2013/48

Self-assessed health of elderly people in Brussels: does the built environment matter?

Claire Dujardin, Vincent Lorant
and Isabelle Thomas

DISCUSSION PAPER

Center for Operations Research
and Econometrics

Voie du Roman Pays, 34
B-1348 Louvain-la-Neuve
Belgium
http://www.uclouvain.be/core

CORE DISCUSSION PAPER
2013/48

Self-assessed health of elderly people in Brussels: does the built environment matter?

Claire DUJARDIN [1], Vincent LORANT [2] and Isabelle THOMAS [3]

August 2013

Abstract

The built environment plays a key role in the strategy of "Aging in Place". Here, we study the influence of the built environment on the health status of elderly people living in Brussels. Using census and geocoded data, we analysed if built environment factors were associated with poor self- assessed health status and functional limitations of elderly aged 65+. We concluded that the evidence of the built-environment hypothesis is weak and vulnerable to the composition of the neighborhood.

Keywords: built urban environment, subjective health, elderly, GIS-based measures, logistic regressions, Brussels.

JEL Classification: I10, I14, R23

---

[1] Université catholique de Louvain, CORE, B-1348 Louvain-la-Neuve, Belgium; Institut Wallon d'Evaluation, de Prospective et de Statistiques (IWEPS), B-5001 Namur, Belgium. E-mail: c.dujardin@iweps.be

[2] Université catholique de Louvain, Institute of Health and Society, B-1200 Brussels, Belgium.
E-mail: Vincent.lorant@uclouvain.be

[3] FSR-FNRS; Université catholique de Louvain, CORE, B-1348 Louvain-la-Neuve, Belgium.
E-mail: isabelle.thomas@uclouvain.be. This author is also member of ECORE, the association between CORE and ECARES.

These analyses were partially financed by the Belgian Federal Scientific Policy (INTERACT - SD/CL/07). At the time the statistical analyses were conducted, Claire DUJARDIN was FRS-FNRS postdoctoral researcher at CORE (Université catholique de Louvain, Belgium). Census data were provided by the National Institute of Statistics of Belgium. We are grateful to Jonathan JONES and Grégory VANDENBULCKE-PLASSCHAERT for their helpful assistance in handling land registry and street network data. We also gratefully thank Annabelle AUBERT for very preliminary analyses of the census database in the context of her master thesis.

1. Introduction

Given that 8% of the OECD population is expected to be aged 80 and more in 2040, most of health, social and housing resources are increasingly considering a "healthy aging" perspective. The control of health care expenditures, the shift towards community care, the promotion of healthy behaviors, and the increasing number of elderly willing to live at home have fostered the "*aging in place*" strategy (OECD, 2005). In this context, a growing body of literature has focused on the role of the environment on elderly health status. The association between area disadvantages (or affluence) and elderly health status has already been investigated in several studies demonstrating that elderly people living in less affluent areas have poorer health status (Bowling and Stafford, 2007; Burton, 2012; Lang et al., 2008; Wight et al., 2008). However, the underlying mechanism is not always clear and deprivation is only one possible component of the living environment that may contribute to elderly health status (Clarke and Nieuwenhuijsen, 2009). One possibility raised is that less affluent areas may benefit from less satisfactory built environment compared with more affluent areas (Frumkin, 2005).

Indeed, the last decade has seen a growing number of papers examining the role of the built environment on various health outcomes and health-related behaviors (in particular, physical activity and obesity) for various age groups. This issue is also particularly relevant for elder adults. Indeed, because of increasing functional and mental decline and the subsequent reduction in mobility and social contacts, elderlies are more vulnerable to barriers in their surrounding environment than other age groups (Clarke and Nieuwenshuijsen, 2009). Better street layouts, wide footways, local services facilities and welcoming green spaces are more likely to support an "aging in place" strategy (Burton, 2012).

There is a clear need for clarifying the role of the "built environment" on elderly health status (Cunningham and Michael, 2004), especially if public resources have to be allocated to improve their living environment. So far, previous studies focusing on old adults emphasized the role of the built environment on physical activity (Brown et al., 2008; Gomez et al., 2010; King et al., 2005; Li et al., 2005), obesity (Hess and Russel, 2012; Li et al., 2009), or disability (Clarke et al., 2008; Freedman et al., 2008), with some studies also addressing psychological wellbeing (Clark et al., 2007). Results unfortunately do not converge. In a review of 14 studies relating the built environment to physical activity, most effects where non-significant, at the exception of recreational facilities (Kerr et al., 2012). More recently, Clarke et al. (2008) suggests that the impact of the built environment may be more important for individuals with more severe limitations.

This paper aims at studying the influence of the built environment on the health status of elderly people living in Brussels (Belgium). The effect of the built environment on health has been investigated in Belgium by Van Dyck et al (2009, 2010) who focus on a sample of middle-aged adults in the city of Ghent. They showed higher residential density, land use mix, street connectivity are positively associated with physical activity. The present study is, to our knowledge, the first to focus on contextual effects on the health of older adults in Belgium. In particular, this paper investigates the role of built environment factors facilitating walkability and social activities as they are known to promote healthier aging. We used a huge database linking official census data coupled with a GIS (Geographic Information System) to investigate the role of the built environment on self-rated health and on functional limitations due to a long-term chronic illness through a set of logistic regressions.

2. Data and methods

2.1. Individual-level data

Data were drawn from the 2001 Belgian Census, which is a 100% sample i.e. all individuals residing officially in the country were included. The analysis is here restricted to members of private households (we exclude communities), aged 65 or more and residing in one of the 19 municipalities of the Brussels-Capital Region; our sample hence comprises 147,367 individuals. For the first (and also last) time in Belgium, the 2001 Census collected information on the perceived health status of individuals, including whether or not they suffer from functional limitations, as well as information on the perception of inhabitants about their local environment, in particular about the presence or quality of a number of amenities and infrastructures (Vanneste et al., 2007). These can be used to compute subjective indicators about the built environment (see next section).

Health status was measured by two variables widely used in population surveys: self-rated health and functional limitations (Deboosere et al., 2006; Lorant et al. 2008). Self-rated health was derived from the question ‘‘How is your health in general?” that proposed 5 options: very bad, bad, fair, good, and very good. We further classified answers in two groups: very bad, bad and fair in one category, good and very good in another. Functional limitation was captured by two questions reporting on long-term illness and the resulting limitations. Individuals reporting a long-term illness with ‘permanent’ limitation were classified as with “severe limitations”, whereas those reporting being limited ‘from time to time’, ‘not or rarely’, or not having a long-term limiting illness were classified as with “no or few limitations”. Individuals’ age, gender, education and nationality and households’ type were used as covariates, as these are all known to influence health and may also confound the relationship between the built environment and health.

