seven variables as binary indicator variables in the analysis, taking the value one if the respondent has been diagnosed with one of the conditions and zero otherwise. However, it has to be highlighted that it is not possible to distinguish between the types of cancer, heart or kidney diseases. It is only known whether one of these conditions has been diagnosed, but not their type or severity.

Table 3.6 reports a summary for each of the chronic health-condition variables, including a description and the sample means with corresponding standard deviations for individuals reporting less than two voids per night and those reporting two or more voids per night. Overall, the sample means suggest that on average an individual reporting two or more voids per night also reports a statistically significantly higher probability of being diagnosed with any of the seven chronic health conditions within the last 12 months.

20 Note that in contrast to the question on whether a respondent had a relative high blood-pressure as described in section 3.3.3, hypertension in this question refers to diagnosed chronic hypertension.

Table 3.6: Summary of chronic health condition variables

		< 2 voids		>= 2 voids		
Variable	**Description**	**Mean**	**SD**	**Mean**	**SD**	**p-value**
Asthma	Clinically diagnosed with Asthma within the last 12 months; (1 yes - 0 no)	0.068	(0.252)	0.092	(0.289)	0.000**
Cardiovascular disease	Clinically diagnosed with Cardiovascular disease within the last 12 month; (1 yes - 0 no)	0.010	(0.100)	0.025	(0.157)	0.000**
Kidney disease	Clinically diagnosed with Kidney disease within the last 12 months; (1 yes - 0 no)	0.005	(0.073)	0.014	(0.118)	0.000**
Cancer	Clinically diagnosed with Cancer within the last 12 months; (1 yes - 0 no)	0.004	(0.061)	0.009	(0.092)	0.000**
Diabetes	Clinically diagnosed with Diabetes within the last 12 months; (1 yes - 0 no)	0.016	(0.124)	0.047	(0.212)	0.000**
Hypertension	Clinically diagnosed with Hypertension within the last 12 months; (1 yes - 0 no)	0.047	(0.211)	0.104	(0.306)	0.000**
Severe mental illness	Clinically diagnosed with severe mental illness (e.g. schizophrenia, bipolar disorder; major depressive disorder) within the last 12 months; (1 yes - 0 no)	0.032	(0.177)	0.057	(0.233)	0.000**

*Notes: based on Vitality BHW survey and AIA surveys 2017 and 2018. Mean of binary variable represents the share of individuals within category and to convert shares into per cent, entries need to be multiplied by 100. SD represents corresponding standard deviation. P-values from t-test reported (** p<0.01, * p<0.05).*

3.3.6. Subjective wellbeing, workplace productivity and engagement

The surveys also include a question regarding the overall life satisfaction of respondents, measured on an 11-point scale (0: not at all – 10: completely). Specifically, the question asks *'how satisfied are you with your life nowadays?'* and is a standard question applied in numerous surveys and studies to measure subjective wellbeing (SWB).[21]

Productivity is measured using the Work Productivity and Activity Impairment Questionnaire (General Health) (WPAI-GH). The WPAI-GH was developed in 1993 to assess productivity loss by measuring

21 See for instance Blanchflower (2008) for further background on this topic.

the effect on work productivity of general health and symptom severity (Tang et al., 2011).[22] The instrument consists of six questions with a recall time frame of seven days. The questions ask whether the respondent is employed; the number of hours missed from work; the number of hours actually worked; and the degree to which the respondent feels that a health problem has affected productivity while at work and their ability to do daily activities other than work. WPAI-GH outcomes are expressed as impairment percentages, where higher percentages indicate greater impairment and lower productivity. We use the following three work-related impairment percentages calculated on the basis of the WPAI-GH scale:

- Per cent work time missed due to ill-health (absenteeism);
- Per cent impairment while working due to ill-health (presenteeism);
- Per cent overall work impairment due to ill-health (absenteeism and presenteeism).

To measure work engagement, the surveys include questions that build the Utrecht Work Engagement Scale (UWES), which includes three dimensions of work engagement: vigour, dedication, and absorption. The nine questions related to the scale are measured on a 7-point Likert scale (0: never, 1: almost never, 2: rarely, 3: sometimes, 4: often, 5: very often, 6: always):

- At my work, I feel bursting with energy;
- At my job, I feel strong and vigorous;
- I'm enthusiastic about my job;
- My job inspires me;
- When I get up in the morning, I feel I like going to work;
- I feel happy when I'm working intensively;
- I am proud of the work that I do;
- I am immersed in my work;
- I get carried away when I am working.

In line with previous research (e.g. Schaufeli et al., 2009), we construct the UWES engagement scale by adding the 7-point scale across all nine questions, with a larger value of the scale showing a larger level of engagement (range 0–54).

Table 3.7 reports a summary for each of the three variables, including life satisfaction, work engagement and work impairment, including a description and the sample mean for individuals reporting less than two voids per night and those reporting two or more voids per night. On average, the sample means suggest that individuals reporting two or more voids per night report lower life satisfaction, as well as somewhat lower work engagement and higher work impairment.

22 It was originally established as a self-reported quantitative assessment of the amount of absenteeism, presenteeism and daily-activity impairment attributable to general health (WPAI-GH) or a specific health problem (WPAI-SHP). It has since been used in a wide range of applications, and several versions for specific health problems are now available, as well as being available in different languages (Lofland et al., 2004).

Table 3.7: Summary of life satisfaction, work engagement and impairment variables

		< 2 voids		>= 2 voids		
Variable	**Description**	**Mean**	**SD**	**Mean**	**SD**	**p-value**
Life satisfaction	Self-reported life satisfaction nowadays measured on 11-point scale (0 ' Not at all satisfied' - 10 'Completely satisfied')	6.891	(1.878)	6.556	(2.101)	0.000**
Work engagement score	Utrecht Work Engagement Scale (UWES) with range (0 to 54) with a higher score measuring higher work engagement	32.879	(8.806)	32.199	(9.435)	0.000**
Work impairment	Per cent work impairment (working time lost) due to absenteeism and/or presenteeism (WPAI-GH scale)	0.169	(0.232)	0.229	(0.266)	0.000**

*Notes: based on Vitality BHW survey and AIA surveys 2017 and 2018. SD represents corresponding standard deviation. P-values from t-test reported (** p<0.01, * p<0.05).*

3.3.7. Limitations of the statistical analysis

The analysis of the 2017 and 2018 BHW and AIA survey data has several strengths. The relatively large sample size and comprehensive collection of data on personal, health and job factors allows an in-depth investigation of the factors associated with nocturia and corresponding outcomes. However, there are some limitations to the empirical approach taken.

Firstly, healthier employees are likely to be more motivated in responding to the surveys, and people who are on long-term sick leave are likely to be under-represented in the data, since it is a workplace survey. There is also potential for selection bias of companies into the survey. For instance, 'healthier' companies probably have a greater incentive to register and compete in both surveys. In our analysis, however, we take care of this potential bias by including in each regression analysis individual company fixed-effects. Furthermore, while our data is cross-sectional, each regression analysis adjusts for a large set of individual employee characteristics.

Secondly, it is important to stress that the data are self-reported. This creates potential for the under-reporting of the real prevalence of bad lifestyle habits – such as smoking or alcohol consumption – or for overstating good ones, physical activity for instance. It is important to stress, though, that this is a common issue in surveys of this nature. Again, if for instance an individual is under-reporting his or her real smoking habits, then our estimates would represent a lower bound of the true parameter value and we would underestimate the true effect rather than overestimating it. Specifically, as we define the nocturia population based on the self-reported frequency of night-time bathroom visits, the main variable in the empirical analysis may be subject to inaccuracies and has not been clinically diagnosed by a health professional. Furthermore, the nocturia variable used in the analysis does not allow differentiation related to different types of nocturia (e.g. nocturnal polyuria or low bladder capacity).

Thirdly, when interpreting the results from the empirical analysis, caution has to be applied with regard to causality. Our statistical regression models capture associations and not necessarily causation. While each regression model adjusts for a large set of covariates, there is a possibility that reverse causality is an issue. For instance, when we examine the association between nocturia and sleep, it is not a priori clear in which direction this relationship holds.

Fourthly, across the years in both surveys some respondents have participated in both years, but currently it is not possible to directly link them over time. Roughly about an estimated 5 per cent of the sample may be included in both the 2017 and the 2018 samples. However, as nocturia is a fluctuating disease (e.g. the number of reported voids per night can vary), and if the factors associated with the condition vary as well (e.g. levels of reported subjective wellbeing), we do not consider this to be a major problem as the individual repeating the survey is treated as a separate individual in each wave of the survey.

4 Factors associated with nocturia in the working-age population – demographics, lifestyle, co-morbidities and sleep

This chapter examines demographic and lifestyle factors, as well as a range of other co-morbidities potentially associated with the prevalence of nocturia in a working-age population. As discussed in Chapter 2, the empirical literature investigating the correlates of nocturia and a range of different factors so-far suggests that gender, age and ethnicity, as well as – among other factors – health conditions (e.g. depression, kidney disease, cardiovascular disease, hypertension, diabetes) and alcohol consumption are associated with nocturia. However, one shortcoming of the existing empirical evidence is that the study population often consists of older individuals, or the data is limited in scope. That is, some studies only look at demographics or lifestyle factors, while others only look at certain co-morbidities separately. The empirical analysis presented here bridges this gap in the literature by analysing a large population of working-age individuals. The data enables a comprehensive investigation of the factors associated with nocturia that are relevant for different demographic groups, while taking account of a range of other factors.

In what follows we report the corresponding empirical findings regarding the factors associated with nocturia, including demographics, lifestyle, co-morbidities and sleep.

4.1. Co-morbidities, demographic and lifestyle factors

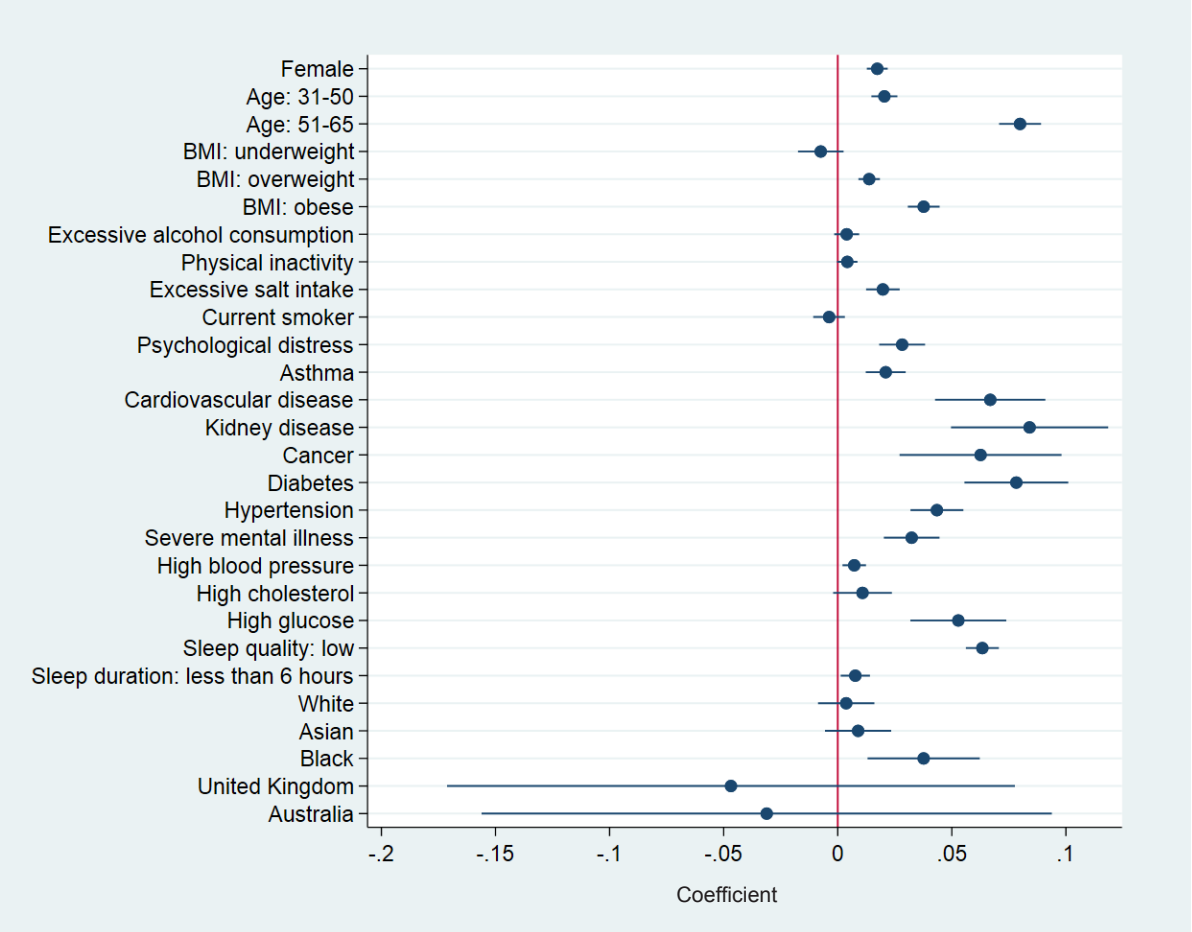
4.1.1. Associations observed in the full sample

Figure 4.1 reports the demographic and lifestyle factors and co-morbidities associated with nocturia in a working-age population. The figure reports the coefficients from a multivariate regression analysis using the LPM with the binary outcome variable taking the value one if the respondent reports two or more voids per night (and zero otherwise) based on the pooled 2017 and 2018 BHW and AIA survey samples.[23] In addition to the covariates reported in the figure, the coefficients are also adjusted for education, income, marital status and job type. The coefficients represent the average associated marginal probabilities for each covariate to predict that an individual is reporting two or more voids per night.[24] The marginal probabilities for the statistically significant factors are reported in Table 4.1.

23 The corresponding regression output table can be found in Appendix A, Table A.1. In order to calculate the percentage difference the coefficients are multiplied by 100.

24 The marginal probabilities are closely associated with the odds ratios that would be reported from a logit or probit regression, where an odds ratio larger than one represents a positive association and an odds ratio smaller than one a negative association (Winkelmann and Boes, 2008).

Figure 4.1: Associations between nocturia and demographic, lifestyle factors and co-morbidities – marginal probabilities



Notes: based on multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval. Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night. In addition to covariates presented in the figure, the coefficients are also adjusted for other covariates including education, main job, income, and marital status, which are not displayed. Based on pooled BHW and AIA samples for the years 2017 and 2018. The full regression output table can be found in Appendix A, Table A.1.

As suggested by the frequency of nocturia in the sample population reported in Table 2.2, the coefficients reported in Figure 4.1 confirm that there is no statistically significant difference in the prevalence of nocturia between the UK and Australian sub-samples compared to the Asian sub-samples.

Similar to previous research, as depicted in Figure 4.1 and reported in Table 4.1, we observe that women tend to be more likely to report two or more voids per night. All else equal, women tend to have a 1.73 percentage point larger probability to report two or more voids per night than men. With regard to age, we also observe that the probability to report two or more voids per night is larger for individuals aged 51 or older compared to individuals age 18 to 30, by almost 8 percentage points,

whereas individuals aged 31 to 50 on average have a 2 percentage point larger probability to report two or more voids per night. Compared to other ethnicities, black individuals have on average a 3.76 percentage point larger probability to report two or more voids.

Beyond gender, age and ethnicity, Table 4.1 reports the magnitude of the associations between nocturia and other lifestyle factors and co-morbidities.

Table 4.1: Associations between nocturia and demographic, lifestyle factors and co-morbidities – marginal probabilities

Factor	Marginal probability (%)	*P value*
Kidney disease	8.41	*0.000***
Age: 51+	7.99	*0.000***
Diabetes	7.82	*0.000***
Cardiovascular disease	6.68	*0.000***
Sleep quality (low)	6.34	*0.000***
Cancer	6.26	*0.001***
High glucose	5.28	*0.000***
Hypertension	4.34	*0.000***
BMI: obese	3.77	*0.000***
Black	3.76	*0.003***
Severe mental illness	3.24	*0.000***
Psychological distress	2.82	*0.000***
Asthma	2.1	*0.000***
Age: 31–50	2.04	*0.000***
Excessive salt intake	1.98	*0.000***
Female	1.73	*0.000***
BMI: overweight	1.38	*0.000***
Sleep duration (less than 6 hours)	0.77	*0.019**
High blood pressure	0.72	*0.006***
Physical inactivity	0.42	*0.05**

***Notes**: table reports the average marginal probabilities for each covariate to predict that an individual is reporting two or more voids per night. Only covariates depicted in Figure 4.1 that are statistically significant are reported and ordered according to magnitude with corresponding p-value (** p<0.01, * p<0.05).*

All else being equal, we observe that an individual who has been clinically diagnosed with a kidney disease within the last 12 months is also more likely to report two or more voids per night, by about 8.41 percentage points, compared to an individual without kidney disease diagnosis. Individuals

clinically diagnosed with chronic diabetes, and more generally those who had a high blood-glucose level when it was last checked, have a higher probability to report two or more voids (7.82 and 5.28 percentage points, respectively). Being clinically diagnosed with cardiovascular disease or cancer increases the probability of reporting two or more voids per night by 6.68 percentage points and 6.26 percentage points, respectively. Individuals clinically diagnosed with chronic hypertension report on average a 4.34-percentage-point-higher probability compared to individuals without the diagnosis. More generally, individuals who had high blood pressure when it was last checked report on average a 0.72-percentage-point-higher probability to report two or more voids per night.

Similar to previous empirical research, we also observe that obesity is associated with nocturia, with individuals with a BMI above 30 having a 3.77 percentage point larger probability to report two or more voids than individuals with a BMI between 18.5 and 25, all else equal. Mental health is also associated with nocturia: individuals reporting diagnosis of a severe mental illness or – more generally – a high level of psychological distress and anxiety have a higher probability to report two or more voids (3.24 percentage points and 2.82 percentage points, respectively) than individuals without mental health problems. Other factors associated with nocturia are low sleep quality, asthma, excessive salt intake and physical inactivity.

Tables A.1 to A.4 in Appendix A also report the empirical findings for the three region-specific sub-samples, which feature some variation in the magnitude of the coefficients based on different samples. Overall, they confirm that independent of the regional sample the probability to report two or more voids per night is positively associated with being female, older age, obesity, excessive salt intake, psychological distress and anxiety, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness, high glucose levels and low sleep quality.

4.1.2. Associations by age and gender

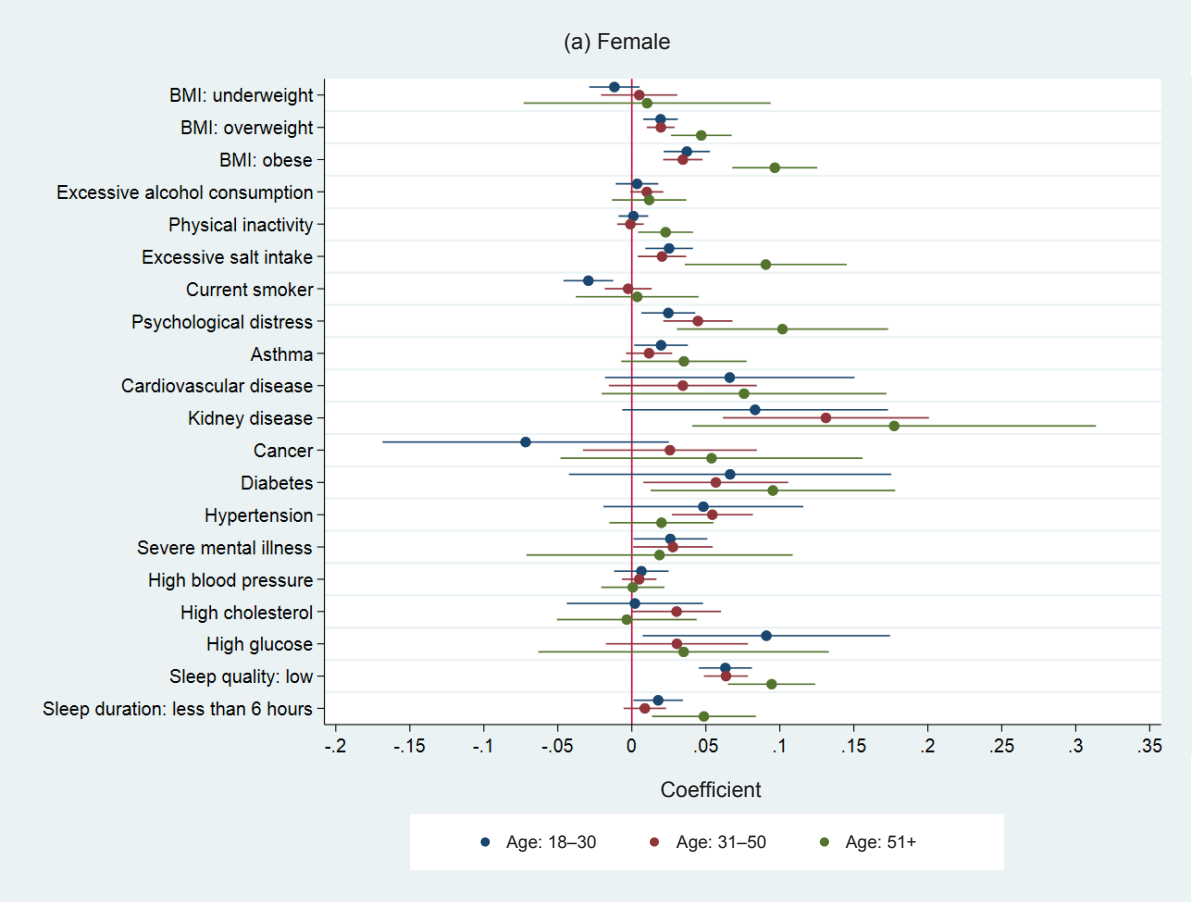
In addition to reporting associations between nocturia and a number of factors for the full sample, we also report the associations separately by age and gender, dividing the overall sample into six sub-samples by female/male and three age cohorts: (1) age 18–30; (2) age 31–50; and (3) age 51 and older. Figures 4.2a and 4.2b report the regression coefficients, which represent the average associated marginal probabilities for each covariate to predict that an individual is reporting two or more voids per night.[25]

By order of appearance in Figures 4.2a and 4.2b, we observe that statistically, obesity is significantly associated with nocturia in the female sample population across all three age cohorts, whereas it is only associated with nocturia in the male middle-age cohort. Excessive salt intake is associated with nocturia across all three age cohorts in the female sample population, but only in the middle-age cohort for the male sample population; a similar pattern is seen in psychological distress and anxiety. Clinically diagnosed cardiovascular disease is associated with nocturia for the older male cohort, but not for the female sample population; a similar pattern is seen in cancer. Kidney disease is associated with nocturia for the two older female age-cohorts and the middle-age male cohort. Clinically diagnosed chronic diabetes is associated with nocturia for both male and female,

25 The corresponding regression output tables related to Figures 4.2a and 4.2b can be found in Tables A.5 to A.10 in Appendix A. In order to calculate the percentage difference the coefficients are multiplied by 100.