2.2. Neighborhood characteristics

Neighborhood definition

This paper focuses on the Brussels Capital Region, which, like Flanders and Wallonia, forms one of the three institutional regions of Belgium. It consists of 19 municipalities and hosts about 1 million inhabitants on a 163 km² area. This area represents the core of the city which in fact sprawls into its Flemish and Walloon countryside (Dujardin et al. 2007; Thomas et al. 2013). It can be considered as fully urban. The smallest spatial unit for which residential locations are officially available is the statistical ward, a subdivision of the municipality defined according to social, economic and architectural similarities. Statistical wards host on average 1,434 inhabitants (222 individuals aged 65 or more) but the variability is quite important with some statistical wards having only a few inhabitants. Therefore, to prevent problems arising from extreme values in neighborhood characteristics, wards with less than 200 inhabitants were not considered, and as a consequence, all elderlies residing in these wards were removed from the analysis (respectively, 123 wards and 865 individuals aged 65+).

In the literature, neighborhood built environment has been measured either by perceived measures, such as rating of some environmental attributes by inhabitants, or by objective measures based on GIS data (Leslie et al., 2007). In this case, neighborhood built environment is often captured by density, design and diversity measurements, which are interpreted as an indicator of walkability (Yamada et al., 2012). Both types of measures are used in this paper.

Perceived built environment

A number of questions were asked in the 2001 Census on the perception of the local environment. Households' head were asked whether they considered their neighborhood as 'very well equipped', 'normally equipped' or 'poorly equipped' in a number of facilities (Vanneste et al., 2007). Some of these were particularly relevant in our analysis, notably sidewalks, green spaces and public transports. For each item, we used the percentage of households' heads unsatisfied about their neighborhood equipment.

GIS-based measures of the built environment

Objective indicators of the built environment were created through the integration of several digitized data sources in a Geographical Information System (GIS). These digitized data sources include: land registry data for 2009 (provided by the AGDP, Administration Générale de la Documentation Patrimoniale), street networks and green spaces (both from BRIC Brussels Urbis 2007-2008 database), land surface elevation information (from the EROS website[1]) as well as boundaries for statistical wards (provided by the National Institute of Statistics).

We here focus on characteristics of the built environment that favor walking and foster social contacts for the ageing population. These are here residential share, land use mix, net retail ratio, street connectivity, green spaces area, and slopes. The first four indicators are similar in spirit to the now standard indicators used in Leslie (2007) and Frank et al. (2004, 2005) except that we do not combine these into a single composite "walkability index", in an attempt to better distinguish the respective roles of land use mix and street networks characteristics. The area devoted to green spaces and slopes of the streets are also considered: green spaces encourage elderlies to walk as these are places where they can easily meet each other, and steeper slopes may discourage to walk (Borst et al., 2008). The definition of these indicators is given hereunder:

(i) *Residential share* is the share of the total surface of the statistical ward[2] devoted to residence. We expect that the higher the index, the more homogeneous the neighborhood, and the lower the walkability will be.

(ii) *Land use mix* stands for the degree of diversity of land use types in each neighborhood. It is measured trough an entropy index:

$$LUM_j = -\frac{\sum_k p_{jk} \ln(p_{jk})}{\ln(N)}$$

where j stands for the statistical ward, k is the category of land use, N is the total number of land use categories, and p_{jk} is the ratio of land occupied by category k to the total surface of the statistical ward. This index ranges from 0 (homogeneity: a single land use category is observed in the neighborhood) to 1 (indicating that the surface of the ward is evenly distributed among all land use categories). A classification of plots in 6 categories was used: residential, employment (offices and industries), retail, institutional (including public services, health and education), recreational (including sport facilities, culture, green spaces and worship), and others.

(iii) *Net retail ratio* is the ratio of the surface occupied by retail buildings to the total surface of the plots devoted to these activities. A value close to 1 stands for retail areas where little space is devoted to parking facilities; the lower the index, the more space is devoted to parking space, making shops more accessible by car and as a consequence reducing the walkability of the neighborhood (Leslie et al., 2007).

---

[1] Earth Resources Observation and Science Center (EROS), 2002. Shuttle Radar Topography Mission(SRTM) – Elevation Data Set (Belgium). http://eros.usgs.gov/

[2] We do not use the net residential density defined by Frank et al. (2005) as the ratio of the number of residential units to the land area devoted to residential land use because this indicator exhibits extreme values in the case of neighborhoods characterized by high-rise buildings. Indeed, we believe that in the case of Brussels, this was more an indicator of deprivation than an indicator of walkability.

(iv) *Street connectivity* is defined as the density of crossroads per area unit (ha), where crossroads are defined as ‘true intersections’ on the street networks i.e. intersections of 3 or more segments at one node. The higher the index, the shorter the trip distances, and so the higher the walkability.

Note that for these four indicators, data were smoothed before-hand, in order to take into account the fact that, in the case of very small statistical wards, an individual’s neighborhood may be larger than its own statistical ward. For smoothing, we considered statistical wards located at a maximum distance of 250 meters (distances are measured between the centroids of statistical wards). Taking the land use mix index as example, this means that the proportion of land in a category k (p_{jk}) is equal to the sum of the surfaces of the plots of category k located in the statistical ward j as well as of the statistical wards whose centroids are located within a 250m radius, divided by the total surface of the statistical wards considered.

(v) The *availability of green spaces* is defined as the sum of the area of all polygons of green spaces located within a 500m radius of the center of the statistical ward.

(vi) *Slopes* are computed along the street network, by combining land surface elevation data with the digitized street network. The mean slope of all streets located in the statistical ward is then calculated.

These six indicators were categorized using quintiles to capture possible non-linear associations.

Neighborhood socio-economic status

Socio-economic composition of the neighborhood can influence health status through social contacts and the effect of deprivation for example. The mean income of the neighborhood is here used for controlling SES (provided by the National Institute of Statistics for 2001).

2.3. Statistical modeling

We estimate logistic regressions of poor health and functional limitations successively, using as regressors the characteristics of the built environment in the neighborhood, as well as a set of individual covariates. Our model can be summarized as such:

$$Log(\frac{P_{ij}}{1-P_{ij}}) = \alpha + \beta Ind_i + \gamma Built_j + \lambda SES_j$$

where P_{ij} is the probability that individual i residing in statistical ward j reports poor health (or functional limitations), Ind_i is a vector of individual characteristics, $Built_j$ is the characteristic of the built environment in neighborhood j, and SES_j stand for the socioeconomic status of the neighborhood (measured by the mean income of the statistical ward). Parameters were estimated using Maximum

Likelihood Estimation. Huber adjusted standard errors were used to correct for within statistical wards clustering (Wooldridge, 2003).

Due to important correlations between some of the variables characterizing the built environment, we use only one at a time in the logistic regression. For each of them, we estimate a set of four models. We begin with a model using only the considered indicator of the built environment as explanatory variables, but no individual controls (except age), nor control for the neighborhood socioeconomic status (the 'age-only' model). Then, we add the full set of individual controls (age, gender, education, nationality, living alone) and the socio-economic status of the neighborhood (mean income) in the 2nd and 3rd specifications respectively.

3. Results

3.1. Descriptive statistics

Descriptive statistics of the studied population and that of neighborhood characteristics included in the analysis are reported in Table 1 and 2 respectively. 147,367 individuals aged 65+ are considered in the 601 statistical wards with more than 200 inhabitants. Information on self-assessed health was missing in 8.2% of the cases, and an additional 9.2 % did not answer the questions about long-term limitations (table 1). Limiting the analysis to non-missing data, we end up with 17.2% of those aged 65 and more reporting being in poor health, and 20.7% suffering from long-term limitations. Mean age was 74.8 years (std=6.8). More than 60% were female, and 57% were living alone. Nearly 90% were of Belgian nationality. Low levels of education were more common, with more than the half of the sample having at most a lower-secondary school degree.

Neighborhood characteristics are provided for the 601 neighborhoods having more than 200 inhabitants (table 2). Regarding subjective characteristics, dissatisfaction with sidewalks and with green space were quite common; on average, about 25% of the population of the neighborhood report not being satisfied regarding these features; variation is quite large for these two features (std: 11.5 and 21.8, respectively). As expected in a large and dense city such as Brussels, dissatisfaction with regard to public transport was less common and showed smaller variation (mean: 9.8; std: 7.3). Regarding objectively measured characteristics (GIS-based data), important variations were also observed.

Table 3 provides the distribution of elderly aged 85+ versus those aged 65-84 according the each built environment quintile and, thus, helps to identify possible selection effects. Broadly there was no evidence of a strong and linear selection effect of the eldest elderly living in systematically better or poorer living environment. However, they are more likely to live in neighborhoods with a lower level of dissatisfaction with public transport and with steeper slopes. These are the sole significant associations shown in Table 3. Yet, this table provides also an interesting picture of where the eldest adults live compared to younger ones. Overall this picture suggests that the "*oldest olds*" are rather evenly distributed according to the built environment features within the Brussels Capital Region. Being 85 or more and living at home does not depend on the characteristics of the neighborhood of residence.

Table 1. Sample descriptive statistics

Dependent variables	Mean or %	Std
Poor self-rated health (*N*=135,318)		
Yes	17.2	
No	82.8	
Long term limitations (*N*=121,708)		
Yes	20.7	
No	79.3	
Covariates (*N*=135,318)[1]	Mean or %	Std
Age	74.8	6.84
Gender		
Male	38.9	
Female	61.1	
Household type		
Living alone	43.1	
Other	56.9	
Nationality		
Belgian	88.3	
South-European	3.1	
Other European	4.9	
North-African or Turk	2.7	
Other nationality	1.1	
Education		
Primary	31.2	
Lower secondary	23.5	
Upper secondary	16.1	
Post-secondary	16.8	
Missing	12.4	

1 Descriptive statistics for covariates are reported for those with non missing values for the health status variable.

Table 2. Descriptive statistics for neighborhood characteristics

Neighborhood characteristics (*N*=601)	Mean	Std	Min	Max
Dissatisfaction with sidewalks (%)	23.3	11.5	2.2	79.5
Dissatisfaction with public transport (%)	8.9	7.3	0.0	61.5
Dissatisfaction with green space (%)	24.2	21.8	0.0	82.5
Residential share (% of the neighborhood area)	41.9	15.6	0.9	84.3
Land use mix (from 0 to 1)	0.54	0.13	0.12	0.85
Net retail ratio (from 0 to 1)	0.68	0.21	0.0	1.0
Street connectivity (intersections / ha)	6.6	3.7	0.0	21.8
Green space area (ha)	7.12	7.24	0.00	47.47
Slope (degrees)	2.8	1.2	0.9	9.0

Table 3. Where do the oldest inhabitants live? Elderly aged 85 + versus aged 65-84, according to the built environment, odds ratio from logistic regressions

		% dissatisf. sidewalks	% dissatisf. public transport	% dissatisf. green spaces	Residential share	Land use mix	Net retail ratio	Street connectivity	Green space area	Slope
Continuous		1.000 (0.002)	0.993** (0.003)	0.999 (0.001)						
Quintiles (ref Q1)	Q2				0.862 (0.079)	0.959 (0.044)	1.002 (0.051)	1.079 (0.063)	1.0030 (0.065)	1.288*** (0.070)
	Q3				1.020 (0.099)	0.942 (0.046)	1.033 (0.049)	0.994 (0.053)	0.9887 (0.063)	1.226*** (0.068)
	Q4				0.988 (0.090)	0.951 (0.049)	0.996 (0.050)	1.032 (0.061)	0.9927 (0.057)	1.239*** (0.064)
	Q5				1.082 (0.100)	0.935 (0.076)	1.012 (0.089)	1.087 (0.075)	1.0209 (0.059)	1.114** (0.053)

Figures in parenthesis are standard errors corrected for within statistical ward dependencies. ***, **, * denote significance at the 1%, 5% and 10% respectively.

3.2. Effect of neighborhood characteristics on health

Table 4 models the risk of poor self-rated health and Table 5 long-term limitations according to the characteristics of the built environment. Only one built environment indicator is used at a time. Continuous measures are used for perceived built environment characteristics (i.e. percentage of households not satisfied with each particular aspect), while quintiles are used for GIS-based measures. Model 1 controls only for age, in addition of the considered built environment indicator, while model 2 includes additional individual risk factors of poor health (gender, nationality, education, living alone). The neighborhood median income enters in model 3 to capture residual confounding.