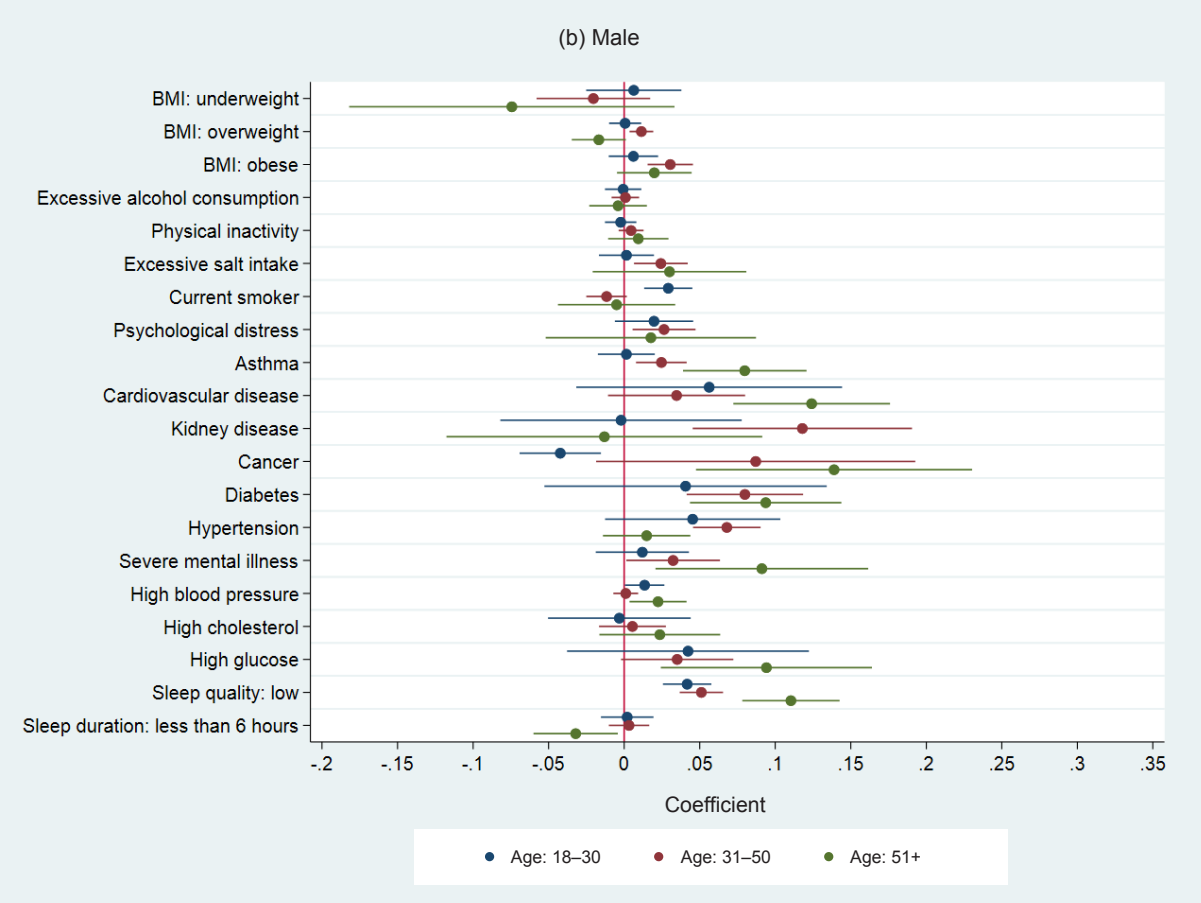
middle- and old-age cohorts, whereas generally high glucose levels are associated with nocturia for the young female cohort and the male population aged 51 and older. Interestingly, clinically diagnosed chronical hypertension tends to be associated with nocturia only for the middle-age cohort for both genders. Finally, the coefficients reported in Figure 4.2a and 4.2b suggest that sleep quality is associated with nocturia, independent of gender or age.

Figure 4.2a: Associations between demographic and lifestyle factors, co-morbidities and nocturia, by age – marginal probabilities (female sample)



Notes: based on a multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval. Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night (estimated separately for each age-gender sub-sample). In addition to covariates presented in the figure, the coefficients are also adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), which are not displayed. Based on pooled BHW and AIA samples for the years 2017 and 2018. The full regression output tables can be found in Appendix A, Tables A.5 to A.7.

Figure 4.2b: Associations between demographic and lifestyle factors, co-morbidities and nocturia, by age – marginal probabilities (male sample)



Notes: based on a multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval. Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night (estimated separately for each age-gender sub-sample). In addition to covariates presented in the figure, the coefficients are also adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), which are not displayed. Based on pooled BHW and AIA samples for the years 2017 and 2018. The full regression output tables can be found in Appendix A, Tables A.7 to A.10.

It is important to stress again that, as identified in the available literature, there are likely to be other factors associated with nocturia that we were not able to adjust for with the variables included in the data sample, including for instance: the prevalence of renal disorders, orthopaedic disorders, gynaecological surgeries, specific medications intake and specific sleep disorders, such as sleep apnoea (Yoshimura, 2012). It is also important to highlight that the factors presented in Figure 4.1, 4.2a and 4.2b represent associations and not causal relationships. For instance, as outlined in Chapter 2, it has been reported in the available literature that insomnia and other sleep disturbances are associated with nocturia, but it is difficult to identify which is the cause and which is the result.

Similar to Table 4.1, Panels A and B in Table 4.2 summarise the three most important factors associated with nocturia within each age-gender sub-sample, ordered by the magnitude of the marginal probability.

Table 4.2: Top three factors associated with nocturia, by age and gender

Panel A: Female			
	Factor	**Marginal probability (%)**	**P value**
Age: 18–30	High glucose	9.09	0.033*
	Sleep quality (low)	6.32	0.000**
	BMI: obese	3.72	0.000**
Age: 31–50	Kidney disease	13.12	0.000**
	Sleep quality (low)	6.36	0.000**
	Diabetes	5.68	0.023*
Age: 51+	Kidney disease	17.73	0.011*
	Psychological distress	10.18	0.005**
	BMI: obese	9.66	0.000**
Panel B: Male			
	Factor	**Marginal probability (%)**	**P value**
Age: 18–30	Sleep quality (low)	4.17	0.000**
	Current smoker	2.92	0.000**
	High blood pressure	1.35	0.042*
Age: 31–50	Kidney disease	11.79	0.002**
	Diabetes	7.99	0.000**
	Hypertension	6.79	0.000**
Age: 51+	Cancer	13.9	0.003**
	Cardiovascular disease	12.41	0.000**
	Sleep quality (low)	11.04	0.000**

*Notes: reports the average marginal probabilities for each covariate to predict that an individual within each age-gender sub-sample is reporting two or more voids per night. Only covariates depicted in Figures 4.2a and 4.2b that are statistically significant are reported and ordered according to magnitude with corresponding p-value (** p<0.01, * p<0.05).*

For instance, Panel A of Table 4.2 reports that, all else equal, a female individual aged 18 to 30 with a high glucose level when it was last checked has a 9.09 percentage point higher probability of reporting two or more voids than with a normal glucose level. A female in the same age cohort has a 6.32 percentage point higher probability of reporting two or more voids, or a 3.72 percentage point higher probability of reporting two or more voids per night compared to a female individual in

the same age cohort with good sleep quality or a normal BMI. For female individuals aged 31 to 50, the strongest factors associated with a higher probability of reporting two or more voids per night are whether the individual has been clinically diagnosed with kidney disease (13.12 percentage points); reports poor sleep quality (6.36 percentage points) or has been clinically diagnosed with diabetes (5.68 percentage points). A female individual aged 51 or older with kidney disease has 17.73 percentage point higher probability of reporting two or more voids per night than a female individual in this age cohort without this disease, all else equal. The two other factors strongly associated with nocturia for the older female cohort are psychological distress (10.18 percentage point increase in the probability of reporting two or more voids) and obesity (9.66 percentage point increase in the probability of reporting two or more voids).

Panel B of Table 4.2 reports the factors associated with nocturia for the male sub-populations by age. For male individuals aged 18 to 30, the main factors associated with a higher probability of reporting two or more voids per night are poor sleep quality (4.17 percentage points), smoking (2.92 percentage points) and high blood pressure (when it was last checked, but not clinically diagnosed as suffering chronic hypertension). A male individual aged 31 to 50 who has been clinically diagnosed with kidney disease has a 11.79 percentage point higher probability of reporting two or more voids per night than a male individual in this age cohort without kidney disease, all else equal. For this male age cohort, diabetes is also associated with nocturia, increasing the probability of reporting two or more voids by about 8 percentage points and – in addition – if a male individual in this age cohort has been clinically diagnosed with chronic hypertension it increase the probability by 6.79 percentage points. In older male individuals, aged 51 and older, being diagnosed with cancer is associated with a 13.9 percentage point higher probability of reporting two or more voids, all else equal, whereas suffering from cardiovascular disease increases the probability by 12.41 percentage points. In addition to cancer and cardiovascular disease, among older male individuals, poor sleep is also associated with nocturia.

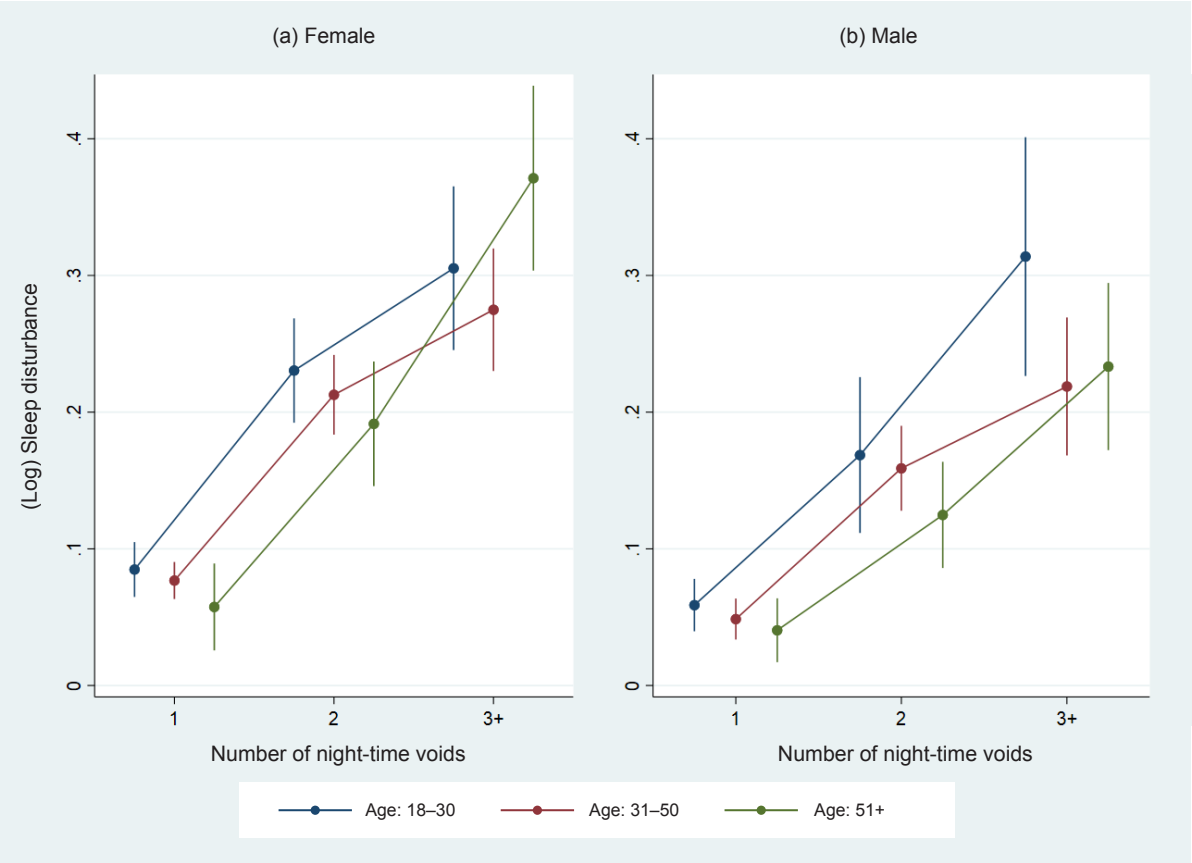
In summary, the main factors associated with nocturia in our sample of working-age individuals vary by age and gender, and nocturia may represent an indicator for underlying morbidities. For instance, in the female sample population we observe that for those aged 18 to 50, high glucose levels (not clinically diagnosed and chronic) and clinically diagnosed chronic diabetes are associated with nocturia, as well as poor sleep quality. The middle-age and older female sample populations (aged 31 and older) have in common that, not surprisingly, kidney disease is a strong factor associated with nocturia. The male sample population aged 18 to 50 has in common a high blood pressure (not clinically diagnosed and chronic) and hypertension, which are associated with nocturia. For the older male sample population we observe that group-specific prevalent chronic conditions – such as cancer or cardiovascular disease – show strong associations with nocturia. Interestingly, low self-reported sleep quality is among the top three factors associated with nocturia for four out of the six age-gender sub-samples. Hence, in what follows we aim to examine in more detail the association between nocturia and a number of measures related to sleep.

4.2. Nocturia symptom-severity and sleep disturbance

Sleep plays a vital role in human physical and mental functioning, and it is increasingly recognised that inadequate sleep can have wider individual and societal repercussions (e.g. Hafner et al., 2016). As the previous paragraphs highlight, nocturia is associated with lower levels of sleep quality, and generally, the literature suggests that nocturia can be one of the causes of poor sleep

quality. Figures 4.3, 4.4 and 4.5 report the associations between nocturia symptom-severity and three different sleep-related measures: (1) a composite score for sleep disturbance (ranging from 0 to 4; higher score represents more disturbance);[26] (2) the self-reported hours to first night-time awakening (FUSP);[27] and (3) a score for daytime fatigue (ranging from 1 to 5; higher score represents higher level of daytime fatigue).[28]

Figure 4.3: Nocturia symptom-severity and self-reported sleep disturbance (compared to individuals reporting zero night-time voids) – by age and gender



Notes: based on multivariate OLS regression models (separate by each age-gender sub-sample) with log-transformed sleep disturbance score as dependent variable and nocturia symptom-severity indicator variables as covariates (zero voids as reference group). Entries represent regression coefficients with corresponding 95% confidence interval. In addition to covariates presented in the figure, the coefficients are also adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol. Based on pooled BHW and AIA samples for the years 2017 and 2018. The full regression output tables can be found in Appendix A, Table A.11.

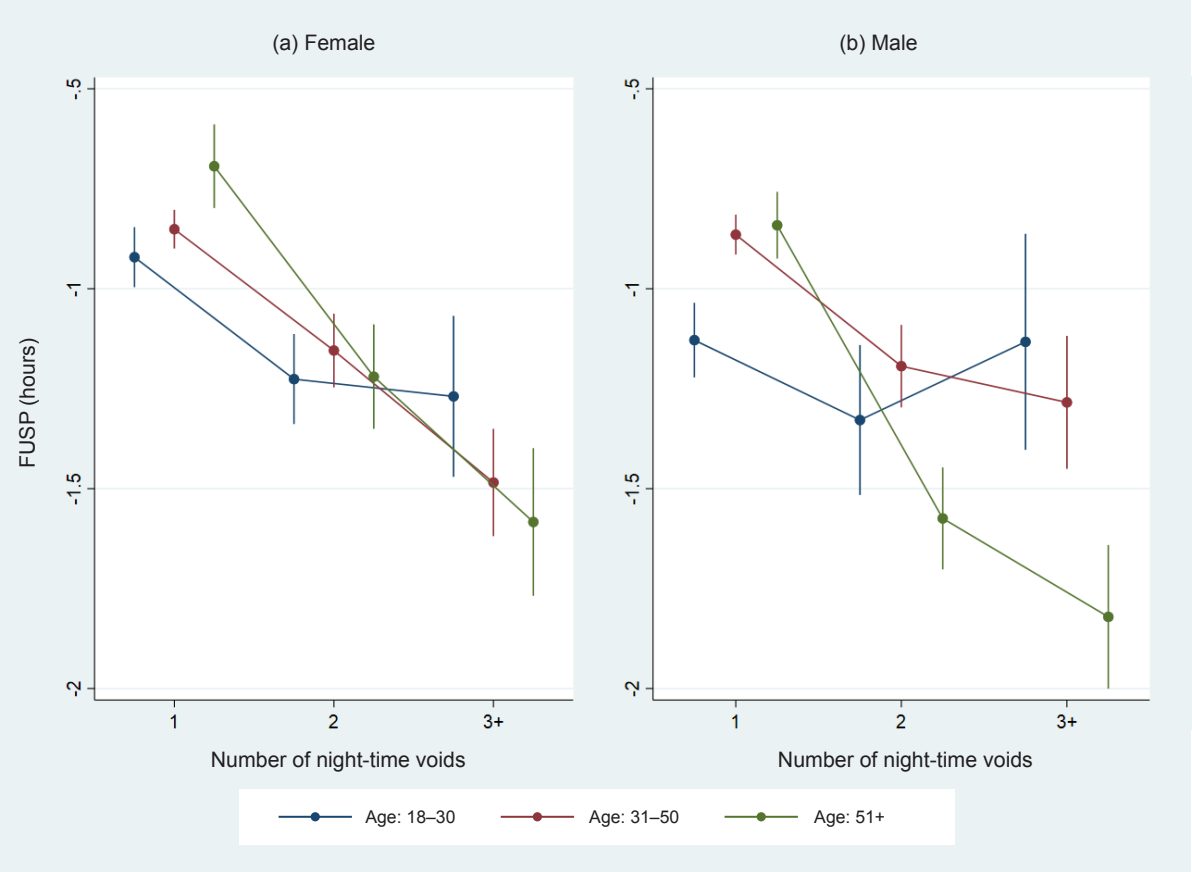
26 In order to take the log-transformed sleep disturbance score we calculate log (sleep disturbance score + 1).

27 Note that FUSP would be expected to be negatively correlated with nocturia symptom-severity, as a larger FUSP means less sleep interruption.

28 See Chapter 3 for a more detailed overview about the three measures.

In essence, the three figures report the regression coefficients from a multivariate OLS regression analysis (separately for six age-gender sub-samples) using the sleep disturbance score, the FUSP and the daytime fatigue score as dependent variables and the number of reported voids per night as independent variables (one void, two voids, three or more voids, with zero voids as reference group), adjusted for a large number of other covariates.[29]

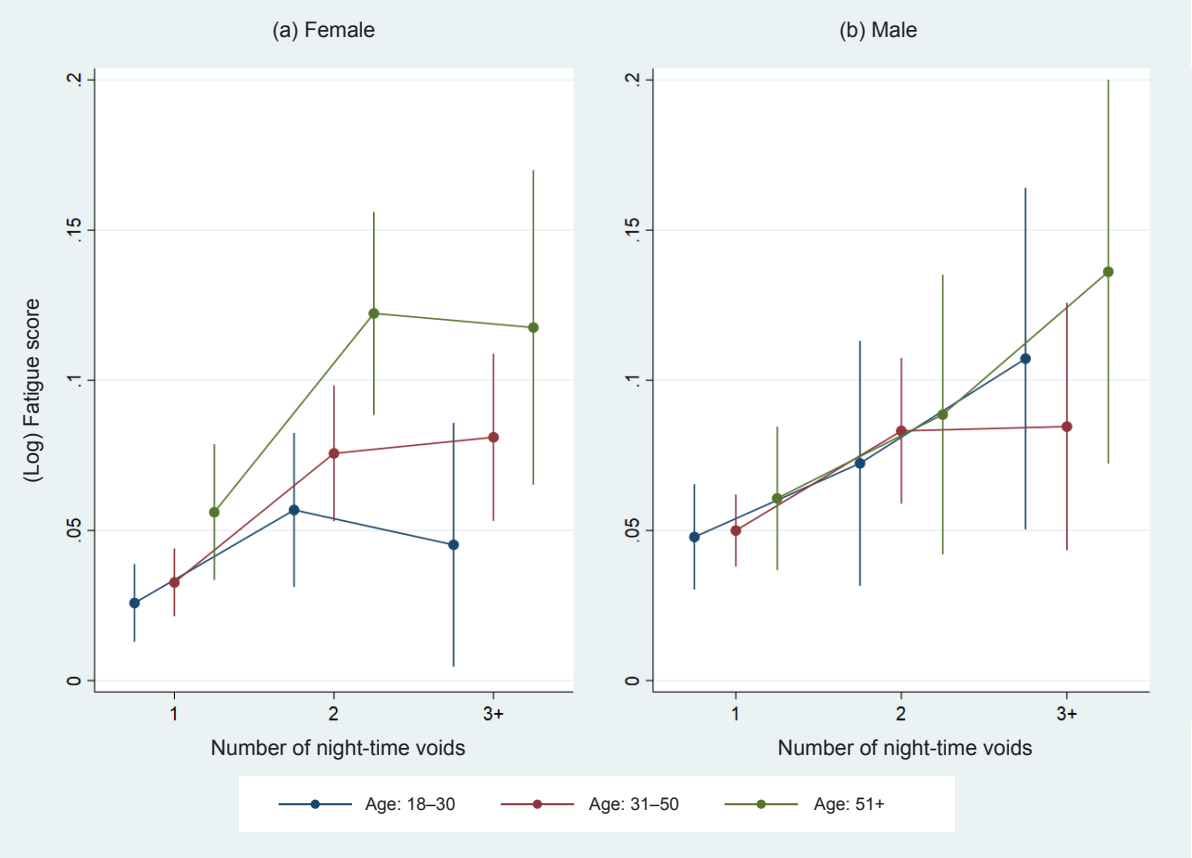
Figure 4.4: Nocturia symptom-severity and self-reported FUSP (compared to individuals reporting zero night-time voids) – by age and gender



Notes: based on multivariate OLS regression models (separate by each age-gender sub-sample) with FUSP in hours as dependent variable and nocturia symptom-severity indicator variables as covariates (zero voids as reference group). Entries represent regression coefficients with corresponding 95% confidence interval. In addition to covariates presented in the figure, the coefficients are also adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol. Based on pooled BHW and AIA samples for the years 2017 and 2018. The full regression output tables can be found in Appendix A, Table A.12.

29 The corresponding regression output tables can be found in Tables A.11 to A.13 in Appendix A. The regression coefficients are adjusted for binary covariates including gender; age; ethnicity; education; income; marital status; occupation; irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol; region.

Figure 4.5: Nocturia symptom-severity and daytime fatigue (compared to individuals reporting zero night-time voids) – by age and gender



Notes: based on multivariate OLS regression models (separate by each age-gender sub-sample) with log-transformed fatigue score as dependent variable and nocturia symptom-severity indicator variables as covariates (zero voids as reference group). Entries represent regression coefficients with corresponding 95% confidence interval. In addition to covariates presented in the figure, the coefficients are also adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol. Based on pooled BHW and AIA samples for the years 2017 and 2018. The full regression output tables can be found in Appendix A, Table A.13.

While Figures 4.3 to 4.5 depict the regression coefficients in a more illustrative way, a summary of the corresponding magnitudes of each of these associations by age and gender can be found in Columns (1) to (3) of Table 4.3.