Overall, we found expected statistical associations for only a small subset of indicators of the built environment. Regarding subjective factors, the risk of poor subjective health increased monotonically with the percentage of households not satisfied with green space and with the percentage not satisfied with sidewalks (Model 1 - Table 4). Most objective built environment variables had an association with subjective health opposite to expectations: poor subjective health decreased with steeper slopes, and with higher residential share; it increased with heterogeneity in the land use mix and with net retail ratio. There is one exception: larger green spaces reduce the risk of reporting poor health (quintiles 4 and 5, OR=0.86 and 0.85 respectively). For street connectivity, estimates in Model 1 show that high densities of crossroads are associated with poor subjective health (quintile 5, OR=1.33).

Yet, area neighborhood's built environment is also associated with different population groups which might confound our results. Model 2 controls for the whole set of individual socio-demographic features while Model 3 adds the median area income. Most odds ratios were affected and became closer to 1.0, suggesting the composition of neighborhood population confounds the relationship between built environment and health status. After controlling for individual features and neighborhood median income, most built environment variables were non significantly related to poor self-rated health, or, when significant, showed associations opposite to expectations. Regarding more particularly those variables that showed significant associations in the expected direction in the naïve model (i.e. dissatisfaction with sidewalks and green spaces and green space area), they all lose their significance when introducing neighborhood median income (in Model 3).

Table 4: Risk of poor self-rated health according to the built environment among elderly aged 65+, odds ratios from logistic regressions

		Model 1		Model 2		Model 3	
Age		Yes		Yes		Yes	
Individual controls[1]		No		Yes		Yes	
Neighborhood median income		No		No		Yes	
Perceived neighborhood characteristics							
% dissatisf. sidewalks		1.007***	(0.002)	1.004***	(0.001)	1.001	(0.001)
% dissatisf. public transport		0.994*	(0.003)	0.997	(0.002)	0.999	(0.002)
% dissatisf. green spaces		1.011***	(0.001)	1.006***	(0.001)	1.001	(0.001)
GIS-based measures							
Residential share	Q2	0.785***	(0.046)	0.831***	(0.037)	0.890***	(0.033)
	Q3	0.730***	(0.043)	0.808***	(0.037)	0.891***	(0.032)
	Q4	0.653***	(0.037)	0.764***	(0.034)	0.882***	(0.032)
	Q5	0.531***	(0.030)	0.669***	(0.030)	0.837***	(0.031)
Land use mix	Q2	1.126**	(0.057)	1.079**	(0.040)	1.006	(0.028)
	Q3	1.275***	(0.065)	1.158***	(0.044)	1.034	(0.030)
	Q4	1.275***	(0.066)	1.146***	(0.044)	1.028	(0.033)
	Q5	1.465***	(0.082)	1.229***	(0.049)	1.020	(0.032)
Net retail ratio	Q2	1.095*	(0.056)	1.047	(0.039)	1.017	(0.034)
	Q3	1.168***	(0.059)	1.092**	(0.041)	1.028	(0.032)
	Q4	1.401***	(0.072)	1.203***	(0.046)	1.050	(0.036)
	Q5	1.837***	(0.106)	1.422***	(0.066)	1.126***	(0.051)
Street connectivity	Q2	0.982	(0.068)	0.961	(0.048)	0.961	(0.034)
	Q3	1.039	(0.070)	0.976	(0.049)	0.946	(0.034)
	Q4	1.047	(0.071)	0.984	(0.049)	0.95	(0.033)
	Q5	1.330***	(0.098)	1.125***	(0.062)	0.977	(0.041)
Green space area	Q2	0.954	(0.061)	0.985	(0.041)	1.007	(0.033)
	Q3	0.973	(0.060)	0.996	(0.041)	1.035	(0.032)
	Q4	0.858**	(0.051)	0.924*	(0.037)	1.025	(0.034)
	Q5	0.853**	(0.054)	0.931	(0.041)	1.028	(0.034)
Slope	Q2	0.844***	(0.042)	0.930**	(0.032)	1.007	(0.028)
	Q3	0.796***	(0.041)	0.894***	(0.032)	1.003	(0.032)
	Q4	0.773***	(0.041)	0.884***	(0.034)	0.993	(0.033)
	Q5	0.757***	(0.044)	0.871***	(0.036)	0.979	(0.033)

[1] Individual controls are age, gender, education, nationality, living alone. Figures in parenthesis are standard errors corrected for within statistical ward dependencies. ***, **, * denote significance at the 1%, 5% and 10% respectively.

Table 5 provides the results for severe long-term limitation; they are consistent with self-rated health. In Model 1, the probability to report long-term limitations was higher in areas with more heterogeneous land use mix (quintile 5, OR=1.32) and with higher net retail ratio (quintile 5, OR=1.52). It decreased with higher proportion of the area devoted to residential activity (quintile 5, OR= 0.63), and with a higher mean slope of the streets (quintile 5, OR= 0.84). Consistently with Table 4, more dissatisfaction with green spaces and sidewalks and fewer areas of green spaces were associated with higher risks of reporting long-term limitations. However, these odds ratios become not significantly different from 1.0 when individual controls and neighborhood median income are added in Models 2 and 3, suggesting that the neighborhood composition partly confounds the effects of the built environment.

Table 5: Risk of functional limitations according to the built environment among elderly aged 65+, odds ratios from logistic regressions