As reported in Figure 4.3, compared to individuals with zero voids per night, the sleep disturbance score is positively (and statistically significantly) associated with nocturia symptom-severity, independent of age and gender. On average, except for the female sample population age 51 and

older, the level of sleep disturbance associated with each level of symptom-severity of nocturia tends to be larger for the younger cohorts.[30]

Figure 4.4 reports the association between the FUSP measured in hours and the number of night-time voids reported. As expected, the FUSP measured in hours tends to (statistically significantly) decrease with the number of voids per night, compared to individuals reporting zero voids. The largest average decrease in FUSP is reported for the older female and male cohorts, with three or more voids per night.

Figure 4.5 reports the association between the daytime fatigue score and nocturia symptom-severity. It shows that, similarly to the sleep disturbance score, and the self-reported FUSP, the level of daytime fatigue score generally (statistically significantly) increases with the number of reported voids, independent of age and gender when compared to individuals reporting zero voids. However, for the young and older female sample population and the male sample population aged 31 to 50, fatigue increases from one to two voids, but then levels off.

By each age-gender sub-sample, Table 4.3 (Panels A to F) summarises the magnitude of the associations between nocturia and the three examined sleep measures. Column (1) of Table 4.3 reports the average percentage difference in the sleep disturbance score between individuals reporting zero voids and individuals reporting one void, two voids or three or more voids per night, respectively. For instance, across the different cohorts by age and gender, all else equal, the sleep disturbance score is on average between 4 and 9 per cent higher for individuals reporting one void per night, compared to individuals reporting zero voids per night, which increases to between 13 and 26 per cent (two voids) and to between 24 and 45 per cent for individuals reporting three or more voids per night, compared to those reporting zero voids.

Column (2) of Table 4.3 reports the average difference in the self-reported FUSP, measured in hours and the percentage difference between individuals reporting zero voids and individuals reporting one void, two voids or three or more voids per night, respectively. The percentage difference has been calculated by dividing the mean difference through the average FUSP in each age-gender sub-sample, which are reported in Table A.14 of Appendix A. When looking at the average reported FUSP, all else equal, we find that for those reporting one void per night, the average FUSP in hours is between 15 and 22 per cent (between 0.7 and 1.13 hours) shorter than for those reporting zero voids. The average FUSP in hours is between 24 and 32 per cent (between 1.15 and 1.57 hours) shorter for those reporting two voids per night and between 22 and 37 per cent (between 1.13 and 1.82 hours) shorter for those reporting three or more voids per night, compared to those reporting zero voids.

30 Note that the regression coefficients depicted in Figure 4.3 can be transformed into an average percentage change compared to the reference group (zero voids) by calculating: $(e^{coefficient} - 1) * 100$.

Table 4.3: Summary of associations between nocturia symptom-severity and sleep disturbance, FUSP and daytime fatigue, by age and gender

	(1)	(2)		(3)
	Sleep Disturbance	FUSP		Fatigue
Panel A: Female; Age: 18–30				
	% Difference (0 voids)	Hours Difference (0 voids)	% to mean Hours (0 voids)	% Difference (0 voids)
1 void	9%	-0.92	-18%	3%
2 voids	26%	-1.23	-24%	6%
3 + voids	36%	-1.27	-25%	5%
Panel B: Female; Age: 31–50				
1 void	8%	-0.85	-18%	3%
2 voids	24%	-1.15	-24%	8%
3 + voids	32%	-1.48	-32%	8%
Panel C: Female; Age: 51+				
1 void	6%	-0.69	-15%	6%
2 voids	21%	-1.22	-27%	13%
3 + voids	45%	-1.58	-35%	12%
Panel D: Male; Age: 18–30				
1 void	6%	-1.13	-22%	5%
2 voids	18%	-1.33	-26%	7%
3 + voids	37%	-1.13	-22%	11%
Panel E: Male; Age: 31–50				
1 void	5%	-0.86	-18%	5%
2 voids	17%	-1.19	-25%	9%
3 + voids	24%	-1.28	-27%	9%
Panel F: Male; Age: 51+				
1 void	4%	-0.84	-17%	6%
2 voids	13%	-1.57	-32%	9%
3 + voids	26%	-1.82	-37%	15%

*Notes: based on statistically significant regression coefficients reported in Tables A.11 to A.13 in Appendix A. Log scores from the sleep disturbance and fatigue score have been transformed in the per cent changes (compared to the reference group of zero voids) as follows: ($e^{coefficient} - 1$) * 100. The average difference for the FUSP has been calculated using the mean FUSP by age and gender sub-sample as reported in Table A.14 of Appendix A.*

Column (3) of Table 4.3 reports the average percentage difference in the daytime fatigue score between individuals reporting zero voids and individuals reporting one void, two voids or more than three voids per night, respectively. Across the different cohorts by age and gender, all else equal, individuals with one void per night report on average between 3 and 6 per cent higher levels in daytime fatigue score than individuals reporting zero voids. This increases to between 6 and 13 per cent for those reporting two voids and to between 5 and 15 per cent for those reporting three or more voids per night, compared to those individuals reporting zero voids.

In summary, nocturia is associated with increased levels of sleep disturbance, shorter time to first sleep interruption (FUSP) and higher levels of daytime fatigue, and the sleep-quality impairing association increases by the frequency of reported night-time voids.

5 Nocturia and the associations with life satisfaction, work engagement and impairment

This chapter examines the associations between nocturia and life satisfaction, work engagement and impairment. Similar to the empirical analysis presented in the previous chapter, prior studies have investigated these associations, but tend to be based on smaller or specific population samples and include for a limited set of covariates. This specifically applies to previous studies that have investigated the associations between nocturia and work impairment (e.g. the working time lost due to nocturia), which have found associations with very large magnitudes but only adjusted for a very small number of confounding variables that are potentially simultaneously associated with nocturia and work impairment. That is, it is expected that these estimated associations might be biased upwards. Furthermore, it remains to be seen whether there is an independent association between nocturia and work impairment, after statistically adjusting for a broader range of relevant covariates that might otherwise explain the association. As the large linked employer-employee data used in this analysis enables adjusting for a large number of covariates, we hope to provide more robust estimates for the association between nocturia and work impairment than previous studies.

In what follows we report the corresponding empirical findings regarding the associations between nocturia, life satisfaction, workplace engagement and work impairment.

5.1. Nocturia and the association with life satisfaction

Using OLS regressions, Table 5.1 reports the estimated associations between nocturia and life satisfaction, comparing individuals reporting two or more voids per night with individuals reporting less than two voids as a reference group. Panel A reports the coefficients for the full sample, whereas Panels B to I report the coefficients for different age-gender sub-samples.

Table 5.1: Associations between nocturia and life satisfaction

	(1)			(2)			(3)		
	Dependent variable: (Log) Life Satisfaction								
	Covariates: none			Covariates: demographics, health behaviour, chronic conditions			Covariates: demographics, health behaviour, chronic conditions, sleep quality and duration		
	Coefficient	CI (95%)	P value	Coefficient	CI (95%)	P value	Coefficient	CI (95%)	P value
Panel A: Full									
2 + voids	-0.0635	-0.074 - -0.053	0.000**	-0.0300	-0.037 - -0.023	0.000**	-0.0188	-0.026 - -0.012	0.000**
Panel B: Female									
2 + voids	-0.0594	-0.070 - -0.049	0.000**	-0.0293	-0.038 - -0.020	0.000**	-0.0181	-0.027 - -0.009	0.000**
Panel C: Male									
2 + voids	-0.0657	-0.081 - -0.050	0.000**	-0.0311	-0.043 - -0.020	0.000**	-0.0206	-0.032 - -0.009	0.000**
Panel D: Female; Age 18–30									
2 + voids	-0.0683	-0.090 - -0.046	0.000**	-0.0359	-0.056 - -0.016	0.000**	-0.0247	-0.045 - -0.005	0.016*
Panel E: Female; Age: 31–50									
2 + voids	-0.0612	-0.076 - -0.046	0.000**	-0.0231	-0.035 - -0.011	0.000**	-0.0132	-0.025 - -0.001	0.031*
Panel F: Female; Age: 51+									
2 + voids	-0.0676	-0.094 - -0.041	0.000**	-0.0282	-0.051 - -0.006	0.015*	-0.0167	-0.039 - 0.006	0.144
Panel G: Male; Age: 18–30									
2 + voids	-0.1061	-0.161 - -0.051	0.000**	-0.0425	-0.076 - -0.009	0.013*	-0.0331	-0.066 - 0.000	0.050
Panel H: Male; Age: 31–50									
2 + voids	-0.0612	-0.076 - -0.046	0.000**	-0.0270	-0.044 - -0.010	0.001**	-0.0164	-0.033 - -0.000	0.045*
Panel I: Male; Age: 51+									
2 + voids	-0.0676	-0.094 - -0.041	0.000**	-0.0239	-0.041 - -0.007	0.005**	-0.0100	-0.026 - 0.006	0.231

Notes: Entries represent OLS regression coefficients with corresponding 95% confidence interval (standard errors clustered at company level). In addition to the binary nocturia variable (two or more voids; reference group less than two voids) as covariate presented in the table, the coefficients in column (2) and (3) are also adjusted for age, education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol, sleep quality, sleeping less than 6 hours. Analysis based on pooled BHW and AIA samples for the years 2017 and 2018.

Column (1) reports the unadjusted coefficients, Column (2) reports the coefficients adjusted for a number of demographic, lifestyle factors and co-morbidities[31] and Column (3) reports the coefficients additionally adjusted for sleep quality and duration.

Overall, the reported parameter estimates suggest that nocturia is negatively associated with self-reported life satisfaction. We find that the magnitude of the coefficient decreases with the adjustment of covariates, and even more if we adjust for sleep quality and sleep duration, suggesting that disrupted sleep may explain some of the relationship between nocturia and reported levels of life satisfaction. Even after adjusting for sleep quality and duration, however, the association between nocturia and life satisfaction holds for most sub-samples, except for the female and male sample-populations aged 51 and older, and the male sample-population aged 18 to 30. To give a sense of magnitude of the association, using the coefficient reported in Panel A and Column (3), the findings suggest that, all else equal, an individual reporting two or more voids per night reports on average a 1.9 per cent lower life satisfaction than an individual reporting less than two voids per night.[32] On average and after adjusting for the full set of covariates including sleep, we observe relatively lower life satisfaction for male and female individuals in the younger cohorts, compared to the middle-age or older cohorts. For instance, using the coefficients in Table 5.1, Panel D and G (Column 3), we observe that on average, a female individual aged 18 to 30 who reports two or more voids per night has, on average, about a 2.5 per cent lower life satisfaction compared to a female individual in the same age cohort with less than two voids per night. A male individual aged 18 to 30 who reports two or more voids per night has, on average, a 3.3 per cent lower satisfaction compared to a male individual in the same age cohort reporting less than two voids per night.

Furthermore, Table 5.2 provides a comparison between the magnitude of the association between nocturia and life satisfaction and the magnitude of the same association for other factors included in the regression analysis.[33] Specifically, the estimated percentage difference in life satisfaction for each corresponding factor is presented, relative to its reference group. For each estimate the lower and upper bound of a 95 per cent confidence interval is provided, and estimates that are statistically significant – at least at the 5 per cent level – are highlighted in bold.

As highlighted above, all else equal, nocturia (measured as two or more voids per night) is associated with a reduction in self-reported life satisfaction by about 1.9 per cent (compared to individuals reporting less than two voids per night). This is in the same level of magnitude as other lifestyle factors such as smoking, being underweight, high levels of cholesterol and smoking, and is larger in magnitude than clinically diagnosed chronic hypertension, asthma and being overweight. Nevertheless the largest percentage decrease in life satisfaction can be observed in people with psychological distress and anxiety (30.7 per cent lower life satisfaction), financial concerns (15.5 per

31 Adjusted for covariates including age, education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol.

32 The regression coefficients reported in Table 5.1 can be transformed into a percent change by calculating: $(e^{coefficient} - 1) * 100$.

33 Based on regression coefficient provided in Panel A of Table 5.1 (Column 3) and the corresponding full regression output is provided in Appendix B, Table B.1.

cent lower life satisfaction), as well as severe mental illness (10.8 per cent lower life satisfaction), compared to individuals not suffering these factors.

Table 5.2: Comparison between nocturia and other lifestyle factors and co-morbidities with regard to lower life satisfaction – full sample

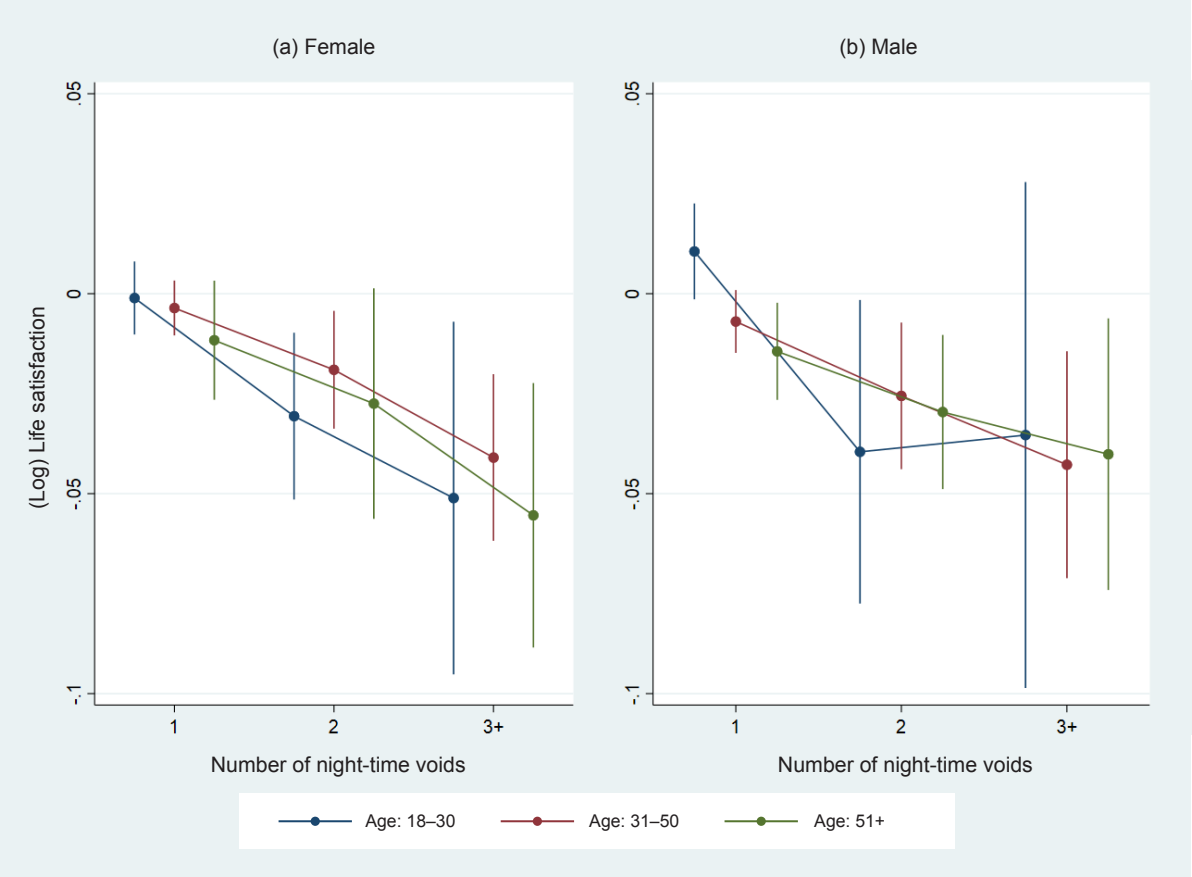
	Life satisfaction: per cent difference compared to reference group		
Factor	**Estimate**	**95% CI: low**	**95% CI: high**
Psychological distress	**-30.7%**	-31.9%	-29.5%
Financial concerns	**-15.5%**	-16.2%	-14.7%
Severe mental illness	**-10.8%**	-12.2%	-9.3%
Sleep quality (low)	**-10.3%**	-11.0%	-9.7%
Sleep duration (less than 6 hours)	**-4.7%**	-5.3%	-4.1%
Physical inactivity	**-3.2%**	-3.7%	-2.8%
Cancer	-2.8%	-5.6%	0.2%
BMI: obese	**-2.5%**	-3.0%	-2.0%
Current smoker	**-2.0%**	-2.7%	-1.3%
BMI: underweight	**-2.0%**	-3.0%	-0.9%
High cholesterol	**-1.9%**	-3.0%	-0.9%
2 + voids	**-1.9%**	-2.5%	-1.2%
Cardiovascular disease	-1.7%	-3.5%	0.1%
Hypertension	**-1.5%**	-2.4%	-0.6%
High glucose	-1.4%	-3.2%	0.5%
Kidney disease	-1.3%	-4.1%	1.6%
Asthma	**-1.1%**	-1.9%	-0.3%
Excessive salt intake	**-0.8%**	-1.5%	-0.1%
High blood pressure	**-0.7%**	-1.2%	-0.2%
BMI: overweight	**-0.6%**	-0.9%	-0.2%
Excessive alcohol consumption	-0.5%	-1.0%	0.0%
Diabetes	1.0%	-0.6%	2.5%

Notes: see Table B.1 in Appendix B for the full corresponding regression output table. The regression coefficients have been transformed as $(e^{coefficient} - 1) * 100$ *in order to get the relative percentage decrease in life satisfaction for individuals reporting two or more night-time voids compared to individuals reporting less than two night-time voids, and the other factors presented in the table and their corresponding reference groups. Estimates that are statistically significant at least at the 5% level are highlighted in bold.*

In addition to nocturia defined as a threshold (two or more night-time voids), Figure 5.1 also reports separately the association between nocturia symptom-severity and life satisfaction for six age-gender sub-samples. As the depicted regression coefficients suggest, life satisfaction generally decreases with the number of voids reported (compared to individuals reporting zero voids per

night).[34] For the female and male sample population we find no statistically significantly different level in life satisfaction for those reporting one void per night compared to those reporting zero voids. Within the female sample population, the largest decrease in life satisfaction in terms of magnitude is observed for the young female cohort. For the male sample population aged 18 to 30 we only find a statistically significant decrease in life satisfaction for individuals reporting two voids, but it is statistically significant for three or more voids for the middle age and older male cohorts.

Figure 5.1: Nocturia symptom-severity and life satisfaction (compared to individuals reporting zero night-time voids) – by age and gender



Notes: based on multivariate OLS regression models (separately for six age-gender sub-samples) with log-transformed life satisfaction (range 1 to 11, with higher values showing a higher satisfaction with life) score as dependent variable and nocturia symptom-severity indicator variables as covariates (zero voids as reference group). Entries represent regression coefficients with corresponding 95% confidence interval. The coefficients are adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol, sleep quality and sleeping less than 6 hours. Based on pooled BHW and AIA samples for the years 2017 and 2018. The full corresponding regression output tables can be found in Appendix B, Table B.2.

34 Corresponding full regression output tables can be found in Table B.2 of Appendix B.

5.2. Nocturia and work engagement

We measure workplace engagement using the Utrecht engagement scale (ranging from 0 to 54),[35] where a larger score represents a higher level of engagement. Using OLS regressions, Table 5.3 reports the estimated associations between nocturia and work engagement (dependent variable), comparing individuals reporting two or more voids per night with individuals reporting less than two voids as a reference group. Panel A reports the coefficients for the full sample, whereas Panels B to I report the coefficients for different age-gender sub-samples. Column (1) reports the unadjusted coefficients, whereas Column (2) reports the coefficients adjusted for a number of demographic, lifestyle factors and co-morbidities[36] and Column (3) reports the coefficients additionally adjusted for sleep quality and duration.

Overall, we find that statistically, nocturia is significantly negatively associated with work engagement when estimated on the full sample (Panel A). The magnitude of the coefficient decreases with the inclusion of covariates. Similar to the findings for the association with life satisfaction, adjusting for sleep quality and sleep duration reduces the magnitude further, suggesting that sleep disturbance at least partially explains the association between nocturia and engagement (Column 3). With regard to the magnitude of the association, the findings suggest that reporting two or more voids per night is associated, all else equal, with a 1.27 per cent reduction in work engagement (compared to individuals reporting less than two voids per night).[37]

For the female and male sample populations (Panel B and C) we still find statistically significant negative associations between nocturia and work engagement, but the associations for the age-gender sub-samples (Panel D to I) are no longer statistically significantly different from zero after controlling for sleep quality and duration, except for the female sample population aged 51 or older. For the older female sample population, reporting two or more voids per night is associated with a 2.3 per cent lower work engagement, compared to female individuals in the same age cohort reporting less than two night-time voids.

Furthermore, Table 5.4 provides a comparison for the magnitude of the association between nocturia and work engagement and the magnitude of the same association with other factors included in the analysis.[38]

35 See section 3.2.5 for more detail on the Utrecht scale.

36 Adjusted for covariates including age, education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol.

37 The regression coefficients reported in Table 5.3 can be transformed into a percent change by calculating: $(e^{coefficient} - 1) * 100$.

38 Based on regression coefficient provided in Panel A of Table 5.3 (Column 3) and the corresponding full regression output is provided in Appendix B, Table B.3.

Table 5.3: Associations between nocturia and work engagement

	(1)			(2)			(3)		
	Dependent variable: (Log) Engagement Score								
	Covariates: none			Covariates: demographics, health behaviour, chronic conditions			Covariates: demographics, health behaviour, chronic conditions, sleep quality and duration		
	Coefficient	CI (95%)	P value	Coefficient	CI (95%)	P value	Coefficient	CI (95%)	P value
Panel A: All									
2 + voids	-0.0414	-0.055 - -0.028	0.000**	-0.0208	-0.029 - -0.013	0.000**	-0.0128	-0.021 - -0.005	0.001**
Panel B: Female									
2 + voids	-0.0332	-0.045 - -0.021	0.000**	-0.0192	-0.030 - -0.009	0.000**	-0.0116	-0.022 - -0.001	0.029*
Panel C: Male									
2 + voids	-0.0497	-0.075 - -0.024	0.000**	-0.0246	-0.038 - -0.012	0.000**	-0.0165	-0.029 - -0.004	0.012*
Panel D: Female; Age 18–30									
2 + voids	-0.0409	-0.066 - -0.015	0.002**	-0.0210	-0.046 - 0.004	0.098	-0.0140	-0.038 - 0.010	0.257
Panel E: Female; Age: 31–50									
2 + voids	-0.0329	-0.047 - -0.019	0.000**	-0.0092	-0.021 - 0.002	0.121	-0.0023	-0.014 - 0.009	0.699
Panel F: Female; Age: 51+									
2 + voids	-0.0568	-0.082 - -0.031	0.000**	-0.0315	-0.054 - -0.009	0.006**	-0.0230	-0.046 - -0.001	0.045*
Panel G: Male; Age: 18–30									
2 + voids	-0.0798	-0.175 - 0.015	0.099	-0.0061	-0.040 - 0.028	0.723	0.0020	-0.032 - 0.036	0.907
Panel H: Male; Age: 31–50									
2 + voids	-0.0329	-0.047 - -0.019	0.000**	-0.0230	-0.040 - -0.006	0.008**	-0.0152	-0.032 - 0.002	0.075
Panel I: Male; Age: 51+									
2 + voids	-0.0568	-0.082 - -0.031	0.000**	-0.0297	-0.057 - -0.002	0.035*	-0.0219	-0.049 - 0.005	0.116

Notes: Entries represent OLS regression coefficients with corresponding 95% confidence interval (standard errors clustered at company level). In addition to the binary nocturia variable (two or more voids; reference group less than two voids) as covariate presented in the table, the coefficients in column (2) and (3) are also adjusted for age, education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol, sleep quality and sleeping less than 6 hours. Analysis based on pooled BHW and AIA samples for the years 2017 and 2018.

Table 5.4: Comparison between nocturia and other factors relating to lower work engagement – full sample

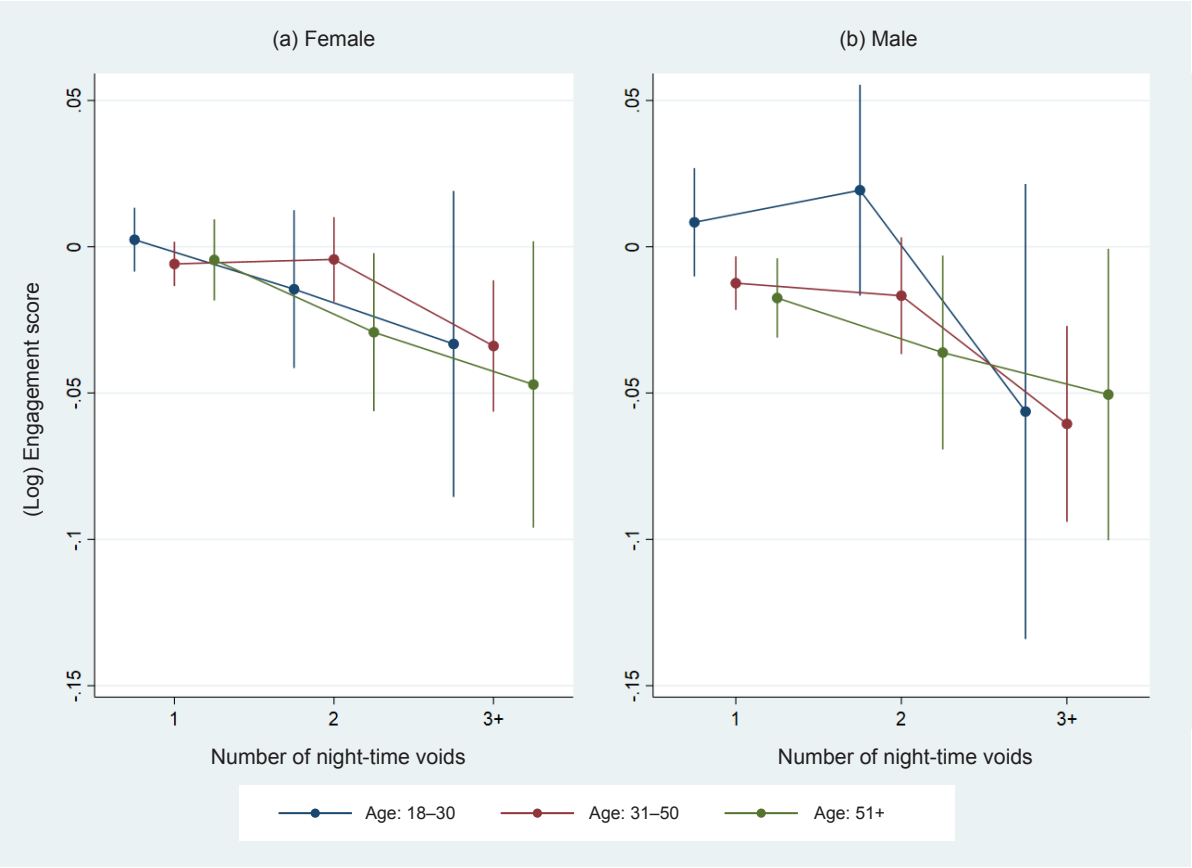
	Work engagement: per cent difference compared to reference group		
	Estimate	**95% CI: low**	**95% CI: high**
Psychological distress	**-21.0%**	-22.5%	-19.6%
Sleep quality (low)	**-8.0%**	-8.7%	-7.3%
Financial concerns	**-7.4%**	-8.4%	-6.4%
Severe mental illness	**-5.4%**	-7.0%	-3.7%
Cardiovascular disease	-2.5%	-5.0%	0.0%
Physical inactivity	**-2.1%**	-2.6%	-1.6%
Hypertension	**-1.9%**	-3.0%	-0.7%
Cancer	-1.8%	-4.8%	1.3%
BMI: underweight	**-1.7%**	-2.9%	-0.6%
Excessive alcohol consumption	**-1.7%**	-2.3%	-1.1%
Sleep duration (less than 6 hours)	**-1.6%**	-2.3%	-0.9%
Kidney disease	-1.3%	-4.6%	2.0%
2 + voids	**-1.3%**	-2.0%	-0.5%
High cholesterol	-1.2%	-2.4%	0.0%
Diabetes	-0.5%	-2.4%	1.5%
Excessive salt intake	-0.5%	-1.2%	0.3%
High blood pressure	-0.2%	-0.7%	0.4%
Asthma	0.1%	-1.0%	1.1%
BMI: overweight	0.3%	-0.2%	0.7%
High glucose	0.6%	-1.2%	2.5%
BMI: obese	0.7%	0.0%	1.3%
Current smoker	3.1%	2.2%	4.0%

Notes: see Table B.3 in Appendix B for the full corresponding regression output table. The regression coefficients have been transformed as $(e^{coefficient} - 1) * 100$ *in order to get the relative per cent decrease in work engagement for individuals reporting two or more night-time voids compared to individuals reporting less than two night-time voids and the other factors presented in the table and their corresponding reference groups. Estimates that are statistically significant – at least at the 5% level – are highlighted in bold.*

Specifically, the estimated percentage difference in work engagement for each corresponding factor is presented, relative to its reference group. For each estimate the lower and upper bound of a 95 per cent confidence interval is provided, and estimates that are statistically significant – at least at the 5 per cent level – are highlighted in bold. All else equal, individuals reporting two or more voids per night have on average a 1.3 per cent lower work engagement compared to individuals reporting less than two night-time voids. This is of similar magnitude to kidney disease, high cholesterol or clinically diagnosed chronic diabetes (although the association between these two factors and work engagement is not statistically significant). The magnitude of the association between nocturia and work engagement is somewhat lower than for other factors, such as short sleep (1.6 per cent lower work engagement), excessive alcohol consumption (1.7 per cent lower work engagement) or being

underweight (1.7 per cent lower work engagement). Not surprisingly, and similar to the findings presented for life satisfaction above, the largest relative percentage decrease in work engagement can be observed in individuals with high levels of psychological distress and anxiety (21 per cent lower work engagement compared to individuals without psychological distress and anxiety), as well as poor sleep (8 per cent lower work engagement) or having financial concerns (7.4 per cent lower work engagement) compared to individuals not affected by these factors. In addition to nocturia defined as threshold (two or more night-time voids), Figure 5.2 also reports the association between nocturia symptom-severity and work engagement separately for six age-gender sub-samples.[39]

Figure 5.2: Nocturia symptom-severity and work engagement (compared to individuals reporting zero night-time voids) – by age and gender



Notes: based on multivariate OLS regression models (separately for six age-gender sub-samples) with log-transformed work engagement score (range 1 to 55), with higher values showing a higher work engagement) as dependent variable and nocturia symptom-severity indicator variables as covariates (zero voids as reference group). Entries represent regression coefficients with corresponding 95% confidence interval. The coefficients are adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol, sleep quality and sleeping less than 6 hours. Based on pooled BHW and AIA samples for the years 2017 and 2018. The full corresponding regression output tables can be found in Appendix B, Table B.4.

39 The corresponding full regression output tables can be found in Table B.4 of Appendix B.

The regression coefficients depicted in Figure 5.2 suggest that compared to individuals reporting zero voids per night, as the number of voids per night increases, work engagement tends to decrease. However, for the female sample population, only the coefficient for two voids per night for those aged 51 and older, as well as for those reporting three or more voids per night aged 31 to 50 are statistically significant. For the male sample population, nocturia is negatively associated with symptom severity for the middle-aged and older cohorts only.

5.3. Nocturia and work impairment

Work impairment is measured as the overall percentage of working time lost due to absenteeism and presenteeism using the WPAI-GH scale.[40] Using OLS regressions, Table 5.5 reports the estimated associations between nocturia and the percentage of work impairment due to absenteeism and presenteeism (dependent variable), comparing individuals reporting two or more voids per night with individuals reporting less than two voids as a reference group.[41] Panel A reports the coefficients for the full sample, whereas Panels B to I report the coefficients for different age-gender sub-samples. Column (1) reports the unadjusted coefficients, whereas Column (2) reports the coefficients adjusted for a number of demographic, lifestyle factors and co-morbidities[42] and Column (3) reports the coefficients additionally adjusted for sleep quality and duration.

Overall, when estimating the association on the full sample (Panel A) we find that, all else equal, individuals reporting two or more voids per night have, on average, a higher work impairment due to absenteeism and presenteeism than individuals reporting less than two voids. For instance, on average an individual reporting two or more voids per night has a 5.5-percentage-point-higher work impairment due to absenteeism and presenteeism compared to an individual reporting less than two night-time voids (Column 1). However, adjusting for covariates, the magnitude of the coefficient reduces to 3.8 percentage points (Column 2), and after adjusting for sleep quality and sleep duration the coefficient shows a 3-percentage-point increase in work impairment for individuals reporting two or more voids compared to individuals reporting less than two voids per night. This is interesting, as it suggests that even after controlling for other potential factors of poor or inadequate sleep, nocturia is still statistically significantly associated with work impairment.

40 See section 3.2.5 for more detail about the WPAI scale.

41 In other words, the coefficients can be interpreted as percentage changes in work impairment compared to the reference group.

42 Adjusted for covariates including age, education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol.

Table 5.5: Associations between nocturia and work impairment

	(1)			(2)			(3)		
	Dependent variable: Per cent Work Impairment due to Absenteeism and Presenteeism								
	Covariates: none			Covariates: demographics, health behaviour, chronic conditions			Covariates: demographics, health behaviour, chronic conditions, sleep quality and duration		
	Coefficient	CI (95%)	P value	Coefficient	CI (95%)	P value	Coefficient	CI (95%)	P value
Panel A: Full									
2 + voids	0.0551	0.048 - 0.062	0.000**	0.0375	0.032 - 0.043	0.000**	0.0303	0.025 - 0.036	0.000**
Panel B: Female									
2 + voids	0.0564	0.048 - 0.064	0.000**	0.0415	0.034 - 0.049	0.000**	0.0340	0.027 - 0.041	0.000**
Panel C: Male									
2 + voids	0.0512	0.040 - 0.062	0.000**	0.0328	0.024 - 0.041	0.000**	0.0259	0.018 - 0.034	0.000**
Panel D: Female; Age 18–30									
2 + voids	0.0733	0.057 - 0.090	0.000**	0.0507	0.035 - 0.067	0.000**	0.0426	0.027 - 0.058	0.000**
Panel E:Female; Age: 31–50									
2 + voids	0.0619	0.051 - 0.073	0.000**	0.0388	0.030 - 0.048	0.000**	0.0321	0.023 - 0.041	0.000**
Panel F: Female; Age: 51+									
2 + voids	0.0514	0.036 - 0.067	0.000**	0.0313	0.016 - 0.046	0.000**	0.0255	0.010 - 0.041	0.001**
Panel G: Male; Age: 18–30									
2 + voids	0.0741	0.043 - 0.105	0.000**	0.0396	0.019 - 0.060	0.000**	0.0326	0.012 - 0.053	0.002**
Panel H: Male; Age: 31–50									
2 + voids	0.0619	0.051 - 0.073	0.000**	0.0357	0.024 - 0.048	0.000**	0.0294	0.018 - 0.041	0.000**
Panel I: Male; Age: 51+									
2 + voids	0.0514	0.036 - 0.067	0.000**	0.0245	0.013 - 0.036	0.000**	0.0158	0.005 - 0.026	0.003**

Notes: Entries represent OLS regression coefficients with corresponding 95% confidence interval (standard errors clustered at company level). In addition to the binary nocturia variable (two or more voids; reference group less than two voids) as covariate presented in the table, the coefficients in column (2) and (3) are also adjusted for age, education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol, sleep quality and less than 6 hours of sleep. Analysis based on pooled BHW and AIA samples for the years 2017 and 2018.

Panels B and C report the associations between nocturia and work impairment for the female and male sample populations, suggesting that on average, female individuals reporting two or more voids per night have a 3.4-percentage-point-higher work impairment due to absenteeism and presenteeism than female individuals reporting less than two voids, after adjusting for all covariates including sleep quality and duration (Column 3). For the male sample population we observe a 2.6-percentage-point increase in work impairment for those reporting two or more voids. Panels D to I of Table 5.5 report the associations between nocturia and work impairment for six age-gender sub-samples. After adjusting for covariates including sleep quality and duration, the magnitude of the association between nocturia and work impairment tends to be relatively larger for the younger cohorts (Panel D and G) than for the cohorts aged 51 or older (Panel F and I). For instance, using the coefficients from Column (3) the female sample population aged 18–30 reporting two or more voids per night have, on average, a 4.3-percentage-point-higher work impairment compared to those reporting less than two voids, whereas the older nocturia female sample population reports on average a 2.6-percentage-point-higher work impairment. Overall it is important to note that our estimates for work impairment, or the percentage of working time lost due to absenteeism and presenteeism associated with nocturia, is markedly lower than previous estimates. For instance, other studies have found working-time losses of more than 10 per cent (e.g. Weidlich et al. 2017). Here it is important to highlight that our analysis adjusts for a wide range of personal and lifestyle factors and health behaviours that can affect workplace productivity beyond nocturia. To that end, we can better identify the independent association of nocturia alongside other factors. Specifically, given that we statistically adjusted for the potential overlap between nocturia and sleep disturbance through sleep disorders such as insomnia, it is not surprising that our results produced a lower estimated effect of nocturia on work-related impairment, as this effect is observed after removing the effect of sleep quality and duration.

Furthermore, Table 5.6 provides a comparison for the magnitude of the association between nocturia and work impairment and the magnitude of the same association with other factors included in the analysis.[43] Specifically, the estimated difference in overall working days lost due to absenteeism and presenteeism[44] for each factor is presented, relative to its reference group. For each estimate the lower and upper bound of a 95 per cent confidence interval is provided, and estimates that are statistically significant – at least at the 5% level – are highlighted in bold.

All else equal, individuals reporting two or more voids per night lose on average about 7.6 working days per year more due to absenteeism and presenteeism compared to individuals reporting less than two night-time voids. This is of similar magnitude to individuals reporting a non-clinically diagnosed or necessarily chronic high glucose-level (7.7 days lost compared to individuals with normal glucose levels) or individuals clinically diagnosed with chronic asthma (7.5 days lost compared to individuals without asthma). Interestingly the association between nocturia and working time lost due to absenteeism and presenteeism is larger than for the same association and clinically diagnosed kidney disease (6.4 working days lost), physical inactivity (6.4 days lost)

43 Based on regression coefficient provided in Panel A of Table 5.3 (Column 3). The corresponding full regression output is provided in Appendix B, Table B.5.

44 Calculated as percentage work impairment times 250 working days.

and clinically diagnosed chronic hypertension (6.2 days lost). Similar to the associations with life satisfaction and work engagement, psychological stress and anxiety is associated with the relatively largest loss in working time due to absenteeism and presenteeism, with an individual reporting psychological distress losing about 43.3 days per year compared to an individual without psychological distress.

Table 5.6: Comparison between nocturia and other factors with regard to annual working days lost – full sample

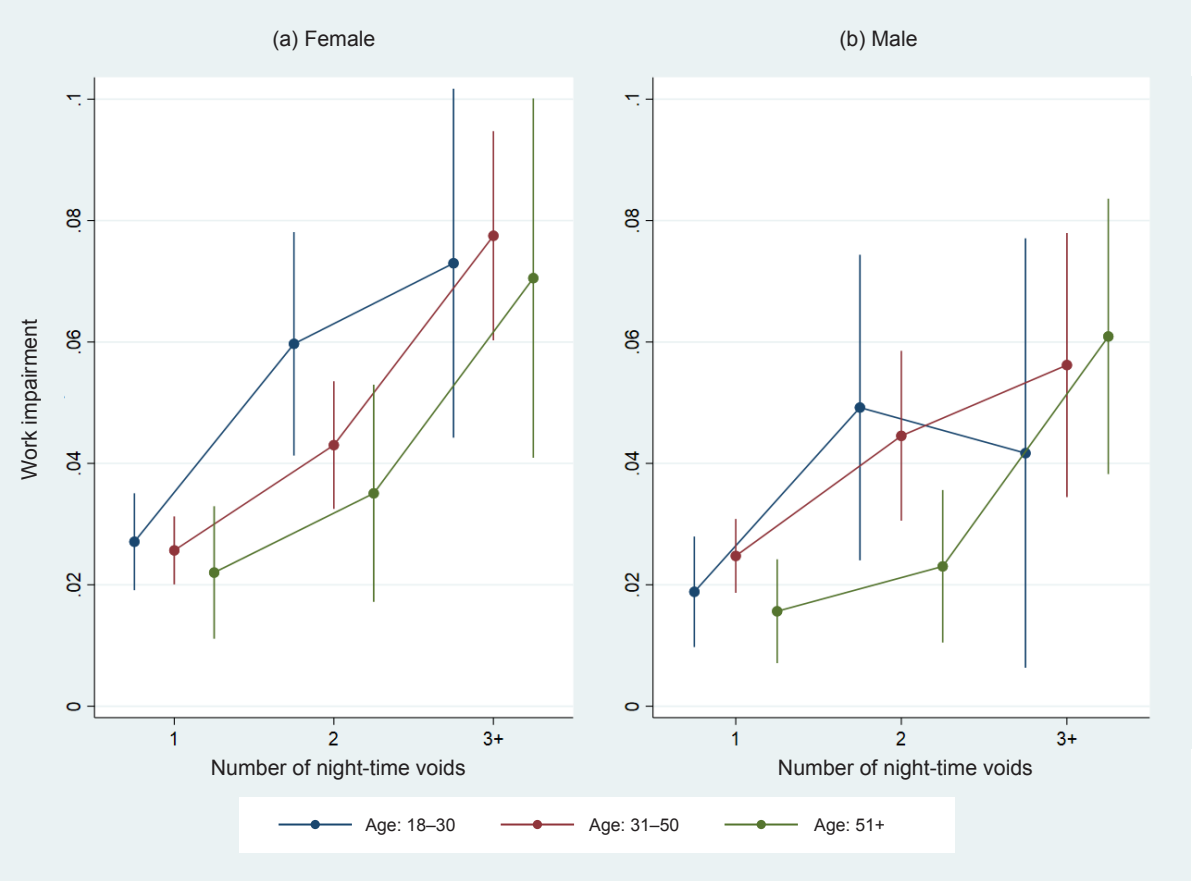
	Working days lost due to absenteeism and presenteeism: difference relative to reference group		
Factor	**Estimate**	**95% CI: low**	**95% CI: high**
Psychological distress	**43.3**	41.5	45.1
Severe mental illness	**30.9**	28.3	33.5
Cancer	**21.9**	15.5	28.3
Sleep quality (low)	**18.7**	17.5	19.8
Financial concerns	**14.1**	12.7	15.5
Cardiovascular disease	**12.8**	9.4	16.3
High glucose	**7.7**	4.3	11.2
2 + voids	**7.6**	6.2	9.0
Asthma	**7.5**	5.9	9.1
Kidney disease	**6.4**	1.6	11.2
Physical inactivity	**6.4**	5.5	7.2
Hypertension	**6.2**	4.6	7.8
Sleep duration (less than 6 hours)	**4.8**	3.6	5.9
High cholesterol	**3.9**	1.9	5.9
BMI: obese	**3.1**	2.0	4.2
Excessive salt intake	**3.0**	1.5	4.5
High blood pressure	**2.9**	1.8	3.9
BMI: underweight	**2.8**	0.6	4.9
Diabetes	1.6	-1.3	4.5
BMI: overweight	0.8	0.0	1.6
Current smoker	0.3	-1.0	1.5
Excessive alcohol consumption	0.0	-0.8	0.8

Notes: see Table B.5 in Appendix B for the full corresponding regression output table. The regression coefficients have been multiplied by 250 annual working days in order to get the relative decrease in work impairment due to absenteeism and presenteeism for individuals reporting two or more night-time voids compared to individuals reporting less than two night-time voids and the other factors presented in the table relative to their reference group. Estimates that are statistically significant – at least at the 5% level – are highlighted in bold.

In addition to nocturia defined as a threshold (two or more voids per night), Figure 5.3 also reports the association between nocturia symptom-severity and work impairment for six age-gender sub-samples.[45]

Except for the male sample population aged 18 to 30, the regression coefficients depicted in Figure 5.3 show that work impairment due to absenteeism and presenteeism increases with the number of voids reported (compared to individuals reporting zero voids.

Figure 5.3: Nocturia symptom-severity and work impairment (compared to individuals reporting zero night-time voids) – by age and gender



Notes: based on multivariate OLS regression models (separately for six age-gender sub-samples) with percentage work impairment due to absenteeism and presenteeism as dependent variable and nocturia symptom-severity indicator variables as covariates (zero voids as reference group). Entries represent regression coefficients with corresponding 95% confidence interval. The coefficients are adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol, sleep quality and sleeping less than 6 hours. Based on pooled BHW and AIA samples for the years 2017 and 2018. The full corresponding regression output tables can be found in Appendix B, Table B.6.

45 The corresponding full regression output tables can be found in Table B.6 of Appendix B.

6 Quantifying the macroeconomic implications associated with nocturia

This chapter aims to estimate the economic effects associated with nocturia relating to workplace productivity (work impairment due to absenteeism and presenteeism) as well as excess mortality for six countries, including the United Kingdom, Germany, Spain, the United States, Japan and Australia. To estimate the economic cost we use a macroeconomic model similar to the WHO's EPIC (Economic Cost of Ill-Health) model, but which is much more detailed and comprehensive in nature. The model is calibrated on the underlying economic data for each of the countries analysed, and the effects of nocturia are based on parameter estimates derived in the previous chapter on the association between nocturia and work impairment productivity and on parameters from the literature review on the prevalence and excessive mortality risk associated with nocturia. This analytical framework allows us to quantify the economic cost of nocturia, measured in terms of lost economic output.

The following sections explain in more detail the analytical approach and the corresponding research findings.

6.1. The macroeconomic model

6.1.1. A CGE model to assess impacts of health on the economy

In order to assess the economic implications of nocturia we use a multi-country computable general equilibrium (CGE). This simultaneously solves multiple equations that relate to production from firms and households' demand, within a country, and between countries through trade linkages. This type of modelling approach has gained ground in health economics in application to HIV/AIDS, Malaria, anti-microbial resistance (AMR), pandemic influenza and non-communicable disease (see e.g. Borger et al., 2008; Dixon et al., 2004; Kambou et al., 1992; Rutten and Reed, 2009; Smith et al., 2005; Taylor et al., 2014).