		Model 1		Model 2		Model 3	
Age		Yes		Yes		Yes	
Individual controls[1]		No		Yes		Yes	
Neighborhood median income		No		No		Yes	
Perceived neighborhood characteristics							
% dissatisf. sidewalks		1.004***	(0.001)	1.003***	(0.001)	1.001	(0.001)
% dissatisf. public transport		0.997	(0.002)	0.999	(0.002)	1.001	(0.001)
% dissatisf. green spaces		1.007***	(0.001)	1.005***	(0.001)	1.001	(0.001)
GIS-based measures							
Residential share	Q2	0.817***	(0.049)	0.843***	(0.046)	0.889**	(0.045)
	Q3	0.774***	(0.045)	0.817***	(0.043)	0.880***	(0.043)
	Q4	0.712***	(0.040)	0.774***	(0.040)	0.863***	(0.042)
	Q5	0.628***	(0.036)	0.717***	(0.038)	0.851***	(0.043)
Land use mix	Q2	1.070*	(0.042)	1.045	(0.033)	0.991	(0.027)
	Q3	1.182***	(0.048)	1.118***	(0.037)	1.027	(0.028)
	Q4	1.163***	(0.055)	1.100**	(0.044)	1.014	(0.362)
	Q5	1.319***	(0.060)	1.205***	(0.046)	1.046	(0.034)
Net retail ratio	Q2	1.023	(0.039)	0.994	(0.031)	0.971	(0.029)
	Q3	1.055	(0.040)	1.010	(0.031)	0.962	(0.027)
	Q4	1.209***	(0.046)	1.109***	(0.034)	1.000	(0.030)
	Q5	1.517***	(0.082)	1.333***	(0.066)	1.115**	(0.058)
Street connectivity	Q2	0.966	(0.052)	0.951	(0.040)	0.948*	(0.028)
	Q3	0.994	(0.050)	0.954	(0.038)	0.928***	(0.026)
	Q4	1.015	(0.052)	0.979	(0.039)	0.954*	(0.027)
	Q5	1.194***	(0.074)	1.094*	(0.056)	0.979	(0.042)
Green space area	Q2	1.010	(0.054)	1.009	(0.044)	1.022	(0.040)
	Q3	1.029	(0.052)	1.018	(0.042)	1.046	(0.037)
	Q4	0.965	(0.048)	0.981	(0.039)	1.060*	(0.037)
	Q5	0.934	(0.051)	0.954	(0.043)	1.028	(0.040)
Slope	Q2	0.905**	(0.038)	0.955	(0.033)	1.013	(0.031)
	Q3	0.842***	(0.035)	0.904***	(0.030)	0.989	(0.028)
	Q4	0.837***	(0.036)	0.904***	(0.032)	0.987	(0.030)
	Q5	0.841***	(0.038)	0.914**	(0.033)	1.003	(0.030)

[1] Individual controls are age, gender, education, nationality, living alone. Figures in parenthesis are standard errors corrected for within statistical ward dependencies. ***, **, * denote significance at the 1%, 5% and 10% respectively.

4. Discussion

Main findings

This paper investigates the role of the built environment on self-rated health and on functional limitations due to a long-term chronic illness by means of logistic regressions with subjective and objective explanatory variables. Overall, mixed and unexpected effects dominate our conclusions. Subjective indicators of the built environment were consistent with expectations: higher dissatisfaction with green spaces or with sidewalks were associated with higher risk of poor health and with higher risk of functional limitations. However, such results were not confirmed by objective measures of the built environment, for which most significant associations do not fit with the literature. Steeper streets and higher proportion of land devoted to residential land use were for instance associated with better health, although these factors are expected to reduce walkability and thus to reduce health status. Similarly, high land use mix and large net retail ratio were associated with poor health, although these built environment features are known to promote walkability, and are thus expected to reduce the risk of poor health status. Available green space area was an exception, as it was significantly associated with good health status in the naïve model (but was not associated with functional limitations). Finally, we found that the effect of the built environment is vulnerable to the socio-economic composition of the neighborhood: the more we control for the composition of the neighborhood (through socio-economic covariates at the individual level and through the median income at the neighborhood level), the lower the effect of the built environment on health. In models with a full set of controls, none of the built environment indicators showed significant association in the expected direction. Our results thus suggest that the composition of neighborhood population confounds the relationship between built environment and health status.

Limitations

This study has some limitations, as in many other observational studies addressing contextual effects. First, we had no information about the residence duration. Our analysis pools together individuals with different duration and intensity of "exposure to the built environment", leading to a possible under-/over-estimation of the true effect of the built environment. To assess such bias, we further restricted the analysis to homeowners only (59%), that are more likely long-term residents in their neighborhood and thus to receive the full "exposure" of the built environment. Overall, estimates were very slightly affected and in most cases they became slightly closer to 1.0 (results available upon request). Because – on average – homeowners are better off than tenants, such results reinforce our findings that the effects of the built environment depend on socio-economic factors.

A second and related limitation is that our results potentially suffer from a selection bias. Indeed, if a neighborhood is particularly unfavourable to elderlies, those who suffer from health problems (or from functional limitations) are more likely to quit these places and to move to more favourable environments (for example neighborhoods with higher land use mix, fostering walking) or even to communities such as nursing homes. These can lead to an overrepresentation of individuals with better health in less favourable environments (i.e. only those who are in better health are able to stay in these "unfavourable neighborhoods"). Without longitudinal data, we are unable to evaluate this bias. However, Table 3 discarded somewhat such risk as the oldest old (i.e. 85+, and hence those that are more likely to have moved away in case of unfavourable environment) were rather evenly distributed according to the built environment compared to those aged 65-84; we hence also speculate that the elderly accommodate themselves to their living environment.

Thirdly, data availability largely constrains the results. In Belgium, because of privacy issues, census data are only made available at the municipality level and exceptionally /upon request at the statistical ward level (as in the present case). This hence leads to strong conceptual and methodological issues: it implies that the neighborhood which matter for the elderly is at least as large as the statistical ward, which is supposed to be homogeneous. Our result showed that everything being equal, living at home and in good health while aging has nothing to do with the built environment *measured at the scale of the statistical ward*. However, statistical wards are likely to be too coarse, and space could matter at a more local scale, that we are unable to grasp. In addition, the boundaries of wards were defined 40 years ago on the basis of contiguity and homogeneity criteria and they may not fit anymore todays' living urban contexts. Moreover, wards vary in shape and size; small wards often correspond to high population densities with smaller distances, but larger wards might exhibit some intra-ward heterogeneity. As in many observational studies, our choice of a scale of analysis was thus constrained by data availability rather than theoretical motivations. This kind of problem is well known in spatial analysis (Openshaw, 1984) and the question is open in health studies (see e.g., Brownson et al., 2009, Weiss et al., 2007, or Yamada et al., 2012). Built environment would gain to be measured for a buffer around the precise address of residence of the old adult. This is only possible through surveys. However, the counterpart of a survey is that it is rarely spatially representative unless a very large budget (time and money) is devoted for it. The best would be combining meso- and micro-scale analyses in order to consider multiple nested scales (also suggested by Yamada et al., 2012 for obesity or Carlson et al., 2012 for public health).

Fourth, our result suggested that the effect of the built environment is vulnerable to the socio-economic composition of neighborhoods. It is worth mentioning that in the Brussels Capital Region, the characteristics of the built environment largely co-vary with the socioeconomic status. For example, central neighborhoods with a high degree of diversity of land use categories are also very close to the most deprived neighborhoods (low incomes). In the contrary, peripheral neighborhoods are more well off but also more homogeneous in terms of land use (devoted essentially to residential land use). It is therefore difficult to disentangle the effect of the built environment from the effect of neighborhood socioeconomic deprivation.