Within a CGE modelling framework the current economic projection for each country is computed using the current underlying economic factors (e.g. so-called 'status quo' or 'baseline scenario') and subsequently compared against a 'what-if' scenario in which various parameters are changed. For instance for the purpose of this analysis we compare how various outcomes (e.g. economic output of a country) would change (e.g. compared to status quo) if nocturia were to be diminished. Specifically in the field of health economics, the application of CGE models has recently become more common due to its advantages against more traditional approaches, such as cost of illness (COI) methods (e.g. Bloom et al. 2018). COI is an easy-to-understand method that summarises the

direct and indirect cost associated with ill-health, taking into account, for instance, the sum of all direct personal medical cost, as well as the indirect cost (e.g. income loss due to absenteeism or premature death). While the approach is relatively straightforward, it does not take into account the potential spillover effects on other agents or markets in an economy. For instance, in reality many adjustment mechanisms play out, such as the substitution between labour and capital should the labour supply be negatively affected due to ill-health or caregiver responsibilities. In contrast, a general equilibrium model such as CGE takes into account these ripple effects on other parts of the economy by reporting how overall economic output is affected.

The model is a multi-regional model whereby each region has bilateral trade with all other regions, simultaneously. World prices are, therefore, determined globally by the model, and each country/region has an effect on all the other regions. Larger regions will have larger effects compared to smaller regions. This is different from small-open economy (SOE) health models in which countries cannot affect world prices, but rather take them as given (e.g. Smith et al., 2005). In each country/region, firms produce three types of outputs (across three industries: Agriculture, Industry and Services), and a government collects tax and provides a public service. Finally, households, the government and foreign countries save/invest within each country following a Ramsey-type modelling approach.[46]

6.1.2. How nocturia affects the economy in the model

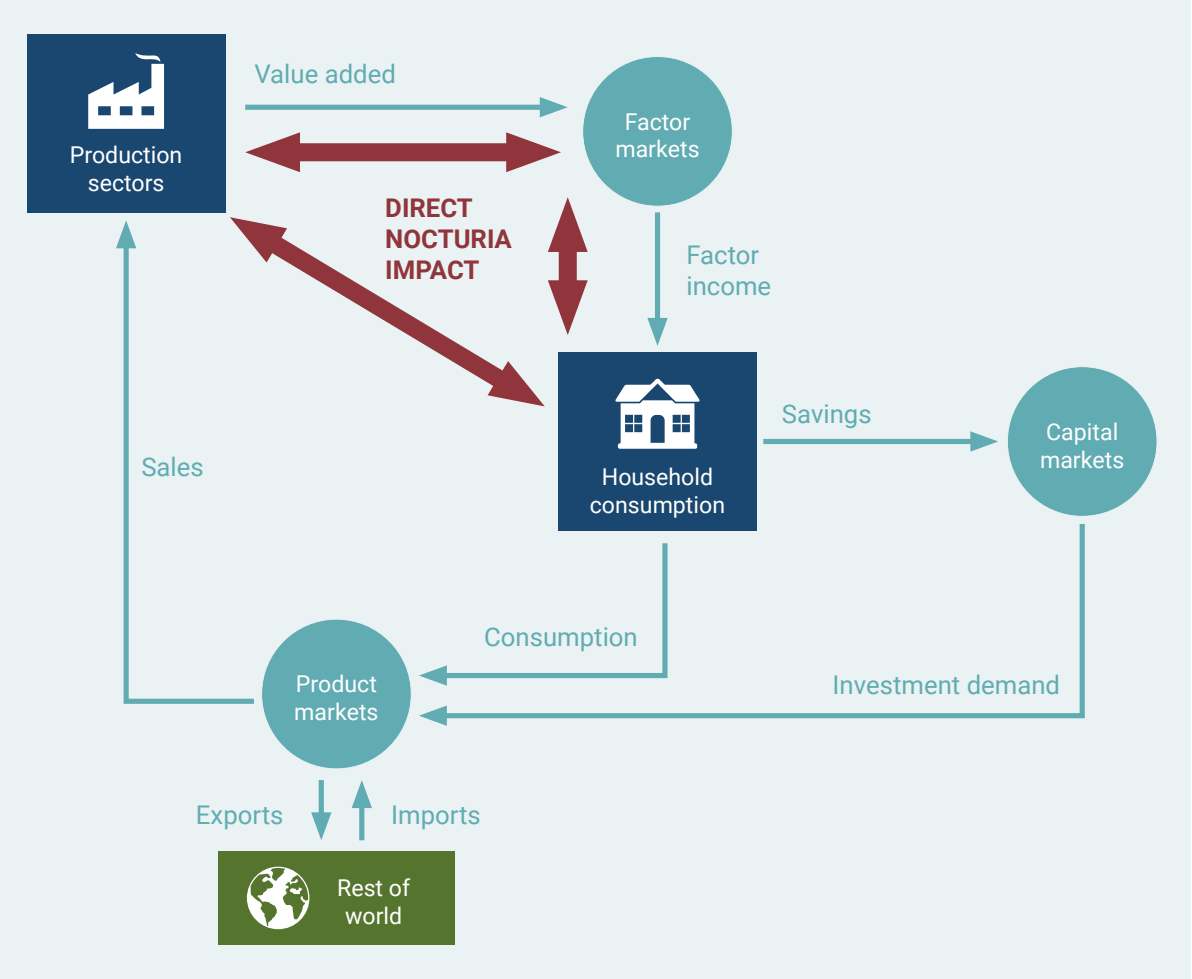
Figure 6.1 depicts the linkages in the CGE model and highlights the main channels through which nocturia affects the economy. In the model, just as in reality, production sectors (e.g. different agricultural, industrial and services sectors) require capital and labour inputs, which they access through the factor markets. Firms hire labour and rent capital from households, which allows households to obtain income. Goods are then sold in product markets, which households pay for, given their available income.

The framework depicted does not include the government, which in our model collects taxes and demands final goods. Finally, households and the governments save/borrow in the capital markets. The economy also trades with the rest of the world through a complex set of international linkages. Specifically, nocturia can directly reduce the supply of effective-labour, which is viewed as a key resource in the economy. Hence, one element of the model is the focus on the effective-labour supply, which is the physical amount of labour (e.g. number of employed people) augmented by their productivity level (e.g. depending on their health or skill).

In a country *r*, output in sector *i* consists of goods and services Y_{ir}, that are produced by capital K_{ir}, other inputs N_{ijr}, (*e.g.,* intermediate inputs from sector *j*), and effective labour L_{ir} (i.e., a labour input adjusted for efficiency units). Thus, production is modelled as a function of $Y=F(K,N,L)$, where subscripts *i* and *r* are omitted for simplicity.

46 A more detailed description regarding the CGE model can be found in Appendix D.

Figure 6.1: The interactions between nocturia and agents in the economy



Similar to the method used by Taylor et al. (2014) and Hafner et al. (2016) in a different context for the study of AMR and sleep, for each time period t, the model assumes that effective labour supply is adjusted for efficiency units by $L_{r,t} = \bar{L}_{r,t} \cdot E_{r,t}$, with the physical supply of labour input $\bar{L}_{r,t}$, and efficiency of labour $E_{r,t}$.

Similar to our previous work on the economic effects of inadequate sleep (Hafner et al., 2016), in the model, the reduction in effective-labour supply is manifested through **two** potential channels:

- **Reduced labour productivity** – prolonged periods of sickness temporarily reduce the country's workforce and may in severe cases lead to permanent reductions in labour efficiency (productivity). As we examined in the previous chapter, nocturia is associated with higher levels of work impairment due to absenteeism and presenteeism, with potentially large economic losses associated.

- **Increased mortality** – potential deaths attributable to nocturia permanently reduce the population size, and the effect of increased mortality on economic output is a decrease in the working-age population.

In essence, in the analysis we compare how the economy of a country today (baseline) would change if the negative factors associated with nocturia, such as lower productivity and mortality, were to be removed (counterfactual scenario).

To calculate the nocturia-related efficiency units of labour, we draw mainly on work-impairment data estimated in Chapter 5, where we found that nocturia increases the number of working days lost due to absenteeism and presenteeism. Thus, in our model, labour efficiency is based on subtracting a number of days (normalised to a year) from the baseline yearly efficiency level for the full working-age population. Simply put, the yearly efficiency of a worker is:

$$E = 1 - Number\ of\ lost\ days\ normalised\ to\ a\ year \quad (1)$$

whereas a decrease in the prevalence of nocturia reduces the number of lost working days due to illness.

6.1.3. Model input data

The base underlying economic data used for the purpose of this analysis is from the Global Trade Analysis Project (GTAP) database. This database has been developed by the Center for Global Trade Analysis at Purdue University since 1993. Overall, GTAP covers 140 countries for 57 GTAP commodities, and includes all bilateral trade patterns, production, consumption and intermediate inputs of commodities and services. We use the latest version, GTAP 9, which has a reference year of 2011. From the GTAP database, we extract a Social Accounting Matrix (SAM) for the specific countries and regions included in the analysis. The SAM is a complex table expressed in terms of incomes and expenditures, i.e. a double-entry accounting method. GTAP includes SAMs for individual countries, which are based on national accounts data (e.g. use-supply tables, input-output tables) and information from household survey data and trade data. Because of the sheer amount of work involved, GTAP collects and coordinates country SAMs from researchers across the world, and cleans and standardizes the data. For the purpose of this analysis we extracted the SAMs for the United Kingdom, Germany, Spain, United States, Japan, Australia and the rest of the world (RoW). In order to make the model tractable we aggregate the different sectors into three industries, including Agriculture, Manufacturing and Services. The data for the underlying population data comes from the UN Population Database (2019).We divide a country's population into the working-age population and the non-working age population, whereas the working-age population is defined as the part of the population between age 15 and 65. Furthermore, we use data from the International Labour Organisation (ILO) on the distribution of educational attainments across countries to divide the working age population further into skilled and unskilled labour. The UN Population Database also provides the current mortality rates by age and gender, which we apply to calculate the counterfactual working-age population in the absence of nocturia-related mortality.

In addition to the underlying economic data, we use nocturia-specific model inputs that determine the effects on the labour supply. Specifically, we use information on:

- The prevalence of nocturia in the population by age and gender;
- The level of work impairment by age and gender;
- The mortality risk of nocturia, measured by the relative mortality risk.

With regards to the prevalence of nocturia, the available literature provides an overview of the prevalence across different age and gender groups (see Chapter 2 for a more detailed discussion). For the purpose of this analysis we use the comprehensive prevalence data provided by Weidlich et al. (2017), which is specific by age and gender. Table 6.1 summarises the assumed prevalence data, which reveals that up to age 50 nocturia tends to be slightly more prevalent among the female population. As previously described, the prevalence increases strongly with age. Note that due to the lack of country-specific data, we assume the same prevalence rates across the six countries analysed. This may seem a strong assumption, however, the evidence provided by Weidlich et al. (2017) and other studies examining the population prevalence of the condition suggests that country-variation overall is limited. Also, the nocturia prevalence in our working-age population sample is very similar across the regions, including the UK, Australia and Asia (see Table 2.2).

Table 6.1: Population prevalence of nocturia (two or more voids per night) by age and gender

	Nocturia prevalence	
Age	**Female**	**Male**
18–30	9.0%	4.0%
31–45	10.5%	6.0%
46–50	13.0%	10.0%
51–60	18.0%	16.0%
61–70	28.0%	29.0%
71–80	40.0%	40.0%
81+	49.0%	52.0%

Source: Weidlich et al. (2017)

Using the prevalence rates of nocturia by age group reported in Table 6.1 and the age-gender specific population figures by country provided by the UN Population Database, Table 6.2 reports the corresponding estimated number of individuals with nocturia (defined as two or more voids per night) by country.

Table 6.2: Number of individuals with nocturia (two or more voids per night) by country

	Total population		Working-age population	
Country	**Millions**	**Share**	**Millions**	**Share**
Japan	21.8	17.0%	12.5	13.8%
UK	9.1	14.2%	5.7	12.8%
Spain	6.9	14.7%	4.2	12.5%
Germany	12.9	16.0%	7.6	13.1%
USA	40.0	12.9%	27.5	12.5%
Australia	2.9	13.0%	2.0	12.3%

Notes: calculated using prevalence rates reported in Table 6.1 and age-gender specific population data provided by the UN Population Database for each of the six countries. 'Working-age population' covers individuals aged 20 to 69.

It is estimated that up to 22 million individuals in Japan have nocturia, compared to 9 million in the United Kingdom, 7 million in Spain, 13 million in Germany, 40 million in the US and about 3 million in Australia, which corresponds to between 13 to 17 per cent of the total population. For the working population (assumed here aged 20 to 69), about 12.5 million of Japan's working-age population might be suffering from nocturia, about 5.7 million of the UK working-age population, 4.2 million in Spain, 7.6 million in Germany, 27.5 million in the US and 2 million in Australia.

With regards to work impairment or working days lost due to absenteeism and presenteeism by age and gender, we utilize the estimates derived in Chapter 5, where we use the fully adjusted regression coefficients reported in Panels D to I in Table 5.5, Column (3), which are summarised for convenience in Table 6.3.

Table 6.3: Nocturia and percentage of working time lost due to absenteeism and presenteeism, by age and gender

	Male		Female	
Age	**Share impairment**	**95% CI**	**Share impairment**	**95% CI**
18–30	0.0325	*(0.012 - 0.053)*	0.0427	*(0.027 - 0.059)*
31–50	0.0285	*(0.017 - 0.040)*	0.0315	*(0.022 - 0.041)*
51–65	0.0142	*(0.004 - 0.025)*	0.0245	*(0.009 - 0.040)*

Source: Author's calculations. Reported parameter estimates related to Table 5.5. Column (3) Panels D to I.

With regards to the elevated mortality risk associated with nocturia, we utilize estimates for the relative mortality risk from the existing literature. A meta-analysis on the relationship between nocturia and all-cause mortality is provided by Fan et al. (2015) for the adult population. The meta-analysis draws information from seven studies, including from studies that define nocturia as three or more voids per night and those that use two or more voids as the relevant nocturia threshold. Another drawback in using the combined relative mortality risks is that not all studies have been able to adjust for a large number of confounding covariates, including chronic conditions or sleep disorders. Hence the variation in magnitude of the relative mortality risks is very high, with some estimates suggesting relative mortality risks of up to 50 per cent for individuals affected with nocturia compared to those without nocturia (Kupelian et al. 2011). Given concerns regarding the robustness of these estimates we report the economic effects related to mortality separately, with the caveat that they are generally less robust, but also use a low relative mortality risk-estimate provided by Fan et al. (2015) that suggests individuals with two or more voids per night have on average a 6 per cent higher mortality risk than individuals with less than two night-time voids (relative risk of 1.06).[47]

6.1.4. Nocturia scenarios

In the analysis, we run two main scenarios that take into account separate productivity and mortality input assumptions. Note that for each scenario we compare how the economy of a

47 Corresponding 95% confidence interval (0.97–1.17).

country would perform in the counterfactual situation where the factors associated with nocturia were to be diminished (e.g. work impairment and excess mortality risk), compared to the baseline scenario with current nocturia prevalence and current associated productivity loss and reduced labour supply due to mortality. The scenarios can be described as follows:

1. **Productivity loss associated with nocturia:** in this scenario we estimate how much larger the economic output of the six countries would be, all else equal, if the current prevalence of nocturia in the working-age population is diminished to zero, and hence also the work impairment associated with nocturia. We also conduct a sensitivity analysis by providing a lower and upper bound of the estimated effects by applying the 95 per cent confidence intervals for the corresponding input parameters (see Table 6.2).
2. **Productivity loss and reduction in labour supply associated with nocturia:** in addition to the previous scenario, scenario 2 also takes into account the potential reduction in labour supply from nocturia associated with the elevated mortality risk for those suffering from the condition.

6.2. The macroeconomic cost associated with nocturia: model results

Table 6.4 reports the annual economic cost associated with the two scenarios, where each of the entries can be interpreted as how much more an economy could produce in terms of economic output, measured as Gross Domestic Product (GDP), if the prevalence of nocturia were to be zero across all age groups.[48]

Table 6.4: Estimated annual economic cost associated with nocturia in GDP terms

	Scenario 1: Real GDP – productivity			Scenario 2: Real GDP – productivity & reduction labour supply		
$ billion (2018 Dollars)						
Country	**Estimate**	*Low*	*High*	**Estimate**	*Low*	*High*
Australia	**3.0**	*1.6*	*4.3*	**3.2**	*1.6*	*4.8*
Japan	**13.7**	*7.2*	*19.7*	**14.6**	*7.2*	*22.2*
USA	**44.4**	*24.2*	*63.3*	**47.9**	*24.2*	*73.1*
Germany	**8.4**	*4.5*	*12.1*	**9.1**	*4.5*	*13.8*
Spain	**3.1**	*1.7*	*4.5*	**3.3**	*1.7*	*5.0*
United Kingdom	**5.9**	*3.2*	*8.4*	**6.3**	*3.2*	*9.6*
% total GDP						
Country	**Estimate**	*Low*	*High*	**Estimate**	*Low*	*High*
Australia	**0.21%**	*0.11%*	*0.30%*	**0.22%**	*0.11%*	*0.33%*
Japan	**0.21%**	*0.11%*	*0.31%*	**0.23%**	*0.11%*	*0.35%*

48 Note that the economic (opportunity) cost is characterised as a potential gain in economic output if nocturia were to be diminished.

	Scenario 1: Real GDP – productivity			Scenario 2: Real GDP – productivity & reduction labour supply		
USA	**0.26%**	*0.14%*	*0.37%*	**0.28%**	*0.14%*	*0.43%*
Germany	**0.22%**	*0.12%*	*0.32%*	**0.24%**	*0.12%*	*0.37%*
Spain	**0.20%**	*0.11%*	*0.29%*	**0.22%**	*0.11%*	*0.33%*
United Kingdom	**0.23%**	*0.12%*	*0.33%*	**0.25%**	*0.12%*	*0.37%*

Notes: *All values are reported in 2018 US Dollars. The contribution of the reduction in labour supply can be calculated using the difference in Real GDP between Scenario 2 and Scenario 1.*

Our scenario analyses suggest that under Scenario 1 – where we only look at the economic cost associated with higher work impairment due to absenteeism and presenteeism – we find that, all else equal, Australia's annual GDP could be $3 billion bigger (0.21 per cent of current GDP) in the absence of nocturia. Using the corresponding lower and upper bound estimates from a 95 per cent confidence interval the annual cost in GDP terms range between $1.6 billion and $4.3 billion. Japan loses annually about $13.7 billion (0.21 per cent of current GDP), ranging between $7.2 billion and $19.7 billion. Due to the size of its economy, in absolute terms the US could produce $44.4 billion more in annual GDP each year in the absence of nocturia, ranging from $24.2 billion to $63.3 billion. For Germany the annual cost in GDP is estimated to be $8.4 billion (ranging from $4.5 billion to $12.1 billion), the annual cost in GDP for Spain is $3.1 billion (ranging from $1.7 billion to $4.5 billion) and the annual cost in GDP for the United Kingdom is $5.9 billion (ranging from $3.2 billion to $8.4 billion).

Scenario 2 incorporates the associated cost from a loss in productivity and lower labour supply due to nocturia. The difference in the cost estimated between Scenario 2 and Scenario 1 provides an estimate of the cost associated with a lower supply due to the elevated mortality risk for those affected by nocturia. The findings suggest that the economic cost associated with a lower labour supply is much lower in magnitude. For instance Australia loses about $0.2 billion of its GDP due to a higher mortality risk associated with nocturia. Japan loses about $0.9 billion, the US $3.5 billion, Germany $0.7 billion, Spain $0.2 billion and the United Kingdom $0.4 billion, annually.

At first glance the estimated economic costs associated with nocturia are smaller compared to the estimates provided by Weidlich et al. (2017) and Holm-Larsen (2014), both using a COI approach.[49] For instance when examining the U.S., Holm-Larsen (2014) estimates the productivity loss in terms of absenteeism and presenteeism associated with nocturia to be around $61 billion. Our estimate with $44.4 billion is lower, but Holm-Larsen (2014) assumed a work impairment estimate of more than 10 per cent working time lost due to nocturia, whereas our parameter estimate applied is much lower (about 3 per cent across all age and gender groups). Our productivity loss estimate for the U.S. is roughly about one-quarter lower than Holm-Larsen's, but with a work impairment estimate that is more than 70 per cent lower. This suggests that the macroeconomic model applied for this analysis is highly likely to take into account not only the direct productivity losses such as the COI approach, but also the indirect spillover effects on other agents in the economy, which

49 See Table 2.1 for a summary of the estimated cost in the two studies.

would lead to larger effects than just using the COI approach. In fact, applying the work impairment estimates used by Holm-Larsen (2014) and Weidlich et al. (2017) would likely lead to much larger cost estimates for nocturia when applied in the CGE model.

Furthermore it is important to highlight that the analysis did not take into account direct costs related to healthcare for treating nocturia patients. Overall, these costs seem to be relatively lower in magnitude in the COI analytical framework applied in Holm-Larsen (2014) and Weidlich et al. (2017) and hence the cost estimates presented in this chapter are likely to be an underestimation of the overall cost.[50]

50 However, it is important to mention that within the CGE modelling framework the overall effect of healthcare cost depends on how these cost are modelled. For instance, if the healthcare cost falls fully on the public purse (e.g. in a fully public healthcare system, like in the UK), the effects would depend on how the public expenditure is financed, for instance either through higher borrowing or shifting existing public budgets, where increased spending in healthcare would have to come from other areas. Also, the dynamic nature would be important as at the macroeconomic level in the short-run, an increase in government expenditure can lead to an increase in demand (and hence an increase in GDP, all else equal) while if the additional government expenditure on health crowds out investments (e.g. in R&D) then a decrease in GDP could follow in the longer run, all else equal. In summary, it is not a priori clear how healthcare expenditure would impact the empirical findings presented in this study.

7 Summary and conclusion

7.1. Summary

Nocturia is a condition that is poorly understood and studied. For many health professionals and patients alike, getting up at night to go to the bathroom has traditionally been seen as a natural and accepted part of getting older. However, the understanding of nocturia is beginning to shift as more evidence emerges. Nocturia is considered to be caused by reduced nocturnal bladder capacity and/or a large urine volume produced during the night. It is also relatively common, with up to 20 per cent of the overall population being affected, and its prevalence increasing with age. Given its sleep interrupting nature nocturia is regarded to have negative implications for individuals' daytime functioning and is potentially associated with lower life satisfaction and reduced levels of workplace productivity.

This study is one of the first to attempt a comprehensive examination of the associations between nocturia and a range of health, wellbeing, demographic and economic variables in a working-age population, across different countries. To understand the relationships between nocturia and a set of wider outcomes and demographic and lifestyle factors, this study uses two main methodological approaches. The first approach is a set of multivariate regression analyses using data from a number of employer–employee workplace surveys in the UK, Australia and across Asia, which asked respondents about their sleep, sleep interruptions in the night due to the need to empty their bladder, their general health, and their work engagement and productivity, among others. The surveys asked consistent questions across the countries, and due to the consequent level of detail allow the statistical analysis to adjust for a large number of covariates (one of the drawbacks of previous empirical studies in this area). The second approach is a computable general equilibrium (CGE) macroeconomic model that models the whole economic system of each country analysed, and then tries to isolate the impacts associated with nocturia, specifically due to higher levels of work impairment due to absenteeism and presenteeism and potential excess mortality risk. The economic model applied in the analysis is akin to the WHO's Economic Cost of Ill-Health (EPIC) model, but is more comprehensive and detailed in the representation of the model economy. Under different nocturia scenarios the model then estimates the GDP losses associated with nocturia for six countries: the United States, United Kingdom, Australia, Germany, Spain and Japan.

Our results show a set of strong associations between nocturia and a range of conditions, outcomes and factors. On the one hand, it confirms in the working-age population what has been seen in other studies that focused more specifically on the general population and older age groups. We

observe a higher prevalence of nocturia in older age groups in the working-age population and among women. We find that a range of chronic conditions are associated with nocturia, though our surveys do not capture all relevant chronic conditions. Not surprisingly, we see a strong association between nocturia and other sleep quality indicators such as the first interrupted period of sleep. The relationships are especially strong after two sleep interruptions associated with two or more voids per night, and increases thereafter with each additional void. On the other hand, our study can be more expansive about the economic and wellbeing effects of the condition given the range of data points that are collected in the workplace surveys. Respondents who report two or more voids have lower work engagement, life satisfaction and lower work productivity resulting in lower individual wellbeing and costs to society and employers. And most importantly, these associations hold not only for the older cohorts of employees but also for those aged 18 to 30, who have more than half of their working lives ahead of them. This lends credence to the hypothesis that this is not just a condition relevant to older age groups.

Finally, our CGE models show the significant impact on national economies from nocturia, with the effect of nocturia potentially costing economies billions of dollars in lost annual economic output globally. Our estimates suggest that Australia's annual GDP could be $3 billion bigger each year in the absence of nocturia. For the other countries analysed, the annual costs in GDP terms are: $13.7 billion for Japan; $44.4 billion for the US; $8.4 billion for Germany; $3.1 billion for Spain and $5.9 billion for the United Kingdom.

7.2. Conclusions

The key insights and contributions from this study are as follows. Firstly, nocturia not only affects older age cohorts, but is also prevalent in younger populations. Furthermore, the condition seems to be 'bothersome' for individuals and the level of 'bother' increases with the number of night-time voids reported. Secondly, nocturia is associated with a considerable number of lifestyle risks and co-morbidities. However, nocturia as a condition is still poorly understood and more research is needed to better understand the mechanisms of whether these lifestyle and health factors are caused by nocturia, or whether nocturia is an underlying clinical indicator of these factors. Thirdly, given its potential sleep-impairing effect, the consequences of nocturia go beyond individuals' health or quality of life – nocturia can potentially negatively affect individuals' productivity and engagement at work, with negative economic ramifications, some of which this study highlights. Fourthly, even after adjusting for a variety of different covariates, including sleep quality and duration, the statistical analysis of this study suggests that nocturia remains to be associated with profound levels of work impairment due to absenteeism and presenteeism. Finally, this study shows strong associations and overlaps between nocturia and sleep quality. These findings suggest that the consequences of nocturia are partially explained by poor sleep, but there remains an independent effect of nocturia on individual health and economic outcomes. This study cannot fully tease apart the directionality of the relationship between nocturia and sleep, which is an important area for future research. However, these findings highlight that both nocturia and poor sleep quality offer important opportunities for intervention. Given the substantial economic implications of untreated nocturia, this should be a 'wake-up' call to diverse stakeholders – including patients, health-care providers, and employers – of the importance of identifying and treating nocturia.

References

Akerla, J., J. S. Pesonen, A. Poyhonen, J. Hakkinen, J. Koskimaki, H. Huhtala, T. L. J. Tammela & A. Auvinen. 2018. 'Impact of Lower Urinary Tract Symptoms on Mortality: a 21-Year Follow-Up Among Middle-Aged and Elderly Finnish Men.' *Prostate Cancer Prostatic Diseases*. doi:10.1038/s41391-018-0108-z

Andersson, F., P. Anderson, T. Holm-Larsen, J. Piercy, K. Everaert & T. Holbrook. 2016. 'Assessing the Impact of Nocturia on Health-Related Quality-of-Life and Utility: Results of an Observational Survey in Adults.' *Journal of Medical Economics* 19(12): 1200–6. doi:10.1080/13696998.2016.1211136. As of 4 March 2019: https://doi.org/10.1080/13696998.2016.1211136

Andersson, F., A. Blemings, T. Holm Larsen & J. P. Nørgaard. 2013. 'Waking at Night to Void can have a Profound Impact on Productivity.' *Value in Health* 16(3): A184. doi:10.1016/j.jval.2013.03.924

Angrist J. D. & J. S. Pischke, 2010. 'The Credibility Revolution in Empirical Economics: How Better Research Design Is Taking the Con out of Econometrics.' *Journal of Economic Perspectives*, American Economic Association, vol. 24(2), pages 3–30, Spring

Appell, R. A., & P. K. Sand. 2008. 'Nocturia: Etiology, Diagnosis, and Treatment.' *Neurourology and Urodynamics* 27(1): 34–9. doi:10.1002/nau.20484

Armington, P. S. 1969. 'A Theory of Demand for Products Distinguished by Place of Production.' Staff Papers (International Monetary Fund) 16(1): 159–78. doi:10.2307/3866403. As of 4 March 2019: http://www.jstor.org/stable/3866403

Asplund, R. 2005 'Nocturia in Relation to Sleep, Somatic Diseases and Medical Treatment in the Elderly.' *BJU International* 90(6): 533–6.

Ayoub, A. I., M. Attia, H. M. El Kady & A. Ashour. 2014. 'Insomnia among Community Dwelling Elderly in Alexandria, Egypt.' *The Journal of The Egyptian Public Health Association* 89(3): 136-42. doi:10.1097/01.epx.0000456621.42258.79

Biliotti, B., F. Andersson, P. Anderson & J. Piercy. 2014. 'Nocturia Results in Work Productivity and Activity Losses Comparable with Other Chronic Diseases.' Conference Paper in *Neurourology and Urodynamics*

Bing, M. H., L. A. Moller, P. Jennum, S. Mortensen, L. T. Skovgaard & G. Lose. 2006. 'Prevalence and Bother of Nocturia, and Causes of Sleep Interruption in a Danish Population of Men and Women Aged 60-80 Years.' *BJU International* 98(3): 599-604. doi:10.1111/j.1464-410X.2006.06390.x

Blanchflower, D. G., & A. J. Oswald. 2008. 'Is Well-Being U-Shaped over the Life Cycle?' *Social Science & Medicine* 66(8): 1733-49. doi:10.1016/j.socscimed.2008.01.030

Bliwise, D. L., L. Friedman, B. Hernandez, J. M. Zeitzer, C. A. Kushida & J. A. Yesavage. 2014. 'Nocturia Reported in Nightly Sleep Diaries: Common Occurrence with Significant Implications?' *Health Psychology*: official journal of the Division of Health Psychology, American Psychological Association 33(11): 1362–5. doi:10.1037/a0034401. As of 4 March 2019: https://www.ncbi.nlm.nih.gov/pubmed/24245840

Bloom, D.E., E.T. Cafiero, E. Jané-Llopis, S. Abrahams-Gessel, L.R. Bloom, S. Fathima, A.B. Feigl, T. Gaziano, M. Mowafi, A. Pandya, K. Prettner, L. Rosenberg, B. Seligman, A. Stein, & C. Weinstein. 2011. 'The Global Economic Burden of Non-Communicable Diseases'. Geneva: World Economic Forum

Bloom, D. E., S. Chen, M. Kuhn, M. E. McGovern, L. Oxley & K. Prettner. 2018. 'The Economic Burden of Chronic Diseases: Estimates and Projections for China, Japan, and South Korea.' *The Journal of the Economics of Ageing*. doi:https://doi.org/10.1016/j.jeoa.2018.09.002 As of 4 March 2019: http://www.sciencedirect.com/science/article/pii/S2212828X18300744

Borger, C., T. F. Rutherford & G. Y. Won. 2008. 'Projecting Long Term Medical Spending Growth.' *Journal of Health Economics*. 27, 69–88. doi:10.1016/j.jhealeco.2007.03.003

Bosch, J. L., & J. P. Weiss. 2010. 'The Prevalence and Causes of Nocturia.' *Journal of Urology* 184(2): 440–6. doi:10.1016/j.juro.2010.04.011

Cobb, C.W. & P.H. Douglas. 1928. 'A Theory of Production.' *American Economic Review*, 18, 139–165. https://www.aeaweb.org/aer/top20/18.1.139-165.pdf

Coyne, K. S., Z. Zhou, S. K. Bhattacharyya, C. L. Thompson, R. Dhawan & E. Versi. 2003. 'The Prevalence of Nocturia and its Effect on Health-Related Quality of Life and Sleep in a Community Sample in the USA.' *BJU International* 92(9): 948–54. doi:10.1111/j.1464-410X.2003.04527.x

DeGroot, M. H., & M.J. Schervish. 2002. *Probability and Statistics.* Addison-Wesley.

Dervis, K., J. de Melo & S. Robinson. 1982. 'General Equilibrium Models for Development Policy.' *Cambridge University Press*.

Dixon, S., S. McDonald & J. Roberts. 2004. Unpublished discussion paper. 'AIDS in Botswana: Evaluating the General Equilibrium Implications of Healthcare Interventions.' As of 4 March 2019: http://eprints.whiterose.ac.uk/10937/

Dmochowski, R., B.M. Brucker, E. Cole, S. Kawahara, R. Pulicharam, C. Burk, A. Tung, & D.Hale. 2019. 'Economic Burden of Illness in Adult Patients with Nocturia', *Journal of Managed Care and Specialty Pharmacy*,24:1-10. doi: 10.18553/jmcp.2019.1806.

Endeshaw, Y. W., A. Schwartz, K. Stone, P. Caserotti, T. Harris, S. Smagula & S. Satterfield. 2016. 'Nocturia, Insomnia Symptoms and Mortality among Older Men: The Health, Aging and Body Composition Study.' *Journal of Clinical Sleep Medicine,* 12(6): 789–96. doi:10.5664/jcsm.5870

Fan, Y., F. Wei, Y. Lang & W. Qi. 2015. 'Meta-Analysis of Nocturia and Risk of All-Cause Mortality in Adult Population.' *International Journal of Cardiology* 195: 120–2. doi:10.1016/j.ijcard.2015.03.168

FitzGerald, M. P., H. J. Litman, C. L. Link & J. B. McKinlay. 2007. 'The Association of Nocturia with Cardiac Disease, Diabetes, Body Mass Index, Age and Diuretic Use: Results from the BACH Survey.' *Journal of Urology* 177(4): 1385–9. doi:10.1016/j.juro.2006.11.057

Groves, R. M., & E. Peytcheva. 2008. 'The Impact of Nonresponse Rates on Nonresponse Bias: A Meta-Analysis.' *Public Opinion Quarterly* 72(2): 167–89. doi:10.1093/poq/

Hafner, M., M. Stepanek, J. Taylor, W. M. Troxel & C. Van Stolk. 2016. 'Why Sleep Matters - the Economic Costs of Insufficient Sleep: a Cross-Country Comparative Analysis.' Santa Monica, Calif.: RAND Corporation, RR-1791-VH

Hafner, M., C. Van Stolk, C. L. Saunders, J. Krapels & B. Baruch. 2015. 'Health, Wellbeing and Productivity in the Workplace: a Britain's Healthiest Company Summary Report.' Santa Monica, Calif.: RAND Corporation, RR-1084-VH

Hakkinen, J. T., R. Shiri, J. Koskimaki, T. L. Tammela, A. Auvinen & M. Hakama. 2008. 'Depressive Symptoms Increase the Incidence of Nocturia: Tampere Aging Male Urologic Study (TAMUS).' *Journal of Urology* 179(5): 1897–901. doi:10.1016/j.juro.2008.01.037

Hashim, H, & J.D. Marcus. 2018. 'Basic Concepts in Nocturia, Based on International Continence Society Standards in Nocturnal Lower Urinary Tract Function.' *Neurourology and Urodynamics* 37(S6): S20–S4. doi:10.1002/nau.23781

Hofmeester, I., B. J. Kollen, M. G. Steffens, J. L. Bosch, M. J. Drake, J. P. Weiss & M. H. Blanker. 2014. 'The Association Between Nocturia and Nocturnal Polyuria in Clinical and Epidemiological Studies: a Systematic Review and Meta-Analyses.' *Journal of Urology* 191(4): 1028–33. doi:10.1016/j.juro.2013.10.100

Holm-Larsen, T. 2014. 'The Economic Impact of Nocturia.' *Neurourology and Urodynamics* 33 Suppl 1: S10–4. doi:10.1002/nau.22593

Jennum, P. 2002. 'Sleep and Nocturia.' *BJU International* 90(s3): 21–4. doi:10.1046/j.1464-410X.90.s3.6.x

Kambou, G., S. Devarajan & M. Over. 1992. 'The Economic Impact of AIDS in an African Country: Simulations with a Computable General Equilibrium Model of Cameroon.' *Journal of African Economies*. 1, 109–130

Kim, S. O., H. S. Choi, Y. J. Kim, H. S. Kim, I. S. Hwang, E. C. Hwang, K. J. Oh, S. I. Jung, T. W. Kang, D. Kwon, K. Park & S. B. Ryu. 2011. 'Impact of Nocturia on Health-Related Quality of Life and Medical Outcomes Study Sleep Score in Men.' *International Neurourology Journal* 15(2): 82–6. doi:10.5213/inj.2011.15.2.82

Kim, S. Y., W. Bang, M. Kim, B. Park, J. Kim & H. G. Choi. 2017. 'Analysis of the Prevalence and Factors Associated with Nocturia in Adult Korean Men.' *Scientific Reports* 7: 41714. doi:10.1038/srep41714. As of 4 March 2019: https://www.nature.com/articles/srep41714

Kim, S. Y., W. Bang, M. Kim, B. Park, J. Kim & H. G. Choi. 2017. 'Nocturia Is Associated with Slipping and Falling.' *PLOS One* 12(1): e0169690-e. doi:10.1371/journal.pone.0169690. As of 4 March 2019: https://www.ncbi.nlm.nih.gov/pubmed/28060916

Kobelt, G., F. Borgstrom & A. Mattiasson. 2003. 'Productivity, Vitality and Utility in a Group of Healthy Professionally Active Individuals with Nocturia.' *BJU International* 91(3): 190–5.

Kupelian, V., M. P. Fitzgerald, S. A. Kaplan, J. P. Norgaard, G. R. Chiu & R. C. Rosen. 2011. 'Association of Nocturia and Mortality: Results from the Third National Health and Nutrition Examination Survey.' *Journal of Urology* 185(2): 571–7. doi:10.1016/j.juro.2010.09.108

Lofgren, H., R.L. Harris & S. Robinson. 2002. *A Standard Computable General Equilibrium (CGE) Model in GAMS*. Washington, D.C : International Food Policy Research Institute

Lofland, J.H., L. Pizzi & K. D. Frick. 2004. 'A Review of Health-Related Workplace Productivity Loss Instruments.' *Pharmacoeconomics* 22(3): 165–84. doi:10.2165/00019053-200422030-00003

Marinkovic, S. P., L. M. Gillen & S. L. Stanton. 2004. 'Managing Nocturia.' *British Medical Journal* 328(7447): 1063. doi:10.1136/British Medical Journal.328.7447.1063. As of 4 March 2019: https://www.bmj.com/content/328/7447/1063

Miller, P. S., H. Hill & F. L. Andersson. 2016. 'Nocturia Work Productivity and Activity Impairment Compared with Other Common Chronic Diseases.' *Pharmacoeconomics* 34(12): 1277–97. doi:10.1007/s40273-016-0441-9

Nakagawa, H., K. Niu, A. Hozawa, Y. Ikeda, Y. Kaiho, K. Ohmori-Matsuda, N. Nakaya, S. Kuriyama, S. Ebihara, R. Nagatomi, I. Tsuji & Y. Arai. 2010. 'Impact of Nocturia on Bone Fracture and Mortality in Older Individuals: a Japanese Longitudinal Cohort Study.' *Journal of Urology* 184(4): 1413–8. doi:10.1016/j.juro.2010.05.093

Pesonen, J. S., R. Cartwright, A. Mangera, H. Santti, T. L. Griebling, A. E. Pryalukhin, J. Riikonen, R. M. Tahtinen, A. Agarwal, J. F. Tsui, C. P. Vaughan, A. D. Markland, T. M. Johnson, 2nd, R. Fonsell-Annala, C. Khoo, T. L. Tammela, Y. Aoki, A. Auvinen, D. Heels-Ansdell, G. H. Guyatt & K. A. Tikkinen. 2016. 'Incidence and Remission of Nocturia: A Systematic Review and Meta-analysis.' *European Urology* 70(2): 372–81. doi:10.1016/j.eururo.2016.02.014

Pressman, M. R., W. G. Figueroa, J. Kendrick-Mohamed, L. W. Greenspon & D. D. Peterson. 1996. 'Nocturia. A Rarely Recognized Symptom of Sleep Apnea and Other Occult Sleep Disorders.' *Archives of Internal Medicine* 156(5): 545–50.

Ramsey, F. P. 1928. 'A Mathematical Theory of Saving.' *The Economic Journal* 38(152): 543–59. doi:10.2307/2224098. As of 4 March 2019: http://www.jstor.org/stable/2224098

Rutten, M. & G. Reed. 2009. 'A Comparative Analysis of Some Policy Options to Reduce Rationing in the UK's NHS: Lessons from a General Equilibrium Model Incorporating Positive Health Effects'. *Journal of Health Economics*. 28, 221–233. doi:10.1016/j.jhealeco.2008.10.002

Samuelsson, E., A. Victor & G. Tibblin. 1997. 'A Population Study of Urinary Incontinence and Nocturia Among Women Aged 20–59 Years. Prevalence, Well-Being and Wish for Treatment.' *Acta Obstetricia et Gynecologica Scandinavica* 76(1): 74–80

Schatzl, G., C. Temml, J. Schmidbauer, B. Dolezal, G. Haidinger & S. Madersbacher. 2000. 'Cross-Sectional Study of Nocturia in Both Sexes: Analysis of a Voluntary Health Screening Project.' *Urology* 56(1): 71–5

Schaufeli, W. B., A. B. Bakker & W. Van Rhenen. 2009. 'How Changes in Job Demands and Resources Predict Burnout, Work Engagement, and Sickness Absenteeism.' *Journal of Organizational Behavior* 30(7): 893–917. doi:10.1002/job.595

Shoven, J. B. & J. Whalley, 1992. 'Applying General Equilibrium.' *Cambridge University Press*

Smith, R.D., M. Yago, M. Millar, J. Coast. 2005. 'Assessing the Macroeconomic Impact of a Healthcare Problem: the Application of Computable General Equilibrium Analysis to Antimicrobial Resistance.' *Journal of Health Economics* 24, 1055–1075. doi:10.1016/j.jhealeco.2005.02.003

Stewart, R. B., M. T. Moore, F. E. May, R. G. Marks & W. E. Hale. 1992. 'Nocturia: a Risk Factor for Falls in the Elderly.' *Journal of the American Geriatrics Society* 40(12): 1217–20

Tang, K., D. E. Beaton, A. Boonen, M. A. M. Gignac & C. Bombardier. 2011. 'Measures of Work Disability and Productivity: Rheumatoid Arthritis Specific Work Productivity Survey (WPS-RA), Workplace Activity Limitations Scale (WALS), Work Instability Scale for Rheumatoid Arthritis (RA-WIS), Work Limitations Questionnaire (WLQ), and Work Productivity and Activity Impairment Questionnaire (WPAI).' *Arthritis Care & Research* 63(S11): S337–S49. doi:10.1002/acr

Taylor, J., M. Hafner, E. Yerushalmi, R.Smith, J. Bellasio, R. Vardavas, T. Bienkowska-Gibbs & J. Rubin. 2014. 'Estimating the Economic Costs of Antimicrobial Resistance: Model and Results.' The Wellcome Trust. As of 4 March 2019: https://www.rand.org/pubs/research_reports/RR911

Tikkinen, K. A., T. M. Johnson, 2nd, T. L. Tammela, H. Sintonen, J. Haukka, H. Huhtala & A. Auvinen. 2010. 'Nocturia Frequency, Bother, and Quality of Life: How Often Is Too Often? A population-based study in Finland.' *European Urology* 57(3): 488–96. doi:10.1016/j.eururo.2009.03.080

Tikkinen, K. A., T. L. Tammela, H. Huhtala & A. Auvinen. 2006. 'Is Nocturia Equally Common Among Men and Women? A Population Based Study in Finland.' *Journal of Urology* 175(2): 596–600. doi:10.1016/s0022-5347(05)00245-4

Tyagi, S., N. M. Resnick, S. Perera, T. H. Monk, M. H. Hall & D. J. Buysse. 2014. 'Behavioral Treatment of Insomnia: Also Effective for Nocturia.' *Journal of the American Geriatrics Society* 62(1): 54–60. doi:10.1111/jgs.12609

United Nations. *Population Databases*. As of 4 March 2019:
http://www.un.org/en/development/desa/population/publications/database/index.shtml

Van Kerrebroeck, P., P. Abrams, D. Chaikin, J. Donovan, D. Fonda, S. Jackson, P. Jennum, T. Johnson, G. Lose, A. Mattiasson, G. Robertson & J. Weiss. 2002. 'The Standardisation of Terminology in Nocturia: Report from the Standardisation Sub-Committee of the International Continence Society.' *Neurourology and Urodynamics* 21(2): 179–83

Vaughan, C. P., R. Eisenstein, D. L. Bliwise, Y. K. Endeshaw, Z. J. Nagamia, R. A. Wolf & T. M. Johnson Ii. 2012. 'Self-Rated Sleep Characteristics and Bother from Nocturia.' *International Journal of Clinical Practice* 66(4): 369–73. doi:10.1111/j.1742-1241.2011.02868.x

Weidlich, D., F. L. Andersson, M. Oelke, M. J. Drake, A. F. Jonasson & J. F. Guest. 2017. 'Annual Direct and Indirect Costs Attributable to Nocturia in Germany, Sweden, and the UK.' *The European Journal of Health Economics* 18(6): 761–71. doi:10.1007/s10198-016-0826-x

Weinberger J. M., J. P. Weiss, M. Kashan & J. G. Blaivas. 2013. 'Nocturia: Why Do People Void at Night.' *Journal of Urology* 189(5): 800–801

Weiss, J. P. & J. G. Blaivas. 2000. 'Nocturia.' *Journal of Urology* 163(1): 5–12

Weiss, J. P., P. E. van Kerrebroeck, B. M. Klein & J. P. Norgaard. 2011. 'Excessive Nocturnal Urine Production Is a Major Contributing Factor to The Etiology of Nocturia.' *Journal of Urology* 186(4): 1358–63. doi:10.1016/j.juro.2011.05.083

Winkelmann, R. & S. Boes. 2008. *Analysis of Microdata*, Springer, Berlin-Heidelberg, 2nd edition

Wooldridge, J. 2015. *Introductory Econometrics: A Modern Approach*, South-Western, Cengage Learning, 5th edition

Yoshimura, K. 2012. 'Correlates for Nocturia: a Review of Epidemiological Studies.' *International Journal of Urology* 19(4): 317–29. doi:10.1111/j.1442-2042.2011.02956.x

Yoshimura, K., Y. Oka, T. Kamoto, T. Tsukamoto, K. Oshiro, Y. Suzukamo, N. Kinukawa & O. Ogawa. 2009. 'Night-Time Frequency, Sleep Disturbance And General Health-Related Quality Of Life: Is There A Relation?' *International Journal of Urology* 16(1): 96–100. doi:10.1111/j.1442-2042.2008.02185.x