Last but not least, the influence of the built environment hypothesis on health relies mostly on the walkability assumption: walking should more likely occur if sidewalk coverage, street intersections, green space for recreational activities, traffic volume and public transportation are more supportive of walking activity (Frank et al., 2005; Leslie et al., 2005; Li et al., 2009; Owen et al., 2007). Because walking promotes physical activity, a protective factor for functional health and life expectancy, it is expected that a 'walkable' built environment reduces the risk of poor health. Yet, because our database does not count with physical activity, it is impossible to disentangle the different intermediary mechanisms linking the built environment to health status.

Consistency

Our study is consistent with previous studies on disability which were quite nuanced about the link between the built environment and walking. Clarke et al. (2008) find that street conditions in Chicago had no effect on outdoor mobility except for those with severe disability. Nagel et al. (2008) found, in a study of Oregon, that low traffic volume and more commercial facilities, but neither street connections neither sidewalk coverage, promote total walking time. Freedman et al. (2008) found that street connectivity had no effect on lower body function (walking, stooping, kneeling and crouching), or on daily activities (bathing, dressing, eating…), although it affected somewhat instrumental daily activities (managing money, using the phone, cooking, shopping).

Our work didn't look directly at economic deprivation or area socioeconomic advantage. Yet, the statistical analysis suggested that controlling for the area income affected the health risk attached to the built environment. Indeed, for some built environment characteristics, we found the expected sign but results became non-significant once we controlled for neighborhood composition. This was the case for dissatisfaction with green space and with sidewalks, as well as for green space area. For these variables the risk of poor health associated with the built environment were very much affected by controlling for the socioeconomic characteristics at the individual level and for the level of socioeconomic affluence in the neighborhood (measured by neighborhood median income). This suggests that, for elderly, dissatisfaction with the built environment or green space accessibility may affect health status through the composition of the neighborhood and through its effect on economic affluence. Similarly, the Health and Retirement study concluded that socioeconomic disadvantage, socioeconomic segregation and criminality remained predictor of cancer onset or heart problems once individual controlled were taken into consideration, meanwhile other built environment (street connectivity or population density) became no longer significant (Freedman et al., 2011).

5. Conclusion

This analysis was conducted in a very “classical” way, trying to understand spatial variations of health status of elderly in Brussels. We concluded that the neighborhood built environment has no significant impact on the health status and functional limitations of elderly people living in Brussels once the socioeconomic composition has been controlled for. However, this conclusion has to be somewhat nuanced. Indeed, the finest spatial level for which data was made available was the statistical ward, which may be too coarse for adequately capture neighborhoods that matter for individuals. Moreover, as suggested in Carlson et al. (2012), built environment and health may not directly correlate, but may be correlated through a series of indirect relationships and feedback loops. While here studying aggregated characteristics of the built environment, we only get one piece of the association, missing more complex spatial relationships. Indirect spatial effects and their complexities should be considered as well as the nested dependence with the microscale (very detailed distance to the closest shops or distance to transport infrastructure, presence of stairs and their ease of use, etc.). While considering the mesoscale independently of the microscale, we are at risk of misinterpreting the results and cannot avoid aggregation biases and ecological fallacies.

If we aim at creating local environments supportive of walking in Brussels for maintaining elderlies active and healthier at home, further analyses are needed to investigate what happens at a microscale. But therefore, a specifically dedicated survey should be conducted. This kind of survey however implies sampling and especially spatial sampling, which it not the case for census data: all individuals are taken into consideration hence making possible large spatial analyses. On the contrary, surveys are less spatially representative but would enable to better grasp complex spatial interactions and also local spatial effects (Loo and Lam, 2012). This kind of study would thus gain to combine both type of data, in a multiple nested scales framework.

References

Borst, H.C., Miedema, H.M.E., de Vries, S.I., Graham, J.M.A., van Dongen, J.E.F., 2008, Relationships between street characteristics and perceived attractiveness for walking reported by elderly people. *Journal of Environmental Psychology*, 28 (4), 353-361.

Bowling, A., Stafford, M., 2007, How do objective and subjective assessments of neighbourhood influence social and physical functioning in older age? Findings from a British survey of ageing. *Social Science & Medicine*, 64 (12), 2533-2549.

Brown, S.C., Mason, C.A., Perrino, T., Lombard, J.L., Martinez, F., Plater-Zyberk, E. et al., 2008, Built environment and physical functioning in Hispanic elders: The role of "Eyes on the Street". *Environmental Health Perspectives*, 116 (10), 1300-1307.

Brownson R., Hoehner C, Day K., Forsyth A., Sallis J., 2009, Measuring the built environment for physical activity: State of the science. *American Journal of Preventive Medicine* 36, 99-A23.

Burton, E., 2012, Streets ahead? The role of the built environment in healthy ageing. *Perspectives in Public Health*, 132 (4), 161-162.

Carlson C., Aytur S., Gardner K ., Orgers S., 2012, Complexity in built environment, health, and destination walking: a neighborhood-scale analysis. *Journal of Urban Health*, 89(2), 270-284.

Clark, C., Myron, R., Stannsfield, S., Candy, B., 2007, A systematic review of the evidence on the effect of the built and physical environment on mental health. *Journal of public mental health*, 6(2), 14-27.

Clarke, P., Ailshire, J.A., Bader, M., Morenoff, J.D., House, J.S., 2008, Mobility disability and the urban built environment. *American Journal of Epidemiology*, 168 (5), 506-513.

Clarke, P., Nieuwenhuijsen, E.R., 2009, Environments for healthy ageing: A critical review. *Maturitas*, 64 (1), 14-19.

Cunningham, G.O., Michael, Y.L., 2004, Concepts guiding the study of the impact of the built environment on physical activity for older adults: A review of the literature. *American Journal of Health Promotion*, 18 (6), 435-443.

Deboosere, P., Demarest, S., Lorant, V., Miermans, P.-J., Portet, M.-I., Van Oyen, H., 2006, *Santé et Soins informels*. Bruxelles, SPF-Economie, P.M.E., Classes moyennes et énergie.

Dujardin, C., Thomas, I., Tulkens, H., 2007, Quelles frontières pour Bruxelles ? Une mise à jour. *Reflets et Perspectives de la Vie Economique*, XLVI(2-3), 155-176.