Appendix A: Factors associated with nocturia in the working-age population: demographics, lifestyle, co-morbidities and sleep – corresponding regression output tables

This appendix provides the full regression outputs for the empirical findings discussed in Chapter 4. The tables are ordered as follows:

- Table A.1: Associations between demographic and lifestyle factors, co-morbidities and nocturia – full sample
- Table A.2: Associations between demographic and lifestyle factors, co-morbidities and nocturia – UK sample
- Table A.3: Associations between demographic and lifestyle factors, co-morbidities and nocturia – Asia sample
- Table A.4: Associations between demographic and lifestyle factors, co-morbidities and nocturia – Australia sample
- Table A.5: Associations between demographic and lifestyle factors, co-morbidities and nocturia – female sample (Age: 18–30)
- Table A.6: Associations between demographic and lifestyle factors, co-morbidities and nocturia – female sample (Age: 31–50)
- Table A.7: Associations between demographic and lifestyle factors, co-morbidities and nocturia – female sample (Age: 51+)
- Table A.8: Associations between demographic and lifestyle factors, co-morbidities and nocturia – male sample (Age: 18–30)
- Table A.9: Associations between demographic and lifestyle factors, co-morbidities and nocturia – male sample (Age: 31-50)
- Table A.10: Associations between demographic and lifestyle factors, co-morbidities and nocturia – male sample (Age: 51+)
- Table A.11: Nocturia symptom-severity and sleep disturbance, by age and gender
- Table A.12: Nocturia symptom-severity and FUSP (hours), by age and gender
- Table A.13: Nocturia symptom-severity and fatigue score, by age and gender
- Table A.14: Average FUSP and sleep length by age and gender

Table A.1: Associations between demographic and lifestyle factors, co-morbidities and nocturia – full sample

	(1)	(2)	(3)
	Sample: Full		
	Dependent variable: 2 or more voids per night		
	Coefficient	*CI (95%)*	*P value*
Female	0.0173	*0.013 - 0.022*	*0.000***
Age: 31–50	0.0204	*0.015 - 0.026*	*0.000***
Age: 51+	0.0799	*0.071 - 0.089*	*0.000***
BMI: underweight	-0.0075	*-0.017 - 0.003*	*0.142*
BMI: overweight	0.0138	*0.009 - 0.018*	*0.000***
BMI: obese	0.0377	*0.031 - 0.045*	*0.000***
Excessive alcohol consumption	0.0039	*-0.002 - 0.009*	*0.160*
Physical inactivity	0.0042	*0.001 - 0.009*	*0.05**
Excessive salt intake	0.0198	*0.012 - 0.027*	*0.000***
Current smoker	-0.0038	*-0.011 - 0.003*	*0.284*
Psychological distress	0.0282	*0.018 - 0.038*	*0.000***
Asthma	0.0210	*0.012 - 0.030*	*0.000***
Cardiovascular disease	0.0668	*0.043 - 0.091*	*0.000***
Kidney disease	0.0841	*0.050 - 0.119*	*0.000***
Cancer	0.0626	*0.027 - 0.098*	*0.001***
Diabetes	0.0782	*0.055 - 0.101*	*0.000***
Hypertension	0.0434	*0.032 - 0.055*	*0.000***
Severe mental illness	0.0324	*0.020 - 0.045*	*0.000***
High blood pressure	0.0072	*0.002 - 0.012*	*0.006***
High cholesterol	0.0108	*-0.002 - 0.024*	*0.099*
High glucose	0.0528	*0.032 - 0.074*	*0.000***
Sleep quality (low)	0.0634	*0.056 - 0.071*	*0.000***
Sleep duration (less than 6 hours)	0.0077	*0.001 - 0.014*	*0.019**
White	0.0037	*-0.009 - 0.016*	*0.558*
Asian	0.0089	*-0.006 - 0.023*	*0.228*
Black	0.0376	*0.013 - 0.062*	*0.003***
United Kingdom	-0.0468	*-0.171 - 0.078*	*0.460*
Australia	-0.0311	*-0.156 - 0.094*	*0.625*
Observations	**91,685**		

*Notes: based on multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table A.2: Associations between demographic and lifestyle factors, co-morbidities and nocturia – UK sample

	(1)	(2)	(3)
	Sample: United Kingdom		
	Dependent variable: 2 or more voids per night		
	Coefficient	*CI (95%)*	*P value*
Female	0.0209	*0.015 - 0.026*	*0.000***
Age: 31–50	0.0236	*0.017 - 0.030*	*0.000***
Age: 51+	0.0872	*0.077 - 0.097*	*0.000***
BMI: underweight	0.0123	*-0.009 - 0.033*	*0.249*
BMI: overweight	0.0115	*0.006 - 0.017*	*0.000***
BMI: obese	0.0336	*0.025 - 0.042*	*0.000***
Excessive alcohol consumption	0.0017	*-0.004 - 0.007*	*0.555*
Physical inactivity	-0.0002	*-0.005 - 0.005*	*0.929*
Excessive salt intake	0.0156	*0.003 - 0.028*	*0.017**
Current smoker	-0.0074	*-0.015 - 0.001*	*0.075*
Psychological distress	0.0307	*0.018 - 0.044*	*0.000***
Asthma	0.0236	*0.013 - 0.034*	*0.000***
Cardiovascular disease	0.0675	*0.039 - 0.097*	*0.000***
Kidney disease	0.0999	*0.056 - 0.143*	*0.000***
Cancer	0.0624	*0.022 - 0.103*	*0.003***
Diabetes	0.0990	*0.068 - 0.130*	*0.000***
Hypertension	0.0435	*0.029 - 0.058*	*0.000***
Severe mental illness	0.0294	*0.015 - 0.043*	*0.000***
High blood pressure	0.0062	*-0.000 - 0.013*	*0.061*
High cholesterol	0.0242	*0.004 - 0.044*	*0.017**
High glucose	0.0436	*0.010 - 0.077*	*0.011**
Sleep quality (low)	0.0626	*0.054 - 0.071*	*0.000***
Sleep duration (less than 6 hours)	0.0270	*0.013 - 0.041*	*0.000***
White	0.0057	*-0.007 - 0.019*	*0.387*
Asian	0.0097	*-0.006 - 0.026*	*0.240*
Black	0.0459	*0.019 - 0.073*	*0.001***
Observations		**56,566**	

*Notes: based on multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night. Based on pooled samples for the years 2017 and 2018.*

Table A.3: Associations between demographic and lifestyle factors, co-morbidities and nocturia – Asia sample

	(1)	(2)	(3)
	Sample: Asia		
	Dependent variable: 2 or more voids per night		
	Coefficient	***CI (95%)***	***P value***
Female	0.0130	*0.004 - 0.021*	*0.003***
Age: 31–50	0.0117	*-0.001 - 0.024*	*0.066*
Age: 51+	0.0471	*0.029 - 0.065*	*0.000***
BMI: underweight	-0.0117	*-0.023 - -0.000*	*0.043**
BMI: overweight	0.0192	*0.010 - 0.028*	*0.000***
BMI: obese	0.0427	*0.030 - 0.056*	*0.000***
Excessive alcohol consumption	0.0442	*0.009 - 0.079*	*0.013**
Physical inactivity	0.0086	*0.001 - 0.017*	*0.05**
Excessive salt intake	0.0211	*0.012 - 0.031*	*0.000***
Current smoker	-0.0010	*-0.014 - 0.012*	*0.881*
Psychological distress	0.0240	*0.007 - 0.041*	*0.005***
Asthma	0.0167	*-0.006 - 0.039*	*0.145*
Cardiovascular disease	0.0732	*0.028 - 0.119*	*0.002***
Kidney disease	0.0300	*0.026 - 0.086*	*0.293**
Cancer	0.0852	*0.005 - 0.166*	*0.038**
Diabetes	0.0477	*0.017 - 0.079*	*0.003***
Hypertension	0.0423	*0.022 - 0.062*	*0.000***
Severe mental illness	0.0628	*0.019 - 0.107*	*0.005***
High blood pressure	0.0095	*-0.001 - 0.020*	*0.067*
High cholesterol	-0.0009	*-0.019 - 0.017*	*0.923*
High glucose	0.0532	*0.021 - 0.085*	*0.001***
Sleep quality (low)	0.0633	*0.050 - 0.077*	*0.000***
Sleep duration (less than 6 hours)	-0.0029	*-0.010 - 0.005*	*0.454*
Asian	0.0070	*-0.027 - 0.041*	*0.686*
Observations	**29,773**		

*Notes: based on multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night. Based on pooled samples for the years 2017 and 2018.*

Table A.4: Associations between demographic and lifestyle factors, co-morbidities and nocturia – Australia sample

	(1)	(2)	(3)
	Sample: Australia		
	Dependent variable: 2 or more voids per night		
	Coefficient	*CI (95%)*	*p value*
Female	0.0165	*-0.001 - 0.034*	*0.062*
Age: 31–50	0.0293	*0.008 - 0.051*	*0.008***
Age: 51+	0.0923	*0.058 - 0.126*	*0.000***
BMI: underweight	-0.0464	*-0.083 - -0.010*	*0.013**
BMI: overweight	0.0108	*-0.009 - 0.030*	*0.269*
BMI: obese	0.0423	*0.019 - 0.066*	*0.001***
Excessive alcohol consumption	0.0334	*0.009 - 0.058*	*0.009***
Physical inactivity	0.0143	*-0.005 - 0.034*	*0.153*
Excessive salt intake	0.0287	*0.005 - 0.052*	*0.017**
Current smoker	-0.0132	*-0.052 - 0.025*	*0.495*
Psychological distress	0.0234	*-0.017 - 0.064*	*0.251*
Asthma	0.0091	*-0.019 - 0.037*	*0.525*
Cardiovascular disease	-0.0026	*-0.106 - 0.100*	*0.960*
Kidney disease	0.1757	*0.030 - 0.322*	*0.019**
Cancer	0.0023	*-0.144 - 0.149*	*0.975*
Diabetes	0.0902	*-0.030 - 0.210*	*0.139*
Hypertension	0.0301	*-0.017 - 0.077*	*0.202*
Severe mental illness	0.0107	*-0.029 - 0.050*	*0.588*
High blood pressure	0.0141	*-0.011 - 0.039*	*0.262*
High cholesterol	0.0140	*-0.029 - 0.057*	*0.519*
High glucose	0.1120	*0.015 - 0.209*	*0.024**
Sleep quality (low)	0.0441	*0.018 - 0.070*	*0.001***
Sleep duration (less than 6 hours)	0.0182	*-0.004 - 0.040*	*0.100*
White	-0.0648	*-0.215 - 0.085*	*0.392*
Asian	-0.0586	*-0.220 - 0.103*	*0.470*
Black	-0.0686	*-0.235 - 0.098*	*0.413*
Observations		**5,346**	

*Notes: based on multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night. Based on pooled samples for the years 2017 and 2018.*

Table A.5: Associations between demographic and lifestyle factors, co-morbidities and nocturia – female sample (Age: 18–30)

	(1)	(2)	(3)
	Sample: Female; Age: 18–30		
	Dependent variable: 2 or more voids per night		
	Coefficient	*CI (95%)*	*P value*
BMI: underweight	-0.0118	*-0.029 - 0.005*	*0.176*
BMI: overweight	0.0195	*0.008 - 0.031*	*0.001***
BMI: obese	0.0372	*0.022 - 0.053*	*0.000***
Excessive alcohol consumption	0.0036	*-0.011 - 0.018*	*0.625*
Physical inactivity	0.0011	*-0.009 - 0.011*	*0.833*
Excessive salt intake	0.0252	*0.009 - 0.041*	*0.002***
Current smoker	-0.0293	*-0.046 - -0.013*	*0.001***
Psychological distress	0.0247	*0.006 - 0.043*	*0.008***
Asthma	0.0197	*0.002 - 0.038*	*0.033**
Cardiovascular disease	0.0662	*-0.018 - 0.150*	*0.123*
Kidney disease	0.0833	*-0.006 - 0.173*	*0.069*
Cancer	-0.0717	*-0.169 - 0.025*	*0.146*
Diabetes	0.0664	*-0.043 - 0.175*	*0.231*
Hypertension	0.0484	*-0.019 - 0.116*	*0.160*
Severe mental illness	0.0260	*0.001 - 0.051*	*0.041**
High blood pressure	0.0065	*-0.012 - 0.025*	*0.491*
High cholesterol	0.0021	*-0.044 - 0.048*	*0.928*
High glucose	0.0909	*0.007 - 0.175*	*0.033**
Sleep quality (low)	0.0632	*0.045 - 0.081*	*0.000***
Sleep duration (less than 6 hours)	0.0178	*0.001 - 0.035*	*0.037**
Observations	**16,990**		

*Notes: based on multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table A.6: Associations between demographic and lifestyle factors, co-morbidities and nocturia – female sample (Age: 31–50)

	(1)	(2)	(3)
	Sample: Female; Age: 31–50		
	Dependent variable: 2 or more voids per night		
	Coefficient	*CI (95%)*	*p value*
BMI: underweight	0.0050	*-0.021 - 0.031*	*0.701*
BMI: overweight	0.0196	*0.010 - 0.029*	*0.000***
BMI: obese	0.0345	*0.021 - 0.048*	*0.000***
Excessive alcohol consumption	0.0101	*-0.001 - 0.021*	*0.075*
Physical inactivity	-0.0010	*-0.010 - 0.008*	*0.834*
Excessive salt intake	0.0204	*0.004 - 0.037*	*0.015**
Current smoker	-0.0025	*-0.018 - 0.013*	*0.758*
Psychological distress	0.0447	*0.021 - 0.068*	*0.000***
Asthma	0.0116	*-0.004 - 0.027*	*0.143*
Cardiovascular disease	0.0345	*-0.015 - 0.084*	*0.175*
Kidney disease	0.1312	*0.062 - 0.201*	*0.000***
Cancer	0.0258	*-0.033 - 0.085*	*0.389*
Diabetes	0.0568	*0.008 - 0.106*	*0.023**
Hypertension	0.0545	*0.027 - 0.082*	*0.000***
Severe mental illness	0.0278	*0.001 - 0.055*	*0.043**
High blood pressure	0.0050	*-0.007 - 0.017*	*0.402*
High cholesterol	0.0303	*0.000 - 0.060*	*0.049**
High glucose	0.0305	*-0.018 - 0.079*	*0.213*
Sleep quality (low)	0.0636	*0.049 - 0.079*	*0.000***
Sleep duration (less than 6 hours)	0.0088	*-0.006 - 0.023*	*0.228*
Observations	**26,132**		

*Notes: based on multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table A.7: Associations between demographic and lifestyle factors, co-morbidities and nocturia – female sample (Age: 51+)

	(1)	(2)	(3)
	Sample: Female; Age: 51+		
	Dependent variable: 2 or more voids per night		
	Coefficient	*CI (95%)*	*p value*
BMI: underweight	0.0103	*-0.073 - 0.094*	*0.808*
BMI: overweight	0.0469	*0.026 - 0.067*	*0.000***
BMI: obese	0.0966	*0.068 - 0.125*	*0.000***
Excessive alcohol consumption	0.0117	*-0.013 - 0.037*	*0.361*
Physical inactivity	0.0228	*0.004 - 0.041*	*0.016**
Excessive salt intake	0.0906	*0.036 - 0.145*	*0.001***
Current smoker	0.0036	*-0.038 - 0.045*	*0.863*
Psychological distress	0.1018	*0.030 - 0.173*	*0.005***
Asthma	0.0352	*-0.007 - 0.078*	*0.103*
Cardiovascular disease	0.0758	*-0.020 - 0.172*	*0.122*
Kidney disease	0.1773	*0.041 - 0.314*	*0.011**
Cancer	0.0539	*-0.048 - 0.156*	*0.300*
Diabetes	0.0953	*0.013 - 0.178*	*0.024**
Hypertension	0.0200	*-0.015 - 0.055*	*0.263*
Severe mental illness	0.0188	*-0.071 - 0.109*	*0.682*
High blood pressure	0.0007	*-0.021 - 0.022*	*0.946*
High cholesterol	-0.0034	*-0.051 - 0.044*	*0.888*
High glucose	0.0350	*-0.063 - 0.133*	*0.483*
Sleep quality (low)	0.0945	*0.065 - 0.124*	*0.000***
Sleep duration (less than 6 hours)	0.0487	*0.014 - 0.084*	*0.007***
Observations	**6,629**		

*Notes: based on multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table A.8: Associations between demographic and lifestyle factors, co-morbidities and nocturia – male sample (Age: 18–30)

	(1)	(2)	(3)
	Sample: Male; Age: 18–30		
	Dependent variable: 2 or more voids per night		
	Coefficient	*CI (95%)*	*p value*
BMI: underweight	0.0064	*-0.025 - 0.038*	*0.692*
BMI: overweight	0.0007	*-0.010 - 0.011*	*0.904*
BMI: obese	0.0061	*-0.010 - 0.022*	*0.461*
Excessive alcohol consumption	-0.0007	*-0.013 - 0.011*	*0.915*
Physical inactivity	-0.0023	*-0.013 - 0.008*	*0.664*
Excessive salt intake	0.0015	*-0.017 - 0.020*	*0.872*
Current smoker	0.0292	*0.013 - 0.045*	*0.000***
Psychological distress	0.0198	*-0.006 - 0.046*	*0.135*
Asthma	0.0015	*-0.017 - 0.020*	*0.879*
Cardiovascular disease	0.0563	*-0.032 - 0.144*	*0.209*
Kidney disease	-0.0021	*-0.082 - 0.078*	*0.960*
Cancer	-0.0423	*-0.069 - -0.015*	*0.002***
Diabetes	0.0407	*-0.053 - 0.134*	*0.393*
Hypertension	0.0453	*-0.013 - 0.103*	*0.125*
Severe mental illness	0.0120	*-0.019 - 0.043*	*0.444*
High blood pressure	0.0135	*0.000 - 0.027*	*0.042**
High cholesterol	-0.0032	*-0.050 - 0.044*	*0.895*
High glucose	0.0423	*-0.038 - 0.122*	*0.300*
Sleep quality (low)	0.0417	*0.026 - 0.058*	*0.000***
Sleep duration (less than 6 hours)	0.0020	*-0.015 - 0.019*	*0.821*
Observations	**11,338**		

*Notes: based on multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table A.9: Associations between demographic and lifestyle factors, co-morbidities and nocturia – male sample (Age: 31–50)

	(1)	(2)	(3)
	Sample: Male; Age: 31–50		
	Dependent variable: 2 or more voids per night		
	Coefficient	*CI (95%)*	*p value*
BMI: underweight	-0.0204	*-0.058 - 0.017*	*0.287*
BMI: overweight	0.0114	*0.004 - 0.019*	*0.004***
BMI: obese	0.0305	*0.016 - 0.046*	*0.000***
Excessive alcohol consumption	0.0008	*-0.008 - 0.010*	*0.861*
Physical inactivity	0.0046	*-0.004 - 0.013*	*0.277*
Excessive salt intake	0.0243	*0.007 - 0.042*	*0.008***
Current smoker	-0.0116	*-0.025 - 0.002*	*0.089*
Psychological distress	0.0264	*0.006 - 0.047*	*0.013**
Asthma	0.0247	*0.008 - 0.041*	*0.004***
Cardiovascular disease	0.0347	*-0.011 - 0.080*	*0.133*
Kidney disease	0.1179	*0.045 - 0.191*	*0.002***
Cancer	0.0871	*-0.019 - 0.193*	*0.106*
Diabetes	0.0799	*0.041 - 0.118*	*0.000***
Hypertension	0.0679	*0.046 - 0.090*	*0.000***
Severe mental illness	0.0324	*0.001 - 0.063*	*0.040**
High blood pressure	0.0011	*-0.007 - 0.009*	*0.801*
High cholesterol	0.0055	*-0.017 - 0.028*	*0.627*
High glucose	0.0351	*-0.002 - 0.072*	*0.064*
Sleep quality (low)	0.0511	*0.037 - 0.065*	*0.000***
Sleep duration (less than 6 hours)	0.0032	*-0.010 - 0.017*	*0.635*
Observations	**23,046**		

*Notes: based on multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table A.10: Associations between demographic and lifestyle factors, co-morbidities and nocturia – male sample (Age: 51+)

	(1)	(2)	(3)
	Sample: Male; Age: 51+		
	Dependent variable: 2 or more voids per night		
	Coefficient	*CI (95%)*	*p value*
BMI: underweight	-0.0743	*-0.182 - 0.033*	*0.176*
BMI: overweight	-0.0168	*-0.035 - 0.001*	*0.066*
BMI: obese	0.0200	*-0.005 - 0.045*	*0.113*
Excessive alcohol consumption	-0.0040	*-0.023 - 0.015*	*0.679*
Physical inactivity	0.0094	*-0.011 - 0.029*	*0.357*
Excessive salt intake	0.0300	*-0.021 - 0.081*	*0.246*
Current smoker	-0.0050	*-0.044 - 0.034*	*0.801*
Psychological distress	0.0177	*-0.052 - 0.087*	*0.617*
Asthma	0.0798	*0.039 - 0.121*	*0.000***
Cardiovascular disease	0.1241	*0.072 - 0.176*	*0.000***
Kidney disease	-0.0131	*-0.118 - 0.091*	*0.806*
Cancer	0.1390	*0.048 - 0.230*	*0.003***
Diabetes	0.0937	*0.044 - 0.144*	*0.000***
Hypertension	0.0149	*-0.014 - 0.044*	*0.312*
Severe mental illness	0.0912	*0.021 - 0.162*	*0.011**
High blood pressure	0.0224	*0.004 - 0.041*	*0.020**
High cholesterol	0.0236	*-0.016 - 0.064*	*0.247*
High glucose	0.0942	*0.024 - 0.164*	*0.008***
Sleep quality (low)	0.1104	*0.078 - 0.143*	*0.000***
Sleep duration (less than 6 hours)	-0.0321	*-0.060 - -0.004*	*0.024**
Observations	**7,487**		

*Notes: based on multivariate linear probability model with binary nocturia variable (two or more voids per night) as dependent variable. Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). Each coefficient represents the average associated marginal probability of the corresponding covariate to predict that the individual reports two or more voids per night. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table A.11: Nocturia symptom-severity and sleep disturbance, by age and gender

	(1)	(2)	(3)
	Dependent variable: (Log) Sleep Disturbance Score		
	A: Sample: Female; Age: 18–30		
	Coefficient	*CI (95%)*	*P value*
1 void	0.0849	0.065 - 0.105	0.000**
2 voids	0.2304	0.192 - 0.269	0.000**
3 + voids	0.3053	0.245 - 0.365	0.000**
	B: Sample: Female; Age: 31–50		
1 void	0.0768	0.063 - 0.090	0.000**
2 voids	0.2127	0.184 - 0.242	0.000**
3 + voids	0.2749	0.230 - 0.320	0.000**
	C: Sample: Female; Age: 51+		
1 void	0.0575	0.026 - 0.089	0.000**
2 voids	0.1915	0.146 - 0.237	0.000**
3 + voids	0.3712	0.304 - 0.439	0.000**
	D: Sample: Male; Age: 18–30		
1 void	0.0588	0.040 - 0.078	0.000**
2 voids	0.1686	0.112 - 0.226	0.000**
3 + voids	0.3138	0.226 - 0.401	0.000**
	E: Sample: Male; Age: 3–50		
1 void	0.0486	0.034 - 0.064	0.000**
2 voids	0.1589	0.128 - 0.190	0.000**
3 + voids	0.2188	0.168 - 0.269	0.000**
	F: Sample: Male; Age: 51+		
1 void	0.0404	0.017 - 0.064	0.001**
2 voids	0.1248	0.086 - 0.164	0.000**
3 + voids	0.2333	0.172 - 0.294	0.000**

*Notes: based on multivariate OLS regression models (separate by each age-gender sub-sample) with log-transformed sleep disturbance score as dependent variable and nocturia symptom-severity indicator variables as covariates (zero voids as reference group). Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). In addition to covariates presented in the table, the coefficients are also adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table A.12: Nocturia symptom-severity and FUSP (hours), by age and gender

	(1)	(2)	(3)
	Dependent variable: FUSP (hours)		
	A: Sample: Female; Age: 18–30		
	Coefficient	*CI (95%)*	*p value*
1 void	-0.9211	-0.996 - -0.846	0.000**
2 voids	-1.2261	-1.339 - -1.114	0.000**
3 + voids	-1.2691	-1.470 - -1.068	0.000**
	B: Sample: Female; Age: 31–50		
1 void	-0.8511	-0.899 - -0.803	0.000**
2 voids	-1.1545	-1.247 - -1.062	0.000**
3 + voids	-1.4845	-1.619 - -1.350	0.000**
	C: Sample: Female; Age: 51+		
1 void	-0.6936	-0.798 - -0.589	0.000**
2 voids	-1.2199	-1.350 - -1.089	0.000**
3 + voids	-1.5833	-1.768 - -1.399	0.000**
	D: Sample: Male; Age: 18–30		
1 void	-1.1285	-1.222 - -1.035	0.000**
2 voids	-1.3284	-1.516 - -1.141	0.000**
3 + voids	-1.1328	-1.403 - -0.863	0.000**
	E: Sample: Male; Age: 31–50		
1 void	-0.8647	-0.915 - -0.815	0.000**
2 voids	-1.1937	-1.297 - -1.090	0.000**
3 + voids	-1.2842	-1.450 - -1.118	0.000**
	F: Sample: Male; Age: 51+		
1 void	-0.8413	-0.925 - -0.758	0.000**
2 voids	-1.5745	-1.702 - -1.447	0.000**
3 + voids	-1.8207	-2.000 - -1.641	0.000**

*Notes: based on multivariate OLS regression models (separate by each age-gender sub-sample) with FUSP in hours as dependent variable and nocturia symptom-severity indicator variables as covariates (zero voids as reference group). Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). In addition to covariates presented in the table, the coefficients are also adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardio-vascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table A.13: Nocturia symptom-severity and fatigue score, by age and gender

	(1)	(2)	(3)
	Dependent variable: (Log) Fatigue Score		
	A: Sample: Female; Age: 18–30		
	Coefficient	*CI (95%)*	*p value*
1 void	0.0258	0.013 - 0.039	0.000**
2 voids	0.0568	0.031 - 0.082	0.000**
3 + voids	0.0452	0.005 - 0.086	0.029*
	B: Sample: Female; Age: 31–50		
1 void	0.0327	0.021 - 0.044	0.000**
2 voids	0.0757	0.053 - 0.098	0.000**
3 + voids	0.0810	0.053 - 0.109	0.000**
	C: Sample: Female; Age: 51+		
1 void	0.0561	0.033 - 0.079	0.000**
2 voids	0.1223	0.088 - 0.156	0.000**
3 + voids	0.1176	0.065 - 0.170	0.000**
	D: Sample: Male; Age: 18–30		
1 void	0.0478	0.030 - 0.065	0.000**
2 voids	0.0723	0.032 - 0.113	0.001**
3 + voids	0.1072	0.050 - 0.164	0.000**
	E: Sample: Male; Age: 31–50		
1 void	0.0500	0.038 - 0.062	0.000**
2 voids	0.0832	0.059 - 0.107	0.000**
3 + voids	0.0846	0.043 - 0.126	0.000**
	F: Sample: Male; Age: 51+		
1 void	0.0607	0.037 - 0.085	0.000**
2 voids	0.0886	0.042 - 0.135	0.000**
3 + voids	0.1362	0.072 - 0.200	0.000**

*Notes: based on multivariate OLS regression models (separate by each age-gender sub-sample) with log-transformed fatigue score as dependent variable and nocturia symptom-severity indicator variables as covariates (zero voids as reference group). Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). In addition to covariates presented in the table, the coefficients are also adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table A.14: Average FUSP and sleep length by age and gender

Cohort	Mean FUSP (hours); 0 voids	Mean sleep length (hours)	N
Female; Age: 18–30	5.0	7.0	17,070
Female; Age: 31–50	4.7	6.8	26,203
Female; Age: 51+	4.5	6.7	6,633
Male; Age: 18–30	5.2	6.9	12,285
Male; Age: 31–50	4.8	6.7	23,671
Male; Age: 51+	4.9	6.8	7,497

Notes: N represents number of individuals within each age-gender sample.

Appendix B: Nocturia and the associations with life satisfaction, workplace engagement and productivity – corresponding regression output tables

This appendix provides the full regression outputs for the empirical findings discussed in Chapter 5. The tables are ordered as follows:

- Table B.1: Associations between nocturia and life satisfaction – full sample
- Table B.2: Nocturia symptom-severity and life satisfaction – by age and gender
- Table B.3: Associations between nocturia and work engagement – full sample
- Table B.4: Nocturia symptom-severity and work engagement – by age and gender
- Table B.5: Associations between nocturia and work impairment – full sample
- Table B.6: Nocturia symptom-severity and work impairment – by age and gender

Table B.1: Associations between nocturia and life satisfaction – full sample

	(1)	(2)	(3)
	Dependent variable: (Log) Life Satisfaction		
	Full Sample		
	Coefficient	***CI (95%)***	***P value***
2 + voids	-0.0189	-0.026 - -0.012	0.000**
Financial concerns	-0.1680	-0.177 - -0.159	0.000**
BMI: underweight	-0.0196	-0.030 - -0.009	0.000**
BMI: overweight	-0.0057	-0.010 - -0.002	0.005**
BMI: obese	-0.0256	-0.031 - -0.020	0.000**
Excessive alcohol consumption	-0.0048	-0.010 - 0.000	0.065
Physical inactivity	-0.0330	-0.037 - -0.029	0.000**
Excessive salt intake	-0.0080	-0.015 - -0.001	0.029*
Current smoker	-0.0199	-0.027 - -0.013	0.000**
Psychological distress	-0.3661	-0.383 - -0.349	0.000**
Asthma	-0.0112	-0.019 - -0.003	0.005**
Cardiovascular disease	-0.0178	-0.036 - 0.000	0.054
Kidney disease	-0.0129	-0.042 - 0.016	0.383
Cancer	-0.0285	-0.058 - 0.001	0.062
Diabetes	0.0092	-0.006 - 0.024	0.235
Hypertension	-0.0157	-0.024 - -0.007	0.000**
Severe mental illness	-0.1140	-0.130 - -0.098	0.000**
High blood pressure	-0.0071	-0.012 - -0.002	0.009**
High cholesterol	-0.0198	-0.031 - -0.009	0.000**
High glucose	-0.0136	-0.032 - 0.005	0.148
Sleep quality (low)	-0.1090	-0.116 - -0.102	0.000**
Sleep duration (less than 6 hours)	-0.0481	-0.054 - -0.042	0.000**
Observations		**91,685**	

Notes: *entries represent OLS regression coefficients with corresponding 95% confidence interval (standard errors clustered at company level) and p-value (** p<0.01, * p<0.05). In addition to the covariates presented in the table, the regression coefficients are also adjusted for age, education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours. Analysis based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table B.2: Nocturia symptom-severity and life satisfaction – by age and gender

	(1)	(2)	(3)
	Dependent variable: (Log) Life Satisfaction		
	Panel A: Female; Age: 18–30		
	Coefficient	*CI (95%)*	*p value*
1 void	-0.0011	-0.010 - 0.008	0.816
2 voids	-0.0306	-0.051 - -0.010	0.004**
3 + voids	-0.0511	-0.095 - -0.007	0.023*
	Panel B: Female; Age: 31–50		
1 void	-0.0036	-0.010 - 0.003	0.307
2 voids	-0.0190	-0.034 - -0.004	0.011*
3 + voids	-0.0410	-0.062 - -0.020	0.000**
	Panel C: Female; Age: 51+		
1 void	-0.0116	-0.027 - 0.003	0.126
2 voids	-0.0275	-0.056 - 0.001	0.062
3 + voids	-0.0554	-0.088 - -0.022	0.001**
	Panel D: Male; Age: 18–30		
1 void	0.0106	-0.001 - 0.023	0.083
2 voids	-0.0395	-0.077 - -0.002	0.041*
3 + voids	-0.0353	-0.099 - 0.028	0.273
	Panel E: Male; Age: 31–50		
1 void	-0.0069	-0.015 - 0.001	0.083
2 voids	-0.0255	-0.044 - -0.007	0.006**
3 + voids	-0.0428	-0.071 - -0.014	0.003**
	Panel F: Male; Age: 51+		
1 void	-0.0144	-0.027 - -0.002	0.020*
2 voids	-0.0296	-0.049 - -0.010	0.003**
3 + voids	-0.0401	-0.074 - -0.006	0.021*

*Notes: based on multivariate OLS regression models (separately for six age-gender sub-samples) with log-transformed life satisfaction (range 1 to 11), with higher values showing a higher satisfaction with life) score as dependent variable and nocturia symptom-severity indicator variables as covariates (zero voids as reference group). Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). The coefficients are adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol, sleep quality and sleeping less than 6 hours. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table B.3: Associations between nocturia and work engagement – full sample

	(1)	(2)	(3)
	Dependent variable: (Log) Engagement score		
	Full Sample		
	Coefficient	*CI (95%)*	*p value*
2 + voids	-0.0128	-0.021 - -0.005	0.001**
Financial concerns	-0.0770	-0.088 - -0.066	0.000**
BMI: underweight	-0.0176	-0.029 - -0.006	0.003**
BMI: overweight	0.0028	-0.002 - 0.007	0.228
BMI: obese	0.0066	-0.000 - 0.013	0.054
Excessive alcohol consumption	-0.0173	-0.023 - -0.011	0.000**
Physical inactivity	-0.0214	-0.027 - -0.016	0.000**
Excessive salt intake	-0.0047	-0.013 - 0.003	0.249
Current smoker	0.0304	0.022 - 0.039	0.000**
Psychological distress	-0.2363	-0.255 - -0.218	0.000**
Asthma	0.0007	-0.010 - 0.011	0.887
Cardiovascular disease	-0.0254	-0.051 - 0.000	0.052
Kidney disease	-0.0136	-0.047 - 0.020	0.423
Cancer	-0.0182	-0.049 - 0.013	0.249
Diabetes	-0.0050	-0.025 - 0.015	0.616
Hypertension	-0.0189	-0.030 - -0.007	0.001**
Severe mental illness	-0.0554	-0.073 - -0.038	0.000**
High blood pressure	-0.0016	-0.007 - 0.004	0.563
High cholesterol	-0.0119	-0.024 - 0.000	0.055
High glucose	0.0061	-0.012 - 0.024	0.508
Sleep quality (low)	-0.0836	-0.092 - -0.076	0.000**
Sleep duration (less than 6 hours)	-0.0162	-0.023 - -0.009	0.000**
Observations	**91,685**		

*Notes: entries represent OLS regression coefficients with corresponding 95% confidence interval (standard errors clustered at company level) and p-value (** p<0.01, * p<0.05). In addition to the covariates presented in the table, the regression coefficients are also adjusted for age, education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours. Analysis based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table B.4: Nocturia symptom-severity and work engagement – by age and gender

	(1)	(2)	(3)
	Dependent variable: (Log) Engagement Score		
	A: Sample: Female; Age: 18–30		
	Coefficient	*CI (95%)*	*p value*
1 void	0.0018	-0.009 - 0.013	0.739
2 voids	-0.0152	-0.042 - 0.012	0.268
3 + voids	-0.0336	-0.086 - 0.019	0.207
	B: Sample: Female; Age: 31–50		
1 void	-0.0050	-0.013 - 0.003	0.198
2 voids	-0.0032	-0.018 - 0.011	0.667
3 + voids	-0.0340	-0.056 - -0.012	0.003**
	C: Sample: Female; Age: 51+		
1 void	-0.0039	-0.018 - 0.010	0.579
2 voids	-0.0279	-0.055 - -0.001	0.043*
3 + voids	-0.0461	-0.095 - 0.003	0.065
	D: Sample: Male; Age: 18–30		
1 void	0.0059	-0.013 - 0.024	0.534
2 voids	0.0178	-0.018 - 0.054	0.332
3 + voids	-0.0567	-0.134 - 0.021	0.152
	E: Sample: Male; Age: 31–50		
1 void	-0.0117	-0.021 - -0.003	0.011*
2 voids	-0.0158	-0.036 - 0.004	0.118
3 + voids	-0.0594	-0.093 - -0.026	0.001**
	F: Sample: Male; Age: 51+		
1 void	-0.0153	-0.029 - -0.002	0.026*
2 voids	-0.0309	-0.064 - 0.003	0.070
3 + voids	-0.0465	-0.096 - 0.003	0.065

*Notes: based on multivariate OLS regression models (separately for six age-gender sub-samples) with log-transformed work engagement score (range 1 to 55), with higher values showing a higher engagement) as dependent variable and nocturia symptom-severity indicator variables as covariates (zero voids as reference group). Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). The coefficients are adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol, sleep quality and sleeping less than 6 hours. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table B.5: Associations between nocturia and work impairment – full sample

	(1)	(2)	(3)
	Dependent variable: % Work Impairment		
	Full Sample		
	Coefficient	***CI (95%)***	***p value***
2 + voids	0.0303	0.025 - 0.036	0.000**
Financial concerns	0.0564	0.051 - 0.062	0.000**
BMI: underweight	0.0111	0.003 - 0.020	0.011*
BMI: overweight	0.0031	-0.000 - 0.006	0.056
BMI: obese	0.0125	0.008 - 0.017	0.000**
Excessive alcohol consumption	0.0001	-0.003 - 0.003	0.969
Physical inactivity	0.0254	0.022 - 0.029	0.000**
Excessive salt intake	0.0119	0.006 - 0.018	0.000**
Current smoker	0.0010	-0.004 - 0.006	0.688
Psychological distress	0.1733	0.166 - 0.181	0.000**
Asthma	0.0302	0.024 - 0.037	0.000**
Cardiovascular disease	0.0513	0.037 - 0.065	0.000**
Kidney disease	0.0256	0.006 - 0.045	0.010**
Cancer	0.0876	0.062 - 0.113	0.000**
Diabetes	0.0065	-0.005 - 0.018	0.270
Hypertension	0.0249	0.018 - 0.031	0.000**
Severe mental illness	0.1235	0.113 - 0.134	0.000**
High blood pressure	0.0114	0.007 - 0.015	0.000**
High cholesterol	0.0157	0.008 - 0.024	0.000**
High glucose	0.0310	0.017 - 0.045	0.000**
Sleep quality (low)	0.0746	0.070 - 0.079	0.000**
Sleep duration (less than 6 hours)	0.0191	0.015 - 0.024	0.000**
Observations	**91,685**		

Notes: *entries represent OLS regression coefficients with corresponding 95% confidence interval (standard errors clustered at company level) and p-value (** p<0.01, * p<0.05). In addition to the covariates presented in the table, the regression coefficients are also adjusted for age, education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours. Analysis based on pooled BHW and AIA samples for the years 2017 and 2018.*

Table B.6: Nocturia symptom-severity and work impairment – by age and gender

	(1)	(2)	(3)
	Dependent variable: Per cent Work Impairment due to Absenteeism and Presenteeism		
	A: Sample: Female; Age: 18–30		
	Coefficient	*CI (95%)*	*p value*
1 void	0.0271	0.019 - 0.035	0.000**
2 voids	0.0597	0.041 - 0.078	0.000**
3 + voids	0.0730	0.044 - 0.102	0.000**
	B: Sample: Female; Age: 31–50		
1 void	0.0257	0.020 - 0.031	0.000**
2 voids	0.0430	0.033 - 0.054	0.000**
3 + voids	0.0775	0.060 - 0.095	0.000**
	C: Sample: Female; Age: 51+		
1 void	0.0220	0.011 - 0.033	0.000**
2 voids	0.0351	0.017 - 0.053	0.000**
3 + voids	0.0705	0.041 - 0.100	0.000**
	D: Sample: Male; Age: 18–30		
1 void	0.0189	0.010 - 0.028	0.000**
2 voids	0.0492	0.024 - 0.074	0.000**
3 + voids	0.0417	0.006 - 0.077	0.021*
	E: Sample: Male; Age: 31–50		
1 void	0.0248	0.019 - 0.031	0.000**
2 voids	0.0445	0.031 - 0.059	0.000**
3 + voids	0.0562	0.034 - 0.078	0.000**
	F: Sample: Male; Age: 51+		
1 void	0.0156	0.007 - 0.024	0.000**
2 voids	0.0230	0.010 - 0.036	0.000**
3 + voids	0.0609	0.038 - 0.084	0.000**

*Notes: based on multivariate OLS regression models (separately for six age-gender sub-samples) with per cent work impairment due to absenteeism and presenteeism as dependent variable and nocturia symptom-severity indicator variables as covariates (zero voids as reference group). Entries represent regression coefficients with corresponding 95% confidence interval and p-value (** p<0.01, * p<0.05). The coefficients are adjusted for other covariates including education, main job, income, marital status, ethnicity and region (UK, Australia, Asia), as well as irregular working hours; BMI: underweight, overweight, obese; excessive alcohol consumption; physical inactivity; excessive salt intake; smoking; psychological distress; financial concerns; clinically diagnosed and chronic: asthma, cardiovascular disease, kidney disease, cancer, diabetes, hypertension, severe mental illness; non-clinically diagnosed or chronic: high blood pressure, high glucose, high cholesterol, sleep quality and sleeping less than 6 hours. Based on pooled BHW and AIA samples for the years 2017 and 2018.*

Appendix C: The BHW and AIA surveys

The empirical analysis in this study is based on data acquired from the 'Britain's Healthiest Workplace' (BHW) competition, established in the UK by health insurer Vitality Health, and in Malaysia, Singapore, Hong Kong, Thailand, Sri Lanka, and Australia by pan-Asian life insurance group AIA. The country-specific competitions were established in order to find outstanding organisations who demonstrate best practice and innovative approaches to workplace health and wellbeing. For instance, the BHW competition represents one of the largest UK national studies, giving employers valuable insights into the wellbeing of their employees. In each country-specific competition, all companies are eligible and are invited to participate. After registering, all participating companies return a corporate health assessment, including general company characteristics (such as the size of the organization and the industry it operates in), as well as information on the organisation's approach to health promotion and wellbeing interventions. Subsequently, employees are invited to respond to an employee health-assessment survey that collects information on lifestyle, behavioural and clinical risk factors (including weight, diet, exercise, smoking, alcohol intake, stress, cholesterol, blood-glucose levels and blood pressure), as well as how often people attend health screenings to monitor and understand their health. It also includes self-reported measures on sleep and how many times an individual wakes at night to visit the bathroom.

The data collected from the BHW and AIA surveys represent a unique research resource, as collecting data from employers and employees generally allows both organisational and individual dimensions to be explored, or at least adjusted for. The scope of the survey across a variety of countries, covering a wide range of health, wellbeing and management indicators, is also unique.

It is, however, important to address limitations of the survey data regarding the representativeness of the data compared to the total population of employers and employees. Firstly, response rates to the surveys are variable, and for some participating companies are low – although, having said that, response rates on their own are a poor indicator of bias in surveys (Groves and Peytcheva, 2008), and BHW and AIA response rates are typical for online surveys.[51] In addition, our survey-sensitivity analyses showed no evidence of a relationship between survey response rate and rankings of company wellbeing, which would be a marker of non-response bias if present. Secondly, comparing the profile of respondents with the profile of employees within participating companies,

51 Ipsos Mori. Weighting online surveys. Available at: https://www.ipsos.com/sites/default/files/publication/1970-01/Ipsos%20MediaCT%20_Weighting%20Online%20Surveys_062010.pdf. Note that for instance the response rate of the BHW survey is around 27 per cent.

we generally find a small over-representation of middle-income and middle-age employees (Hafner et al., 2015). However, all age, gender and income groups are represented across participating companies, and we adjust for age, gender, income and other potentially important factors in the regression analyses. Thirdly, there are also some differences between the samples of companies participating in the surveys (participation is voluntary) and all companies in a given country. We account for the sampling approach in the analysis by controlling for company fixed-effects, which should account for company factors related to selection into the survey (e.g. company size).

In conclusion, our analysis accounts for the survey sampling approach and the possible over-representation of certain groups. We have explored the nature and extent of possible biases in the surveys and acknowledge that these may limit attempts to fully generalize our findings to the full population of companies. Nevertheless, the representation of a broad range of workplaces in our sample suggests that findings are relevant for the population of employees within a specific country.

Appendix D: Description of the CGE model

The CGE model is a multi-regional model whereby each region has bilateral trade with all other regions, simultaneously. World prices are, therefore, determined globally by the model, and each country/region has an effect on all the other regions. Larger regions will have larger effects compared to smaller regions. This is different from the small-open economy (SOE) health models in which countries cannot affect world prices, but rather take them as given (e.g. Smith et al., 2005). In each country or region, firms produce a single good using a multi-level, differentiable, constant return to scale production function that combines factor inputs (i.e. capital and labour) with intermediate goods. The model uses a constant elasticity of transformation function to split production into domestic production and exports. Then, domestic production is combined with imports to form the final Armington good (Armington, 1969). The representative agent in each country/region is assumed to be rational with a locally, non-satiated preference and demand for final Armington goods. Thus, subject to disposable income, the representative agent in each country/region maximizes a continuous, multi-level utility function. First, we assume a Ramsey type utility function, which imposes a fixed share between savings and a consumption bundle (Ramsey, 1928). This is an appropriate function for a recursive dynamic model, because agents are assumed to be myopic and do not alter their consumption-savings behaviour in anticipation of future. Multi-level functions mean that they are a combination of different functions stacked together to form a more complex function. Breaking them into levels makes it simpler to analyse and describe. The Armington assumption allows for cross-hauling, thus allowing for product differentiation between import and exports of similar goods.

Second, subject to the net-savings disposable income, the representative agent maximizes a typical Cobb-Douglas utility function (Cobb and Douglas, 1928). As previously discussed, the government has no active role in the model because of our assumption that the government maintains its current methods (i.e. policies) towards providing the public good. Therefore, the public and private sectors are aggregated together, which simplifies the model, reduces the number of assumptions necessary and increases transparency.

Finally, a virtual investment firm 'builds' new capital stock for the next period by demanding some Armington final-inputs in fixed proportion. Capital is accumulated under the assumption of a competitive capital market. This means that the purchase price of one unit of new capital is equal to the rental earnings of that unit, plus the value of the remaining capital sold in the subsequent period (net of depreciation).