Frank, L.D., Andresen, M.A., Schmid, T.L., 2004, Obesity relationships with community design, physical activity, and time spent in cars, *American Journal of Preventive Medecine*, 27 (2), 87-96.

Frank, L.D., Schmid, T. L., Sallis, J. F., Chapman, J., Saelens, B. E., 2005, Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. *American Journal of Preventive Medecine*, 28 (2 Suppl 2), 117-125.

Freedman, V.A., Grafova, I. B., Schoeni, R. F., Rogowski, J., 2008, Neighborhoods and disability in later life. *Social Science and Medicine*, 66 (11), 2253-2267.

Freedman, V.A., Grafova, I.B., Rogowski, J., 2011, Neighborhoods and chronic disease onset in later life. *American Journal of Public Health*, 101 (1), 79-86.

Frumkin, H., 2005, Health, equity, and the built environment. *Environmental Health Perspectives*, 113 (5), A290-A291.

Gomez, L., Parra, D. C., Buchner, D., Brownson, R.C., Sarmiento, O.L., Pinzon, J.D. et al, 2010, Built Environment Attributes and Walking Patterns Among the Elderly Population in Bogota. *American Journal of Preventive Medicine*, 38 (6), 592-599.

Hess, D.B., Russell, J. K., 2012, Influence of built environment and transportation access on body mass index of older adults: Survey results from Erie County, New York. *Transport Policy*, 20, 128-137.

Kerr, J., Rosenberg, D., Frank, L., 2012, The Role of the Built Environment in Healthy Aging: Community Design, Physical Activity, and Health among Older Adults. *Journal of Planning Literature*, 27 (1), 43-60.

King, W.C., Belle, S. H., Brach, J. S., Simkin-Silverman, L. R., Soska, T., Kriska, A. M., 2005, Objective measures of neighborhood environment and physical activity in older women. *American Journal of Preventive Medicine*, 28 (5), 461-469.

Lang, I.A., Llewellyn, D.J., Langa, K.M., Wallace, R.B., Melzer, D., 2008, Neighbourhood deprivation and incident mobility disability in older adults. *Age and Ageing*, 37 (4), 403-410.

Leslie, E., Coffee, N., Frank, L., Owen, N., Bauman, A., Hugo, G., 2007, Walkability of local communities: Using geographic information systems to objectively assess relevant environmental attributes, *Health & Place*, 13, 111-122.

Leslie, E., Saelens, B., Frank, L., Owen, N., Bauman, A., Coffee, N. et al, 2005, Residents' perceptions of walkability attributes in objectively different neighbourhoods: a pilot study. *Health Place*, 11 (3), 227-236.

Li, F., Fisher, K.J., Brownson, R.C., Bosworth, M., 2005, Multilevel modelling of built environment characteristics related to neighbourhood walking activity in older adults. *Journal of Epidemiology and Community Health*, 59 (7), 558-564.

Li, F., Harmer, P., Cardinal, B J., Bosworth, M., Johnson-Shelton, D., Moore, J.M. et al, 2009, Built environment and 1-year change in weight and waist circumference in middle-aged and older adults: Portland Neighborhood Environment and Health Study. *Am.J.Epidemiol.*, 169 (4), 401-408.

Loo, B., Lam, W., 2012, Geographic accessibility around health care facilities for elderly residents in Hong Kong: a microscale walkability assessment, *Environment and Planning B: Planning and Design* **39**(4), 629-646.

Lorant, V., Van Oyen, H., Thomas, I., 2008, Contextual factors and immigrants' health status: Double jeopardy. *Health & Place*, 14 (4), 678-692.

Nagel, C.L., Carlson, N. E., Bosworth, M., Michael, Y. L., 2008, The relation between neighborhood built environment and walking activity among older adults. *American Journal of Epidemiology*, 168 (4), 461-468.

OECD, 2005, *Long-Term Care for Older People*. OECD, Paris.

Openshaw, S., 1984, Ecological fallacies and the analysis of areal census data, *Environment and Planning A*, 16, 17-31.

Owen, N., Cerin, E., Leslie, E., duToit, L., Coffee, N., Frank, L. D. et al., 2007, Neighborhood walkability and the walking behavior of Australian adults. *American Journal of Preventive Medicine*, 33 (5), 387-395.

Thomas, I., Cotteels, C., Jones, J., Peeters, D., 2013, Revisiting the extension of the Brussels urban agglomeration: new methods, new data … new results? *E-Belgeo* (forthcoming)

Van Dyck, D., Cerin, E., Cardon, G., Deforche, B., Sallis, J. F., Owen, N. et al, 2010, Physical activity as a mediator of the associations between neighborhood walkability and adiposity in Belgian adults. *Health & Place*, 16 (5), 952-960.

Van Dyck, D., Delforche, B., Cardon, G., De Bourdeaudhuij, I., 2009, Neighbourhood walkability and its particular importance for adults with a preference for passive transport, *Health and Place*, 15 (2), 496-504.

Vanneste, D., Thomas, I., Goossens, L., 2007, *Le logement en Belgique*. Bruxelles, SPF-Economie, P.M.E., Classes moyennes et énergie.

Weiss, L., Ompad, D., Galea, S., Vlahov, D., 2007, Defining neighborhood boundaries for urban health research, *American Journal of Preventive Medicine*, 32(6S), 154-159.

Wight, R.G., Cummings, J.R., Miller-Martinez, D., Karlamangla, A.S., Seeman, T.E., Aneshensel, C. S., 2008, A multilevel analysis of urban neighborhood socioeconomic disadvantage and health in late life. *Social Science and Medicine*, 66 (4), 862-872.

Wooldridge, J., 2003. Cluster-sample methods in applied econometrics. *American Economic Review*, 93, 133–138.

Yamada I., Brown B., Smith K., Zick C, Kowaleski L., Fan J. (2012), Mixed Landuse and Obesity: an empirical comparison of alternative landuse measures and geographic scales, *The Professional Geographer*, 64:2, 157-177.

Recent titles

CORE Discussion Papers

2013/8 Per J. AGRELL and Peter BOGETOFT. Benchmarking and regulation.

2013/9 Jacques H. DREZE. When Borch's Theorem does not apply: some key implications of market incompleteness, with policy relevance today.

2013/10 Jacques H. DREZE. Existence and multiplicity of temporary equilibria under nominal price rigidities.

2013/11 Jean HINDRIKS, Susana PERALTA and Shlomo WEBER. Local taxation of global corporation: a simple solution.

2013/12 Pierre DEHEZ and Sophie POUKENS. The Shapley value as a guide to FRAND licensing agreements.

2013/13 Jacques H. DREZE and Alain DURRE. Fiscal integration and growth stimulation in Europe.

2013/14 Luc BAUWENS and Edoardo OTRANTO. Modeling the dependence of conditional correlations on volatility.

2013/15 Jens L. HOUGAARD, Juan D. MORENO-TERNERO and Lars P. OSTERDAL. Assigning agents to a line.

2013/16 Olivier DEVOLDER, François GLINEUR and Yu. NESTEROV. First-order methods with inexact oracle: the strongly convex case.

2013/17 Olivier DEVOLDER, François GLINEUR and Yu. NESTEROV. Intermediate gradient methods for smooth convex problems with inexact oracle.

2013/18 Diane PIERRET. The systemic risk of energy markets.

2013/19 Pascal MOSSAY and Pierre M. PICARD. Spatial segregation and urban structure.

2013/20 Philippe DE DONDER and Marie-Louise LEROUX. Behavioral biases and long term care insurance: a political economy approach.

2013/21 Dominik DORSCH, Hubertus Th. JONGEN, Jan.-J. RÜCKMANN and Vladimir SHIKHMAN. On implicit functions in nonsmooth analysis.

2013/22 Christian M. HAFNER and Oliver LINTON. An almost closed form estimator for the EGARCH model.

2013/23 Johanna M. GOERTZ and François MANIQUET. Large elections with multiple alternatives: a Condorcet Jury Theorem and inefficient equilibria.

2013/24 Axel GAUTIER and Jean-Christophe POUDOU. Reforming the postal universal service.

2013/25 Fabian Y.R.P. BOCART and Christian M. HAFNER. Fair re-valuation of wine as an investment.

2013/26 Yu. NESTEROV. Universal gradient methods for convex optimization problems.

2013/27 Gérard CORNUEJOLS, Laurence WOLSEY and Sercan YILDIZ. Sufficiency of cut-generating functions.

2013/28 Manuel FORSTER, Michel GRABISCH and Agnieszka RUSINOWSKA. Anonymous social influence.

2013/29 Kent WANG, Shin-Huei WANG and Zheyao PAN. Can federal reserve policy deviation explain response patterns of financial markets over time?

2013/30 Nguyen Thang DAO and Julio DAVILA. Can geography lock a society in stagnation?

2013/31 Ana MAULEON, Jose SEMPERE-MONERRIS and Vincent VANNETELBOSCH. Contractually stable alliances.

2013/32 Jean-François CAULIER, Ana MAULEON and Vincent VANNETELBOSCH. Allocation rules for coalitional network games.

2013/33 Georg KIRCHSTEIGER, Marco MANTOVANI, Ana MAULEON and Vincent VANNETELBOSCH. Limited farsightedness in network formation.

2013/34 Ana MAULEON and Vincent VANNETELBOSCH. Relative concerns and delays in bargaining with private information.

2013/35 Kristof BOSMANS, Koen DECANCQ and Erwin OOGHE. What do normative indices of multidimensional inequality really measure?

2013/36 Alain PHOLO BALA, Dominique PEETERS and Isabelle THOMAS. Spatial issues on a hedonic estimation of rents in Brussels.

Recent titles

CORE Discussion Papers - continued

2013/37 Lionel ARTIGE, Antoine DEDRY and Pierre PESTIEAU. Social security and economic integration.
2013/38 Nicolas BOUCKAERT and Erik SCHOKKAERT. Differing types of medical prevention appeal to different individuals.
2013/39 Pierre M. PICARD. Trade, economic geography and the choice of product quality.
2013/40 Tanja B. MLINAR and Philippe CHEVALIER. Pooling in manufacturing: do opposites attract?
2013/41 Chiara CANTA and Marie-Louise LEROUX. Public and private hospitals, congestion, and redistribution.
2013/42 Mathieu LEFEBVRE, Pierre PESTIEAU and Gregory PONTHIERE. FGT poverty measures and the mortality paradox: Theory and evidence.
2013/43 Nada BELHADJ, Jean J. GABSZEWICZ and Ornella TAROLA. Social awareness and duopoly competition.
2013/44 Volker BRITZ, P. Jean-Jacques HERINGS and Arkadi PREDTETCHINSKI. On the convergence to the Nash bargaining solution for action-dependent bargaining protocols.
2013/45 Pasquale AVELLA, Maurizio BOCCIA and Laurence WOLSEY. Single item reformulations for a vendor managed inventory routing problem: computational experience with benchmark instances.
2013/46 Alejandro LAMAS, Tanja MLINAR, Liang LU and Philippe CHEVALIER. Revenue management for operations with urgent orders.
2013/47 Helmuth CREMER, Firouz GAHVARI and Pierre PESTIEAU. Uncertain altruism and the provision of long term care.
2013/48 Claire DUJARDIN, Vincent LORANT and Isabelle THOMAS. Self-assessed health of elderly people in Brussels: does the built environment matter?

Books

V. GINSBURGH and S. WEBER (2011), *How many languages make sense? The economics of linguistic diversity*. Princeton University Press.
I. THOMAS, D. VANNESTE and X. QUERRIAU (2011), *Atlas de Belgique – Tome 4 Habitat*. Academia Press.
W. GAERTNER and E. SCHOKKAERT (2012), *Empirical social choice*. Cambridge University Press.
L. BAUWENS, Ch. HAFNER and S. LAURENT (2012), *Handbook of volatility models and their applications*. Wiley.
J-C. PRAGER and J. THISSE (2012), *Economic geography and the unequal development of regions*. Routledge.
M. FLEURBAEY and F. MANIQUET (2012), *Equality of opportunity: the economics of responsibility*. World Scientific.
J. HINDRIKS (2012), *Gestion publique*. De Boeck.
M. FUJITA and J.F. THISSE (2013), *Economics of agglomeration: cities, industrial location, and globalization.* (2nd edition). Cambridge University Press.
J. HINDRIKS and G.D. MYLES (2013). *Intermediate public economics.* (2nd edition). MIT Press.
J. HINDRIKS, G.D. MYLES and N. HASHIMZADE (2013). *Solutions manual to accompany intermediate public economics.* (2nd edition). MIT Press.

CORE Lecture Series

R. AMIR (2002), Supermodularity and complementarity in economics.
R. WEISMANTEL (2006), Lectures on mixed nonlinear programming.
A. SHAPIRO (2010), Stochastic programming: modeling and theory.